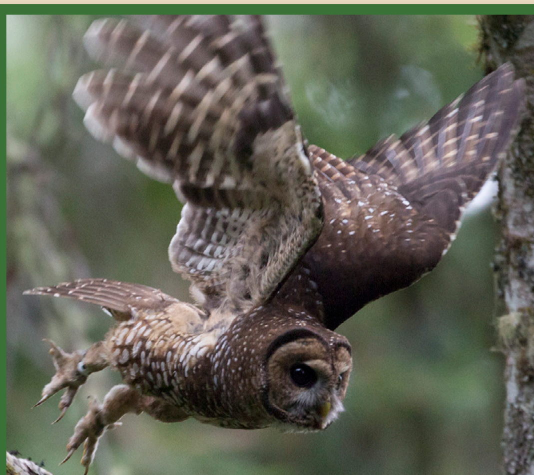
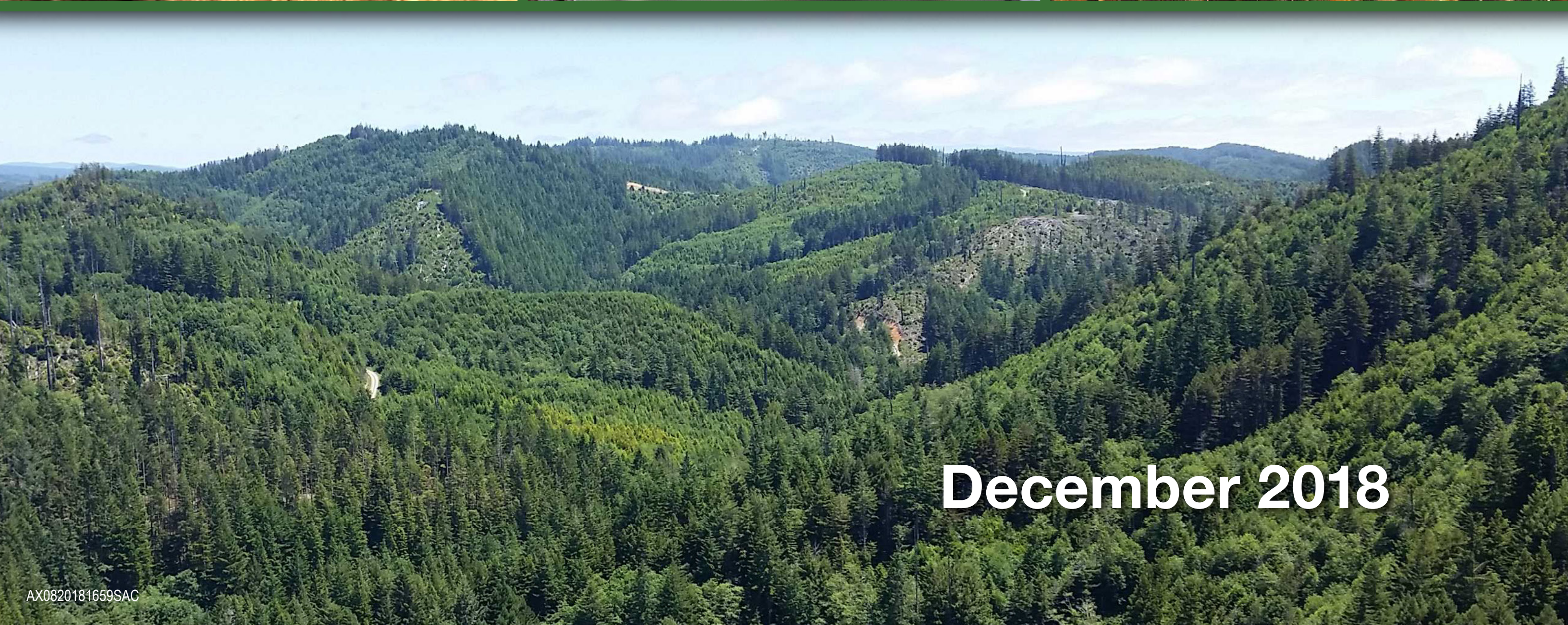
Forest Habitat Conservation Plan

on the California Timberlands of Green Diamond Resource Company

Prepared by:

GREEN DIAMOND
Resource Company





December 2018

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Forest Habitat Conservation Plan

Prepared for:

U.S. Fish and Wildlife Service

Prepared by:

GREEN DIAMOND
Resource Company

FINAL

December 2018

FHCP Sections

In Memoriam

Lowell V. Diller

This Forest Habitat Conservation Plan is dedicated to Dr. Lowell V. Diller. Lowell initiated his work with northern spotted owls in 1989 with Green Diamond (formerly Simpson Timber Company). Lowell's passion for field work and his ambition to learn about northern spotted owl ecology led to the scientific investigations that created the largest data set on northern spotted owls on managed forest lands and the development of the first habitat conservation plan for the northern spotted owl in 1992. Lowell was the architect behind three Habitat Conservation Plans on Green Diamond's California Timberlands: The 1992 NSO HCP, the 2007 Aquatic HCP and this Forest HCP. He worked on developing and implementing these plans throughout his career with Green Diamond. Lowell has left an indelible mark on this company, its forest management practices, and the stewardship of our timberlands. Lowell's positive influence on the knowledge of terrestrial and aquatic wildlife species' use of managed coastal redwood forests reached well beyond Green Diamond's ownership. His work informed private landowners, public land managers and agencies. Lowell was well respected by his peers and numerous natural resource professionals throughout the nation for his integrity and objectivity of scientific data. Lowell retired in 2014 after 24 years with Green Diamond.

Acknowledgements

The effort to develop this Forest HCP covered a span of about 10 years, and the total body of work spanned approximately 25 years. The necessary field work and data collection was an extraordinary task carried out by numerous employees at Green Diamond. Many were seasonal employees dedicated to collecting data on the Covered Species while others are long-time employees with decades of service to the company. We are grateful for their dedication and efforts that in many ways contributed to this HCP. We all have learned a lot along the way, and we are enriched by the unique privilege to work on a conservation plan that will outlast our own professional careers.

We would also like to recognize employees and other individuals that made contributions to writing and review of various parts of this document. Those individuals are: Mike Kennedy, Matt House, Joel Thompson, Trent McDonald, Jim Hawkins and Jason Woodward. There were many folks with USFWS that attended meetings and contributed to the review of this document. We thank Ray Bosch, James Bond, Kathleen Brubaker, Liisa Schmoele, Lynn Roberts, Jennifer Norris, Gary Falxa, John Hunter, Laurel Goldsmith, John Peters and Nancy Finley.

We are also grateful to Steve Thompson, former Director of Region 8 USFWS for his guidance and assistance in bringing this Forest HCP across the finish line. He was an inspiration and advocate for collaborative conservation efforts such as this Forest HCP. Thank you, Steve.

The Green Diamond HCP Team,

Lowell Diller, Mike Kennedy, Keith Hamm, David Lamphear, Desiree Early, Galen Schuler

In Memoriam

Steve Thompson (1953-2018)

Addendum

PURPOSE OF THE ADDENDUM

Since public review of the Draft Forest Habitat Conservation Plan, Green Diamond Resource Company (Green Diamond) has worked with staff of the U.S. Fish and Wildlife Service (USFWS) to respond to comments on and revise sections and appendices of the FHCP. This process occurred in October – November 2018 and yielded the documents identified as the Final FHCP and Appendices. The changes to the Draft FHCP were made with the concurrence of USFWS and Green Diamond and include corrections, revised language, and new language in the FHCP. Upon issuance of the incidental take permit by USFWS, Green Diamond will prepare a map that shows Green Diamond's current ownership within the Eligible Plan Area. The current ownership will comprise the Initial Plan Area as defined in the FHCP. After permit issuance, Green Diamond may continue to acquire or sell property in accordance with the terms of the FHCP.

GREEN DIAMOND RESOURCE COMPANY (GDRC)

FOREST HABITAT CONSERVATION PLAN (FHCP)

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1.1 BACKGROUND

Green Diamond Resource Company (Green Diamond) owns and manages approximately 365,152 acres of commercial timberland in Del Norte and Humboldt Counties in northern California (Map 1-1, Green Diamond Ownership). Green Diamond's California timberlands consist of redwood forests located on the west slope of the Coastal and Klamath Mountains. The periphery of Green Diamond's California timberlands consists of Douglas-fir and mixed conifer forests located on higher elevation and interior lands in eastern Del Norte and Humboldt counties.

Portions of these California timberlands are used or may be used by several wildlife species which are listed as threatened or endangered under the federal Endangered Species Act of 1973, as amended (ESA), or which could be listed under the ESA in the future. This plan includes the following Covered Species: Northern Spotted Owl (NSO), fisher, Sonoma tree vole and red tree vole. Green Diamond's commercial timber operations may cause the incidental take of listed wildlife species. Under ESA Section 10, the U.S. Fish and Wildlife Service (Service, or USFWS) and the National Marine Fisheries Service (NMFS) may, upon the approval of a Habitat Conservation Plan (HCP) meeting certain criteria, issue an incidental take permit authorizing such take. An HCP must specify measures the applicant will take to minimize and mitigate to the maximum extent practicable the impacts of the proposed incidental take of listed species.

Green Diamond currently manages and operates its California commercial timberlands in accordance with two HCPs and their associated incidental take permits:

- In 1992, the Service approved the *Habitat Conservation Plan for the NSO on the California Timberlands of Simpson Timber Company* (NSO HCP). The Service subsequently approved certain amendments to the NSO HCP requested by Green Diamond.[1] The NSO HCP will expire in 2022.
- In 2007, the Service and NMFS approved the *Green Diamond Aquatic Habitat Conservation Plan and Candidate Conservation Agreement with Assurances* (AHCP/CCAA) (Green Diamond, 2007). The AHCP/CCAA will expire in 2057.
- The NSO HCP covers all Green Diamond California timberlands, while the AHCP/CCAA covers the slightly smaller core area of these timberlands (approximately 365,964 acres).

Green Diamond prepared this new Forest HCP (FHCP) that will replace the NSO HCP based on:

- Its experience implementing the NSO HCP
- The results of research and monitoring performed pursuant to the NSO HCP
- The opportunity to build on the conservation measures in the AHCP/CCAA to conserve additional terrestrial species

[1] On December 31, 2001, Simpson Timber Company transferred its California timberlands, and associated permits and obligations, to Simpson Resource Company. On April 30, 2004, Simpson Resource Company changed its name to Green Diamond Resource Company.

This FHCP establishes a superior conservation program for the NSO based on the best available scientific data, and a new conservation program for three terrestrial mammals, which could be listed under the ESA in the future (the Covered Species listed in Section 1.4.3).

1.2 REGULATORY CONTEXT

1.2.1 Federal ESA (16 U.S.C. §1531 et seq.)

1.2.1.1 Overview: Sections 7, 9 and 10

The ESA was enacted in 1973 to provide a means for conserving endangered and threatened species and the ecosystems upon which they depend, in order to prevent species extinctions. The ESA has three major components relevant to this FHCP:

- **Section 7** – Requires federal agencies ensure, in consultation with the Service and the NMFS, that Their actions are not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat
- **Section 9** – Prohibits take of listed fish and wildlife species
- **Section 10** – Provides for permit issuance to non-federal entities authorizing the take of listed fish and wildlife species incidental to otherwise lawful activities

ESA Section 7 requires each federal agency to ensure, in consultation with the Secretary of the Interior or Commerce, that any actions authorized, funded, or carried out by the agency are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of areas determined to be critical habitat.[2] Section 7 requires federal agencies engage in formal consultation with the Service for any proposed federal actions likely to adversely affect listed species or their designated critical habitat. A biological opinion is issued by the Service at the completion of formal consultation. The biological opinion can conclude that the project as proposed is either likely or not likely to jeopardize the continued existence of the species, or result in the adverse modification of designated critical habitat. If the biological opinion concludes no jeopardy, the proposed action can proceed without modification. If the biological opinion concludes jeopardy, the Service will identify reasonable and prudent alternatives to the proposed action that would avoid jeopardizing the species. Included in the biological opinion is an incidental take statement that determines whether the action is likely to result in the incidental taking of any listed species, and if take is anticipated, the Service authorizes a specified level of take resulting from the proposed action. The incidental take statement may include mandatory reasonable and prudent measures designed to minimize the level and degree of incidental take and require implementation as a condition of take authorization.[3] If the incidental take statement includes one or more such measures, those measures include mandatory terms and conditions that identify the means whereby such measures must be implemented as part of the project.

ESA Section 9(a)(1)(B) prohibits the take by any person of any endangered fish or wildlife species; Take of threatened fish or wildlife species is prohibited by regulation. Take is defined broadly to mean harass, harm, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct.[4] Harm is defined by regulation to mean an act that actually kills or injures wildlife, including activities causing significant habitat modification or degradation

[2] 16 United States Code (U.S.C.) Section (§) 1536(a)(2).
[3] 50 *Code of Federal Regulations* (CFR) § 402.14(i)(5).
[4] 16 U.S.C. § 1532 (1988).

resulting in the killing or injuring of wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering.[5] The take prohibition applies unless take is specifically authorized or permitted pursuant to ESA Section 7 or Section 10. Protection for ESA-listed plant species is more limited than protection for ESA-listed fish and wildlife. [6]

ESA Section 10 addresses the authorization of take by nonfederal entities. Under Section 10(a)(1)(B), the Service may permit the take of listed species that may occur incidental to otherwise lawful activity. To obtain a Section 10(a)(1)(B) permit, an applicant must prepare an HCP meeting the following five criteria:

- The taking is incidental to an otherwise lawful activity
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking
- The applicant will ensure that adequate funding is provided for HCP implementation
- The taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; and
- Other measures, if any, which the Service requires as necessary or appropriate to meet HCP purposes [7]

The Service must conduct an internal Section 7 consultation and conclude that jeopardy will not occur before approving an HCP and issuing a Section 10(a)(1)(B) permit.

1.2.1.2 Section 10 Five-Point Policy Guidance

In June 2000, the Service adopted a five-point policy designed to clarify elements of the Section 10 HCP program as they relate to biological goals, adaptive management, monitoring, permit duration and public participation.[8] The five-point policy requires that the following elements be addressed in the development of habitat conservation plans:

- **Biological Goals and Objectives** – HCPs must define biological goals (broad guiding principles for the conservation program – the rationale behind the minimization and mitigation strategies) and biological objectives (the measurable targets for achieving the biological goals). Biological goals and objectives clarify the purpose and direction of the HCP's conservation program.
- **Adaptive Management** – The five-point policy encourages including adaptive management strategies in appropriate circumstances. Adaptive management is an integrated method for addressing biological uncertainty, devising alternative strategies for meeting biological goals and objectives, and, if necessary, adjusting future conservation management actions according to new information.

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[5] 50 CFR § 17.3.

[6] ESA Section 9(a)(2)(B) prohibits removal, possession, or malicious damage or destruction of endangered plants in areas under federal jurisdiction. It also prohibits actions that remove, cut, dig up, damage, or destroy endangered plants in areas outside of federal jurisdiction that violate any state law or regulation, including state criminal trespass law. Threatened plant species protection only applies to areas under federal jurisdiction 50 CFR § 17.71(a). ESA section 7(a)(2) prohibition against jeopardy applies to plants, wildlife, and fish equally, and USFWS and NMFS may not issue a section 10(a)(1)(B) permit if that permit issuance puts any listed species in jeopardy.

[7] 16 U.S.C. § 1539(a)(2)(A).

[8] Final Addendum to the Handbook for Habitat Conservation Planning and Incidental Take Permitting, 65 CFR 106, June 1, 2000 (*Five Point Policy*).

- **Monitoring** – HCPs must include provisions for monitoring to gauge the effectiveness of the plan in meeting the biological goals and objectives and to verify proper implementation of plan terms and conditions.
- **Permit Duration** – Under the five-point policy the Service considers several factors in determining the incidental take permit term, including the applicant's proposed activity duration and the expected positive and negative effects on covered species associated with the proposed duration. The Service will also consider the scientific and commercial data underlying the proposed operating conservation program, the time necessary to implement and achieve operating conservation program benefits, and the extent to which adaptive management strategies are included in the conservation program.
- **Public Participation** – The five-point policy increases public participation in the HCP process, including greater opportunity for the public to assess, review and analyze HCPs and associated National Environmental Policy Act (NEPA) documentation.

1.2.1.3 This FHCP and Section 10

The intention of this FHCP is to meet all regulatory requirements necessary for the Service to issue to Green Diamond a Section 10 Incidental Take Permit (ITP) authorizing incidental take of the "Covered Species" (defined below) due to "Covered Activities" specified in FHCP Section 2. This FHCP assessment of direct and indirect effects on Covered Species provides information and analysis for the Service to conduct internal Section 7 consultation required for FHCP evaluation.

Upon approval of this FHCP (the "Effective Date"), the Service will issue Green Diamond an ITP under ESA Section 10(a)(1)(B), authorizing incidental take by Green Diamond of each listed Covered Species resulting from Covered Activities in the Plan Area and, upon its listing, the incidental take by Green Diamond of any currently unlisted Covered Species. The ITP will identify all Covered Species, and shall take effect for listed Covered Species at the time the ITP is issued. For each unlisted Covered Species, the ITP shall take effect upon the listing of such species, subject to compliance with all other terms of this FHCP.

1.2.2 Migratory Bird Treaty Act (16 U.S.C. §703 et seq.)

The Migratory Bird Treaty Act (MBTA) implements various migratory bird protection treaties and conventions between the U.S. and Canada, Japan, Mexico, and the former Soviet Union. Under the MBTA, taking, killing or possessing migratory birds is unlawful as is taking any such birds' parts, nests or eggs. The MBTA defines take more narrowly than the ESA and includes only the death or injury of an individual bird from a migratory bird species or their eggs. 50 CFR. §10.13 includes a list of MBTA-protected birds.

The Service has developed policy guidance regarding the incidental take of bird species that are listed as threatened or endangered under the ESA, and are also protected under the MBTA. Under these guidelines, an ESA incidental take permit can function as a Special Purpose Permit under the MBTA for the take of all ESA-listed covered species in the amount and/or number and subject to the terms and conditions specified in an HCP. Any such take will not be in violation of the MBTA.

This FHCP covers the NSO, which is listed under both the ESA and the MBTA. Pursuant to Service guidance described previously, the ESA Section 10(a)(1)(B) permit Green Diamond seeks through this FHCP would also serve as an MBTA Special Purpose Permit for the NSO.

This FHCP also raises a separate MBTA issue. The proposed FHCP Conservation Program includes the management of barred owls, a species that competes with NSOs for food, nest sites, other resources, and may injure or kill them. To implement barred owl management, Green Diamond must receive authorization from the Service in the form of a Scientific Collection Permit or Depredation Permit or Special Purpose Permit under the MBTA (MBTA Permit). This FHCP supports Green Diamond's application to the Service for an MBTA Permit.

1.2.3 Bald and Golden Eagle Protection Act (16 U.S.C. §§ 668-668c)

Similar to the MBTA, Bald and Golden Eagle Protection Act (BGEPA) prohibits the "taking" of bald or golden eagles, including their parts, nests, or eggs. Under BGEPA prohibited "take" includes activities that "disturb" bald or golden eagles "to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior.

Green Diamond is not seeking incidental take coverage for bald or golden eagle under the Forest HCP, but take avoidance measures for these species are implemented through the California Forest Practice Act (Section 1.2.5). The general measures that Green Diamond implements for bald and golden eagles in THPs is provided in Appendix A.

1.2.4 National Environmental Policy Act (42 U.S.C. § 4321 et seq.)

The purpose of NEPA is to ensure that federal agencies consider the environmental impact of their actions and decisions. To accomplish this purpose, NEPA requires a process and approach for analyzing the environmental impacts of proposed federal actions. This analysis is documented in either an Environmental Assessment (EA) and its accompanying Finding of No Significant Impact, or an Environmental Impact Statement (EIS) and its accompanying Record of Decision.

Approval of this FHCP by the Service and issuance of the associated ITP under ESA Section 10(a)(1)(B) would constitute a federal action that is subject to NEPA. The Service has determined that it will prepare an EIS. The EIS will analyze the environmental impacts associated with the implementation of this FHCP and requested ITP, as well as the environmental impacts of related federal actions including Service approval for termination of the existing NSO HCP (which will be replaced by this FHCP) and Service issuance of the MBTA Permit for barred owl management.

1.2.5 California Forest Practice Act (Pub. Res. Code §4511 et seq.)

The twin goals of the California Forest Practice Act (FPA) are to:

- Restore, enhance, and maintain the long-term productivity of the state's timberlands, and achieve maximum sustained production of high-quality timber products
- Protect recreation, watershed, wildlife, range and forage, fisheries, regional economic vitality, employment and aesthetic enjoyment

The FPA is implemented through regulations knows as the Forest Practice Rules (FPRs), which are applied through Timber Harvesting Plans (THPs) reviewed and approved by California Department of Forestry and Fire Protection (CDF).

The FPRs include standard prescriptions required in every THP, including:

- Protection measures for watercourse zones (minimum buffer sizes, canopy closure requirements, and equipment exclusion)
- Restrictions on construction, use, and maintenance of roads, trails, landings, and watercourse crossings
- Snag Retention requirements and measures providing for retention of late seral elements

The FPRs also require a site- and area-specific assessment of potential individual and cumulative impacts of timber harvesting on the environment, including terrestrial resources. Any significant impacts remaining after application of the standard prescriptions require adoption of other measures to mitigate or avoid such impacts.

1.2.6 Other California Laws

Several other California environmental laws and associated regulations can apply to commercial timber operations. These include provisions in the California Fish and Game Code (including the California Endangered Species Act [CESA]), and the California Water Code (including the Porter Cologne Water Quality Control Act.

The CESA lists and protects Coho salmon that inhabit Green Diamond's timberlands. In 2008, the California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) made a consistency determination under the CESA, finding that Green Diamond activities under the AHCP/CCAA are also compliant with the California's Coho salmon protection standards.

Under the California Fish and Game Code, Green Diamond must obtain a permit from CDFW for the construction, removal, or replacement of stream-crossing structures on forest roads. Based on AHCP/CCAA conservation commitments, CDFW provided long-term authorization for all stream crossing work on Green Diamond's California timberlands under a Master Agreement for Timber Operations approved in 2010 (https://greendiamond.com/responsible-forestry/california/reports).

The California North Coast Regional Water Quality Control Board (Water Board) similarly approved a 2010 Waste Discharge Requirement (WDR) for all storm water discharges from Green Diamond's forest roads within the AHCP/CCAA plan area based on the road management requirements of the AHCP/CCAA (https://greendiamond.com/responsible-forestry/ california/reports). And, in 2012, the same Water Board approved a WDR for all forest management activities on Green Diamond's California Timberlands (https://greendiamond.com/ responsible-forestry/california/reports).

1.3 CONSERVATION HISTORY CONTEXT

1.3.1 Green Diamond's 1992 NSO HCP

On September 17, 1992, the Service issued an ITP to Simpson Timber Company and its subsidiaries based on an approved NSO HCP on the California Timberlands of Simpson Timber Company. The NSO HCP is now the responsibility of Simpson's successor, Green Diamond, which owns the California Timberlands managed under the NSO HCP. The NSO HCP was approved with a 30-year term, but the ITP issued in 1992 authorized take of up to 50 pairs of NSO during the first 10 years of the plan based on an estimated take rate of 5 NSO pairs displaced per year. The incidental take authorization was limited to the first ten years of plan implementation because it was understood that additional take authorization would be addressed through a comprehensive review scheduled to occur after the first 10 years of implementation.

The mitigation required under the NSO HCP matched the quantity of take authorized for the first decade of the plan. Although Simpson's 30-year projection of forest management indicated that suitable NSO habitat would increase over the permit term, the Service required more evidence of NSO habitat recruitment to be gathered under the NSO HCP research program and reported to the Service in the 10-year comprehensive review. While the research was in process, mitigation was required at plan inception in the form of substantial NSO reserve areas to be maintained for a period of at least ten years. A Special Management Area of over 36,000 acres was established for a period of ten years and an additional 13,000 acres of set-asides were required with the understanding that the purpose and function of the set asides would be re-evaluated in a comprehensive review after 10 years of plan implementation. The comprehensive nature of the review was evident in its express purposes:

- Comparison of actual and estimated levels of NSO displacement
- Comparison of actual and estimated distribution of NSO habitat
- Reevaluation of the biological basis of the conservation strategy based on data collected through the NSO HCP research program and other research
- A detailed analysis of the efficacy of and continued need for the set asides and of the long-term viability of the NSO population in the permit area
- An estimate of annual NSO displacement for subsequent portions of the permit period
- The timing and need for future comprehensive reviews during the permit process

An earlier comprehensive review was required if more than two-thirds of the authorized take for the first decade occurred within the first five years of the plan. However, the actual rate of take during the first decade of implementation was significantly less than the estimate. This allowed the Service and Green Diamond to extend the 10-year comprehensive review for four years while Green Diamond continued to implement all the NSO HCP conservation measures, including research on the habitat needs and preferences of NSO and the location of the most productive NSO habitat.

In 2006, although Green Diamond had not yet exhausted the original take authorization of 50 pairs, Green Diamond and the Service completed the first comprehensive review of the NSO HCP. Intensive research conducted by Green Diamond during the first 14 years of the NSO HCP resulted in creation of a sophisticated, site-specific model of habitat utilization and habitat fitness for the survival and reproduction of NSOs on Green Diamond's lands (Green Diamond 2010). That research revealed that the dusky-footed wood rat is the primary prey base for NSOs on Green Diamond's lands, and that spotted owls benefit from habitat that provides a mature timber nesting stand with edges where young forests grow after timber harvest and where woodrats thrive. Green Diamond's research also confirmed that the amount of suitable NSO habitat or NSO habitat fitness would continue to improve on Green Diamond property for many decades to come. The research also revealed that many of the no-harvest set-aside areas established by the NSO HCP for spotted owl conservation purposes were never or rarely occupied by NSOs, while other sites within and outside set-asides were more useful and productive for NSOs. During this time, Service and Green Diamond scientists also recognized a new, significant threat to NSO survival and recovery in the form of the progressive influx of barred owls onto Green Diamond's lands.

The implications of the first comprehensive review were far reaching. Green Diamond recognized the opportunity to make dramatic improvements in the efficiency and effectiveness of the NSO HCP, but more information was needed on the barred owl threat to NSO. In 2006, Green Diamond applied to the Service for an amendment of the NSO HCP. The proposed amendment adjusted the NSO nest site survey protocol to account for the masking effect of barred owl presence and it added research on barred owl and NSO interaction. In addition, the proposed amendment reinstated the special management area through 2012 and it scheduled a second comprehensive review for 2012. In 2007, the Service approved the proposed amendments and authorized an additional take of eight NSO pairs based on the amendments, which included additional conservation measures and the continued implementation of the original conservation measures of the NSO HCP. The Service recognized that the authorization of eight additional takes would provide Green Diamond with operational flexibility while Green Diamond and the Service completed further research and analysis in preparation for the second comprehensive review scheduled in 2012.

The second review, like the first review, was expressly intended to be comprehensive. The second comprehensive review required assessment of actual take in comparison to estimated take and progress on the growth of suitable NSO habitat. That assessment of take and habitat development would then be used in reevaluation of the NSO HCP conservation strategy, reevaluation of the efficacy and need for set asides, and reevaluation of the likely future level of take incidental to Green Diamond timber management that may be authorized by the Service. Unlike the first comprehensive review, the second review also incorporated an analysis of the effect of barred owls on NSO conservation in the permit area and potential responsive adjustments to the NSO conservation strategy.

In 2010, Green Diamond and the Service commenced the second comprehensive review with a re-evaluation of the NSO HCP and development of a refined NSO conservation strategy for implementation in the permit area over the next 50 years. In 2011, the Service completed a Revised Recovery Plan for the NSO, which helped to inform the development of a refined NSO conservation strategy for Green Diamond timberlands. Under NSO HCP amendments approved by the Service in 2007, Green Diamond also initiated research on NSO and barred owl interaction that demonstrated the need for urgent action to manage barred owls, as recommended in Recovery Actions 22, 26, and 28-30 of the Revised Recovery Plan for the NSO (USFWS, 2011a).

Building on the first comprehensive review, the second comprehensive review identified certain ineffective and inefficient conservation measures and strategies in the NSO HCP, and other conservation measures and strategies requiring adjustment, addition or improvement. In consultation with the Service, Green Diamond considered extending the NSO HCP term and adjusting its NSO conservation measures based on extensive site-specific research done to date. Green Diamond also identified opportunities to build on conservation measures provided in Green Diamond's AHCP/CCAA to conserve additional terrestrial species that are found on Green Diamond timberlands and may be listed under the ESA in the future. The result of the second comprehensive review of the NSO HCP is a newly proposed multi-species FHCP covering four terrestrial species including the NSO.

1.3.2 Green Diamond's 2007 AHCP/CCAA

In 2007, the Service and NMFS approved the AHCP/CCAA (Green Diamond, 2007) for management of Green Diamond's core northern California timberlands, including approximately 400,000 acres. The AHCP/CCAA targets aquatic species and resource conservation and provides substantial protection of riparian forest stands and geologically unstable areas, resulting in little or no timber harvest in substantial portions of Green Diamond timberlands. Projections of future landscapes created through AHCP/CCAA implementation indicate that 25% of the lands managed under the AHCP/CCAA are in riparian management zones and geological protection areas. By the end of the 50-year AHCP/CCAA permit (2057), approximately two-thirds of the riparian management zone acreage will consist of the dominant and co-dominant trees in the 51-to 100-year-old age class, with the remaining third over 100 years-old. This provides a well-distributed network of late seral habitat benefiting all aquatic species covered by the AHCP/CCAA and many other forest species. Accordingly, the AHCP/CCAA riparian zone management are included in this FHCP conservation program. This ensures that the habitat benefits for FHCP Covered Species associated with these conservation measures are legally enforceable elements of the ITP for terrestrial Covered Species issued upon approval of this FHCP. This FHCP adaptive management program is also structured so that any modifications to the riparian management under the adaptive management provisions of the AHCP/CCAA are also reviewed and approved by the Service to ensure that they do not compromise the effectiveness of this FHCP.

For planning and management purposes, this FHCP is the terrestrial species counterpart of the AHCP/CCAA, with a substantially equivalent term and Plan Area. For Green Diamond, this FHCP is a management tool that builds on and complements the AHCP/CCAA to conserve covered species in both aquatic and terrestrial forest ecosystems located on Green Diamond's core California timberlands.

1.3.3 Other Complementary Conservation Efforts

Other ongoing conservation efforts, other than the AHCP, near Green Diamond lands include:

- Implementation of the Yurok Habitat Conservation Plan (YHCP) based on assignment and assumption of responsibility for implementation of the Green Diamond AHCP/CCAA conservation measures on over 22,000 acres of timberland, which has been conveyed by Green Diamond to the Yurok Tribe in the lower Klamath River Basin
- Green Diamond has conveyed over 24,500 acres in the Blue Creek drainage to Western Rivers Conservancy for conservation purposes
- Memorandum of Understanding among the Service and seven other federal and state agencies, non-governmental organizations, and private resource owners regarding Humboldt Marten Conservation (2012)
- Memorandum of Understanding among the Service and 13 other federal and state agencies, non-governmental organizations, and private resource owners regarding California Condor Conservation (June 2016)
- Hoopa Tribal Forestry research and monitoring of spotted owls and fisher and the Forest Management Plan (2011-2025) that addresses forest management practices and other tribal activities that may affect the Covered Species
- Late seral forest restoration projects implemented by the Redwood National Park and Del Norte Redwoods State Park within previously harvested areas of Mill Creek and

Redwood Creek that are now intensively managed to accelerate mature forest stand regrowth

- A cooperative effort with Redwood National Park to monitor and study NSO and barred owl interactions
- Management of the nearby Six Rivers National Forest and Headwaters Forest Reserve subject to the Northwest Forest Plan amendments designed to promote conservation of the NSO and numerous additional late-successional forest species
- Collaboration and cooperation with the Willow Creek NSO demographic study conducted on Service lands east of this FHCP's Eligible Plan Area (EPA)
- Collaboration and cooperation with the CDFW on trapping fisher inhabiting Green Diamond timberlands and experimental relocation of those fisher on private timberlands in the Sierra Nevada subject to a Service-approved Candidate Conservation Agreement
- Humboldt Redwood Company's (HRC's) management of over 200,000 acres of timberland adjacent to this FHCP EPA pursuant to an HCP assumed by HRC when it acquired Pacific Lumber Company timberlands
- Safe Harbor Agreement between Green Diamond and CDFW for Humboldt Marten (2018)

1.4 PURPOSE, SCOPE AND ORGANIZATION OF THIS FHCP

1.4.1 Purpose

The primary purposes of this FHCP are as follows:

- Provide for the conservation of the Covered Species (as defined herein below) and their habitats on commercial northern California timberlands owned and managed by Green Diamond
- Coordinate and facilitate Green Diamond's practicable and reliable compliance with the ESA to support long-term investment in and sustainable management of Green Diamond's California timberlands
- Provide assurances to Green Diamond that, pursuant and subject to the Service's "No Surprises" regulations, as long as the obligations of this FHCP and ITP are performed, no additional mitigation shall be required of Green Diamond with respect to Covered Species
- Provide the Service with an appropriate basis for authorizing Green Diamond to incidentally take Covered Species pursuant to the ITP

This FHCP describes conservation objectives Green Diamond will implement to meet the following objectives:

- Minimize and mitigate, to the maximum extent practicable, the impacts of any authorized taking of listed Covered Species that may occur incidental to Green Diamond's northern California timber management operations
- Ensure that any authorized take will not appreciably reduce the likelihood of survival and recovery in the wild of any Covered Species
- Help reduce the need to list currently unlisted Covered Species under the ESA by providing conservation benefits to those species

The measures in this FHCP are designed to be a comprehensive conservation program for the Covered Species on the Green Diamond timberlands managed under this FHCP. The measures, supporting analysis, and related authorizations also help Green Diamond comply with any California FPRs related to the ESA and Covered Species.

1.4.2 Geographic Scope

As noted in the previous section, Green Diamond's California timberlands consist of over 365,152 acres located in northern California's Del Norte and Humboldt Counties. The core timberlands consist of redwood forests on the west slope of the Coastal and Klamath Mountains. The remainder of Green Diamond's timberlands consists of Douglas-fir and mixed conifer forests on higher elevation and interior lands in eastern Del Norte and Humboldt Counties.

Since 1992, all of Green Diamond's California timberlands (today, approximately 365,152 acres) have been managed pursuant to the NSO HCP, as amended. Since 2007, Green Diamond's California timberlands have also been managed pursuant to the AHCP/CCAA. This FHCP addresses Green Diamond's California timberlands in two parts. Approximately 357,412 acres managed under the AHCP/CCAA is also the focus of this FHCP conservation program for all Covered Species (Section 5.2), and the 7,741-acre peripheral area is managed solely as a no-take zone for the NSO (Section 5.3).

Green Diamond periodically buys and sells timberlands in the general area covered by this FHCP and expects to continue this practice in the normal course of business during this FHCP 50-year term. To accommodate Green Diamond's business practices, this FHCP is designed to allow some flexibility in the application of this FHCP and ITP to Green Diamond's timberland ownership adjustments. Section 1.4.7 includes several defined terms describing the terms and procedures for adjustments that may occur to this FHCP and ITP covered area.

1.4.3 Covered Species

This FHCP provides a conservation program, and supports the issuance of an ITP covering four terrestrial species referred to as the Covered Species:

- Northern spotted owl (*Strix occidentalis caurina*)
- Fisher (*Pekania pennanti*)
- Red tree vole (*Arborimus longicaudus*)
- Sonoma tree vole (*Arborimus pomo*)

Table 1-1 identifies the Covered Species including one avian and three mammalian species. Each Covered Species is a forest species with habitat requirements sensitive to timber management. The NSO is currently listed under the ESA as a threatened species. The other three Covered Species could become listed under the ESA in the future, and are addressed in this FHCP as if they are listed. Should these currently unlisted species become listed under the ESA during the term of this FHCP, incidental take of such species would automatically be authorized under the ITP issued to Green Diamond upon approval of this FHCP, and full implementation of conservation measures identified in Section 5.

Table 1-1. The Covered Species

Species Common Name, *Scientific Name*	Listing Status in Plan Area	
	Federal	State
Northern Spotted Owl, *Strix occidentalis caurina*	FT	ST
Fisher, *Pekania pennanti*	None	None
Tree voles (2):		
Red tree vole, *Arborimus longicaudus* (north of the Klamath River)	None	CSC
Sonoma tree vole, *Arborimus pomo* (south of the Klamath River)	None	CSC

Codes

Candidate – USFWS finds significant information to propose listing the species, but higher priority listing actions preclude a listing decision

CSC – California Department of Fish and Game Species of Special Concern

FT – Federal threatened species

ST – State threatened species

None – Currently not listed, proposed for listing, a candidate for listing, or a CSC

Notes

This FHCP treats the two tree vole species as ecologically identical and as a single species. However, tree vole species north of the Klamath River are genetically distinct from voles south of the river.

Section 3 and Appendix B describe the Covered Species characteristics and general habitat requirements. Section 4 and Appendix C describe the Covered Species' current habitat conditions and status where Green Diamond will implement this FHCP.

1.4.4 Covered Activities

The activities covered by this FHCP and ITP (Covered Activities) include all of Green Diamond's lawful timber operations and other forest management activities that could result in the incidental take of the Covered Species in the Plan Area defined below. Section 2 describes the Covered Activities, including those activities needed to execute all conservation measures identified in Section 5 (the Conservation Program).

1.4.5 Permit Duration

This FHCP and associated ITP term is 50 years. This term is necessary to fully implement the Conservation Program and maximize FHCP ecological benefits.

1.4.5.1 Initial Term This FHCP and ITP shall become operative on the Effective Date, and shall remain in effect for a period of fifty (50) years from the Effective Date, except as provided below.

1.4.5.2 Extension of the ITP. If requested by Green Diamond and approved by the Service in compliance with all applicable laws, the term of the ITP may be extended under regulations of the Service in force on the date of such extension. If Green Diamond desires to extend the term of the ITP, it shall so notify the Service at least 360 days before the then-current term is scheduled to expire. Extension of the term of the ITP constitutes extension of this FHCP for the same amount of time, subject to any modifications that the Service may require under regulations of the service in force at the time of extension.

1.4.6 Organization of this FHCP includes:

- **Section 1 –** Purpose and background, regulatory context, conservation history context, and scope and organization
- **Section 2 –** Detailed description of the Covered Activities, including Green Diamond's timber operations and other forest management activities
- **Section 3 –** Detailed description of the Covered Species, marten[9] and their habitats
- **Section 4 –** Description and assessment of habitat conditions and occurrence of Covered Species and the marten in this FHCP implementation area
- **Section 5 –** Description of:
  - FHCP statement of biological goals and objectives
  - Conservation Program fulfilling those biological goals and objectives with minimization and mitigation measures for take of Covered Species
  - Conservation Program compliance and effectiveness monitoring and reporting
  - Conservation Program adaptive management process, and contingent actions and assurances for foreseeable and unforeseen circumstances that may arise during FHCP implementation
  - Measures for prevention of NSO take by timber harvest in the Peripheral Area
- **Section 6 –** Assessment of the potential for timber operations and other activities governed by this FHCP to directly or indirectly influence Covered Species and potentially result in take of listed species
- **Section 7 –** Assessment of how the Conservation Program minimizes and mitigates Covered Species take to the maximum extent practicable
- **Section 8 –** Description of alternatives to Covered Species take that Green Diamond considered, and a discussion of the reasons for not pursuing those options
- **Appendices –** Additional information, analysis, and details about FHCP components:
  - **Appendix A –** The general take avoidance measures that Green Diamond implements for bald and golden eagles in THPs
  - **Appendix B –** Additional information about the biology, habitat requirements, and sensitivities of each Covered Species (Supports Section 3)

[9] The marten (*Martes caurina humboldtensis*) is not a Covered Species, but this FHCP evaluates it for potential coverage in Section 8 (Alternatives Considered). Sections 3 and 4 also describe marten biology, and its status and habitat in this FHCP Plan Area.

- **Appendix C –** Studies, surveys and assessments of Covered Species and their habitats conducted in the current Plan Area (Supports Section 4)
- **Appendix D –** Details of the 2007 AHCP Riparian Protection Measures
- **Appendix E –** Guidance document for Terrestrial Retention of Ecosystem Elements (TREE)
- **Appendix F –** Detailed research, methods and protocols for this FHCP Conservation Program implementation including Green Diamond NSO survey protocols and effectiveness monitoring protocols that will be followed during FHCP implementation
- **Appendix G –** Table describing the fecundity and occupancy characteristics of NSO sites not designated as Dynamic Core Areas (DCA)
- **Appendix H –** Detailed analyses of NSO detection probabilities and number of surveys for Timber Harvest Plans (THP) and NSO sites
- **Appendix I –** Describes the process for validating the NSO habitat fitness and occupancy models
- **Appendix J –** Glossary of terms and abbreviations used in this document
- **Appendix K –** List of literature cited in this document

- **Atlas** – Collection of large (11x17), foldout map figures referenced in this document

1.4.7 Key FHCP Implementation Area Definitions and Adjustment Procedures

As noted above, this FHCP, like the AHCP/CCAA currently in effect, accommodates modest potential changes in Green Diamond land ownership, subject to certain restrictions, within an overall specified area of similar landscapes and habitat. Under this approach, this FHCP covers certain specified lands upon approval. During this FHCP term, some lands may be removed from FHCP coverage if Green Diamond sells them, while other lands within the broader analyzed area may be added to and covered by this FHCP. The key definitions that implement this approach include:

- **Eligible Plan Area or "EPA"** – All privately owned commercial timberlands and all roads within the geographic area described in Map 1-2. The EPA is further analyzed in Section 4.
- **Plan Area** – All commercial timberlands within the EPA which, at any point in time during which this FHCP is in effect, are owned by Green Diamond or upon which Green Diamond possesses perpetual harvesting rights if such lands or perpetual harvesting rights have been enrolled in this FHCP as part of the Initial Plan Area (IPA) or upon acquisition, and all roads used to access such lands.
- **Perpetual Harvesting Rights –** Perpetual rights to conduct timber operations on lands owned in fee by another. Short-term harvesting rights generally expire upon the conclusion of timber operations, upon a certain date, or a combination of the two. Perpetual harvesting rights pertain to existing and subsequent crops of timber and continue without expiration. Lands on which Green Diamond holds Perpetual Harvesting Rights may be included in the Plan Area only where Green Diamond has sufficient legal control during the term of the ITP to implement this FHCP.
- **Initial Plan Area or "IPA" –** The Plan Area that exists on this FHCP Implementation Agreement and Permit effective date as defined below. Map 1-2 displays the IPA based on 2017 Green Diamond ownership and perpetual harvesting rights, which is approximately 357,415 acres.

- **Adjustment Area** – Commercial timberland acreage and associated roads within the EPA which, at any point in time while this FHCP is in effect are not within the Plan Area and thus not covered by this FHCP.
- **Peripheral Area** – The Peripheral Area consists of timberlands that Green Diamond does not intend to own and manage as part of its long term business plan and conservation plan for Covered Species. The Peripheral Area consists of any other Green Diamond Ownership in Del Norte or Humboldt Counties, California that is outside the EPA of this FHCP. Upon approval of this FHCP, Green Diamond timberland management in the Peripheral Area will be managed solely for the prevention of NSO take by timber harvest. Table 1-2 displays the Peripheral Area based on 2015 Green Diamond Ownership.

Table 1-2. Plan Area and Peripheral Area Acreages

County	IPA	Adjustment Area	EPA	Peripheral Area
Del Norte	81,652	18,590	100,244	4,996
Humboldt	275,760	321,077	596,837	2,745
TOTAL	357,412	339,667	697,082	7,741

1.4.7.1 EPA Characteristics and Components

Map 1-2 displays the EPA of approximately 697,082 acres and its components, the IPA (357,412 acres) and Adjustment Area (339,667 acres).

The scope of the EPA equals the eligible plan area of the AHCP/CCAA, which provides consistent and reliable commitments on long-term Plan Area management for the conservation of aquatic resources. The EPA also provides an appropriate scale for analyzing habitat conditions and potential impacts and benefits for Covered Species from the combined effect of management under this FHCP and the AHCP/CCAA. The commercial timberlands in the EPA also have common characteristics directly related to habitat conditions for Covered Species. Section 4 describes these characteristics in detail, including:

- Forest ecosystems with conifer stands dominated by coastal redwood and Douglas-fir
- A pattern of forest stand structure produced by Green Diamond management and California FPRs that consists of a mosaic of small patches of harvest and various ages of reproduction with intermittent closed-canopy mature stands where land owners elect to manage under a selective harvest regime
- A dendritic pattern of larger and older forest stands following riparian corridors and unstable geologic areas resulting from management under the AHCP/CCAA and, to a lesser degree, FPRs
- Steep and rugged terrain, several highly unstable bedrock types, and extensive geologic folds and fault lines
- Seasonally intense precipitation
- More than a century of logging, mining, road building and grazing

The EPA is bordered by national forests and wilderness areas on the north and east and abuts Redwood National Park and various state parks on the west. Other adjacent ownerships include the Peripheral Area managed by Green Diamond, industrial timberlands managed by Sierra Pacific Industries, Soper-Wheeler Company, Humboldt Redwood Company and other private holdings. The Hoopa Valley Indian Reservation is located east of the EPA, and lands administered by the Yurok Tribe or Bureau of Indian Affairs are located along the lower Klamath River. Adjacent land use varies by location but generally follows land ownership patterns. The federal and state land management supports multiple uses, including conservation and recreation, and various levels of timber harvesting allowed in designated areas. On adjacent private lands, commercial timber operations and ranching predominate, while other uses include gravel mining and residential development. Map 1-2 displays the Adjustment Area and includes adjacent commercial timberlands but excludes public and Indian lands, non-forested commercial timberlands and third party-owned commercial timberlands covered by an approved HCP.

The IPA is that portion of the EPA owned and managed by Green Diamond at the time of ITP approval. It is a substantial and cohesive block of forest habitat, representative of and well distributed throughout the EPA. The forest ecosystem habitat within the IP and the EPA connects to forest ecosystem habitat in large blocks of national and state park land to the north and west, large blocks of national forest and tribal lands to the north and east, and a large private commercial timberland ownership to the south managed under an HCP.

The Adjustment Area is the balance of the EPA that is not within the IPA. This FHCP may expand into the Adjustment Area through property acquisitions by Green Diamond. Based upon the analyses in this FHCP, it is presumed that all commercial timberlands within the EPA share similar relevant characteristics and, therefore, that adding such lands to the Plan Area during the term of the ITP will not likely result in adverse effects on the Covered Species different from those analyzed in connection with this FHCP when approved.

This FHCP's allowance for Plan Area adjustments is justified by the similarity of habitat conditions and the potential impacts of Covered Activities to Covered Species throughout the EPA. The EPA and Adjustment Area are further analyzed in Section 4. Because of these similarities, the Conservation Program may be applied with the same or substantially similar benefits on any Green Diamond timberlands or perpetual harvesting rights within the EPA during this FHCP term. In addition, given the IPA size and EPA location relative to forested habitat on federal, state, and tribal forest lands to the north and east and private timberlands managed under an HCP to the south, a net increase or decrease in the IPA of no more than 15% will not significantly alter the effectiveness of this FHCP for the conservation of Covered Species.

1.4.7.2 Plan Area Adjustments Over Time

During the term of this FHCP and ITP, Green Diamond may elect to add to the Plan Area any commercial timberlands within the EPA by submitting to the Service a description of the lands within the Adjustment Area that it intends to add, along with a summary of relevant biological and physical characteristics that such lands share with existing Plan Area lands. As discussed above, Green Diamond estimates there are approximately 339,667 acres of other commercial timberlands in the Adjustment Area that could be added to the Plan Area in the future. However, the Plan Area cannot be more than 15% larger than the IPA without an FHCP amendment. Further, the Plan Area may contract automatically with Green Diamond Ownership sales or disposals, so long as contraction is not more than 15% smaller than the IPA. All Plan Area expansions and contractions are subject to the following conditions.

1.4.7.2.1 Green Diamond's Right to Acquire and Sell Lands. Subject to the conditions in Section 1.4.7.2, nothing in this FHCP or ITP limits Green Diamond's right to acquire or sell or otherwise transfer interests in lands within the Eligible Plan Area or elsewhere.

However, unless commercial timberland acreage that Green Diamond acquires is included in the IPA or added to the Plan Area by operation of this FHCP's land adjustment conditions, Green Diamond's activities that take place on those lands shall not be covered by the ITP.

1.4.7.2.2 Reporting of Land Transactions. Green Diamond shall notify the Service of any transfer of ownership of real property or harvesting rights located within the Plan Area at the time of such transfer, except where prior notification occurs pursuant to Paragraph 1.4.7.2.4 below. Such notice shall describe the affected real property with particularity, identify the name and address of the transferee, and include a detailed map showing the location of the transferred real property or harvesting rights.

1.4.7.2.3. **Additions to the Plan Area.** Green Diamond may elect to add to the Plan Area additional commercial timberlands consisting of fee lands and harvesting rights that it acquires within the EPA pursuant to this paragraph, provided however, that the total acreage covered within the Plan Area shall not expand the IPA by more than 15%, in total, without an amendment to this FHCP and ITP. Areas subject to harvesting rights acquired and added to the Plan Area pursuant to this subparagraph after the Effective Date will count toward the net change in Plan Area. If Green Diamond elects to add commercial timberlands to the Plan Area pursuant to this paragraph, Green Diamond shall submit to the Service a description of the lands it intends to add, along with a summary of relevant characteristics they share with existing Plan Area lands. Such characteristics may include vegetation types, forest habitat conditions and age classes, habitat elements, areas of riparian habitat (Section 5.3.1.3), known occurrence and status of the Covered Species including NSO sites that may qualify as DCAs (Section 5.3.1.4), and occurrence of barred owls.. Unless the Service objects in writing to Green Diamond within 60 days of receipt of the submission described herein, the subject lands shall be included in the Plan Area subject to the 15% limit on IPA expansion provided above. The Service may object to a Green Diamond election by providing a written statement with specific reasons why the Service believes the presumption described herein is incorrect. In that case, the Service and Green Diamond shall confer in good faith and pursue the dispute resolution mechanisms set forth in this FHCP in an effort to reach an agreement. Until concurrence is reached, such lands will not become part of the Plan Area except pursuant to the Major Amendment process set forth in Section 5.3.7. The ITP and FHCP shall be effective for Covered Activities on all lands that meet the definition of Plan Area upon their inclusion pursuant to this Paragraph or a Major Amendment required under Section 5.3.7.

1.4.7.2.4 Deletions from the Plan Area. Subject to the reporting requirements in Paragraph 1.4.7.2.2 and this Paragraph, the Plan Area shall contract automatically, i.e., without an amendment to this FHCP or ITP, to reflect each sale or other transfer of Green Diamond real property within the Plan Area, including transfers of perpetual harvesting rights; provided, however, that the acreage of the IPA shall not contract by more than 15% without a Major Amendment pursuant to Section 5.3.7. The ITP and FHCP shall cease to be effective as to any Green Diamond lands removed from the Plan Area in accordance with this Paragraph 11 upon Green Diamond's sale, transfer or other deletion, provided that Green Diamond shall notify the Service and shall maintain and make available to the Service upon request a record of each such transaction or deletion. None of the following shall count toward the 15% limit on reduction of the total acreage of the IPA or require a Major Amendment pursuant to Section 5.3.7:

1.4.7.2.4.1 Transfers to an agency of the federal government, including transfers involving third parties in which the ultimate owner of the property will be an agency of the federal government, where, prior to transfer, the Service has determined that the transfer shall not compromise the effectiveness of this FHCP based on adequate commitments by that agency regarding management of such land;

1.4.7.2.4.2 Transfers to a non-federal entity that, prior to transfer, has entered into an agreement acceptable to the Service (e.g., Green Diamond's grant of a conservation easement to be held by the state fish and wildlife agency with the Service as third-party beneficiary) or has another legally binding commitment (e.g., by legislative mandate) acceptable to the Service to ensure that the lands shall be managed in such a manner and for such duration so as not to compromise the effectiveness of this FHCP or

1.4.7.2.4.3 Transfers to a non-federal entity that, prior to completion of the land transaction, has agreed to be bound by this FHCP as it applies to the transferred land and has obtained an incidental take permit following normal permit procedures covering all species then covered by the ITP

1.4.7.2.4.4 Sale and transfer of short-term harvesting rights (i.e. stumpage agreements rather than perpetual harvesting rights) to third parties subject to this FHCP and expiration of short-term harvesting rights held by Green Diamond shall not be considered deletions from the Plan Area.

1.4.7.3 Peripheral Area

Map 1-2 displays the Peripheral Area, which is owned by Green Diamond but excluded from the EPA because Green Diamond does not intend to own and manage such timberlands as part of its long term business plan and conservation plan for Covered Species. This FHCP's Operating Conservation Program (Section 5.3) and incidental take authorization for all Covered Species and Covered Activities do not apply to the Peripheral Area.

The Peripheral Area currently is part of the permit area for the NSO HCP, but it may be sold and removed from the NSO HCP permit area with notice to the Service and no other limitation. The Peripheral Area does not include set-asides that provide demographic support for the NSO under the NSO HCP.

Under this FHCP, Green Diamond may not add timberlands to the Peripheral Area, but may remove timberlands from the Peripheral Area with a transfer to a third party and notice to the Service.

The Peripheral Area shall not be part of this FHCP EPA or its components, the Plan Area and Adjustment Area. Consequently, adjustments to the Peripheral Area shall not affect the adjustment limits for the Plan Area of this FHCP.

1.4.8 Multiple Uses of this FHCP

In addition to satisfying ESA requirements on incidental take authorization, the Conservation Program in Section 5 addresses other significant, closely related issues such as cumulative beneficial wildlife impacts and cumulative beneficial impacts of carbon sequestration mitigation for emission of Green House gases and climate change. This FHCP's multiple uses are important because some FHCP measures and mitigation levels will exceed the minimum requirements necessary for ESA Section 10 approval.

1.4.9 Related Federal Actions

FHCP approval and implementation will require Service approval for termination of the existing NSO HCP implemented by Green Diamond. In addition, portions of the Conservation Program involving experimental barred owl control will require MBTA authorization from the Service.

1.4.9.1 Termination of Green Diamond's NSO HCP

This FHCP adapts and improves the original conservation measures provided under the NSO HCP and includes major new conservation measures under the AHCP/CCAA. Accordingly, this FHCP will replace the NSO HCP, which will be terminated upon approval of this FHCP. Termination of the NSO HCP upon approval of this FHCP is a federal action that is appropriate at this time because Green Diamond and its predecessor, Simpson, have provided all of the mitigation required under the NSO HCP through the date of FHCP approval,.

The termination and replacement of the NSO HCP with this FHCP was anticipated and provided for in the NSO HCP. Although it was a 30-year plan, the NSO HCP was approved with a 10-year permit and comprehensive review process that was intended to re-evaluate and, if appropriate, discontinue, adjust, or supplement any aspect of the conservation strategy for the NSO. Although it pre-dated the Service's Five Points Policy described in Section 1.2.1.2, the NSO HCP was designed as a research-driven conservation plan with adaptive management at ten-year intervals. Section 1.3.1 summarizes the implementation of the NSO HCP, the most significant research findings under the NSO HCP research program, and the results of the first and second comprehensive reviews of the NSO HCP. This FHCP is the result of the second comprehensive review of the NSO HCP and describes in detail the results of research under the NSO HCP and the insights on NSO conservation strategy improvements that were derived from that research.

Because the NSO HCP was designed for comprehensive review at ten-year intervals, the incidental take authorization and matching mitigation commitments under the plan are also based on 10-year intervals. As described in Section 1.3.1, upon approval of the NSO HCP, the Service issued an ITP for displacement of 50 NSO pairs over the first 10 years of this FHCP with the understanding that additional take authorization would be considered in a 10-year comprehensive review. The incidental authorization was based on an estimated take rate of five pairs per year for the first ten years and the key mitigation measures, such as the special management area and set asides, were established for a period of 10 years, subject to comprehensive review of the purpose, function, and need for such mitigation after 10 years. In other words, the agreed exchange of mitigation for take authorization under the NSO HCP was a pay-as-you-go plan on a decadal basis.

When the first comprehensive review was completed in 2006, 44 of the 50 authorized NSO pair displacements had been used, indicating that the original exchange of mitigation for take authorization from the Service was fully satisfied by a surplus of mitigation relative to take. After the first comprehensive review, the NSO HCP was amended, most of its initial conservation commitments were continued, additional research was required, eight additional NSO pair displacements were authorized, and a second comprehensive review was scheduled for 2012. As of 2017 (NSO HCP plan year 25), 3 of the original 50 NSO pair displacements authorized for the first 10 years of the plan were unused and the 8 NSO pair displacements added in 2007 were utilized. Again, Green Diamond analyses indicate that the mitigation provided through plan year 20 is more than adequate for the amount of NSO take authorized and actually used through plan year 20.

Upon approval of this FHCP and termination of the NSO HCP, Green Diamond's ITP issued under the NSO HCP would also be terminated and Green Diamond would relinquish all unused incidental take authorization. Under these circumstances, termination of the NSO HCP is appropriate without a deficit of mitigation or need for compensatory mitigation. This also means that this FHCP may be evaluated and approved by the Service based on ESA Section 10 criteria applied only to the prospective take incidental to Covered Activities and mitigation provided under this FHCP.

1.4.9.2 MBTA Authorization

The proposed FHCP Conservation Program includes barred owls management and control experiments. The barred owl competes with and may injure or kill NSOs. Section 5 includes a detailed barred owl control experiment. As reflected in the Service's Revised NSO Recovery Plan (USFWS, 2011a), the Service considers barred owl management and control an essential component of NSO recovery. To implement the barred owl management and control experiments, Green Diamond must receive authorization through a Scientific Collection Permit or Depredation Permit or Special Purpose Permit issued by the Service under the MBTA Permit. This FHCP and its experimental barred owl management support Green Diamond's application to the Service for an MBTA Permit. The Service may issue an MBTA Permit with or after FHCP approval, and, depending on its term, may renew or extend it several times during this FHCP term.

Green Diamond cannot implement experimental barred owl management without issuance of an appropriate MBTA Permit. However, FHCP approval and ITP issuance and implementation are not contingent upon an MBTA Permit, because this FHCP NSO conservation program minimizes and mitigates take to the maximum extent practicable without an MBTA Permit.

Section 2. Covered Activities

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2.1 INTRODUCTION

This FHCP and the associated ITP will cover and provide incidental take authorization for Green Diamond's timber operations and related land management activities in the Plan Area, as well as the activities needed to carry out the Conservation Program described in Section 5. The following sections describe Green Diamond's Covered Activities:

- Timber-Product Harvest
- Silvicultural Regimes and Methods
- Timber Stand Regeneration and Improvement
- Minor Forest-Product Harvest
- Administration, Implementation and Monitoring Activities

2.2 TIMBER-PRODUCT HARVEST

The following sections describe Green Diamond's timber-product harvest activities:

- Felling and bucking timber
- Yarding timber
- Landing construction, maintenance and loading
- Salvaging timber products
- Transporting timber and rock products
- Road construction, maintenance and use
- Rock pit development and use
- Water drafting and storage
- Equipment maintenance

2.2.1 Felling and Bucking Timber

Timber felling is the first step in logging operations. It usually includes felling of the tree and may include bucking, or cutting felled trees into predetermined log lengths specified by the timber owner to maximize tree value. Some trees may also be felled and left "tree length" that will be manufactured into logs later in the process. Contractors ("timber fallers" sometimes working in pairs) are hired to fell and buck trees with chain saws. Where terrain is not too steep, mechanical felling machines (feller-bunchers) cut down trees. These machines are structurally similar to tracked excavators. Using an articulated attachment, they grab, cut, and bunch the trees with other trees or logs for subsequent skidding to the landing. Feller-bunchers that are more complex have processor heads to delimb and buck trees into logs. Some of these machines have tracked undercarriages and self-leveling mechanisms so they can operate on moderate slopes. Feller-bunchers have no blade or attachments capable of moving soil. Their wide track design and ability to travel on top of forest debris (limbs and chunks) minimize soil disturbance and compaction.

2.2.2 Yarding Timber

Yarding or skidding involves moving logs from the stump where they are felled to the landing. Major yarding system classifications include: ground based, cable, and aerial logging. Section 2.4 describes biomass or slash debris yarding, an additional classification involving non-traditional wood products (not exclusively in log form).

2.2.2.1 Ground-Based Yarding

Ground based logging traditionally involves tracked or rubber tired tractors (rubber tired skidders) skidding logs to the landing. These machines grasp the log using either powered grapple attachments or wire rope winch lines. They require constructed skid trails to operate on all but the mildest terrain (generally under 35%). A related system, forwarder logging, is used only for small logs on mild terrain. It uses a specialized tractor with a small hydraulic boom loader. The boom loader travels into the logging unit and lifts logs onto bunks mounted on a rearward tractor frame extension. This specialized machine is a small self-loading truck designed with low pressure tires, gearing, and ground clearance that allows off-road operation.

Whenever possible, Green Diamond utilizes a more modern and technically improved ground skidding variant called shovel logging. A shovel, or hydraulic boom log loader, is an excavator equipped with a log loading boom and grapple instead of an excavator boom and bucket. These machines are specially designed for yarding and provide more off-road mobility because they have additional horsepower and are mounted on tracked undercarriages with generous ground clearance. The shovel is capable of walking off the truck road, picking up felled logs in a unit, and passing them back towards the truck road using its upper structure 360 degree rotation or swing function. This system is very efficient over short distances, since the same machine that does the yarding can load the logs on trucks. It is not used over longer distances because increased distance from the truck road requires repeated log handling. As with feller-bunchers, shovels have no blade or other attachment capable of moving soil and have the additional benefit of operating without requiring road or trail construction. Shovel harvesters also have very wide tracks that have low ground pressure and very low grousers (traction blades) that operate on top of the natural layer of residual slash debris and the residual stumps. This provides significant additional protection by minimizing soil compaction and ground disturbance. Green Diamond prefers to use the shovel logging ground-based yarding method wherever feasible, rather than tractor or skidder logging. Shovel logging can only be used in evenaged units, and is not compatible with selection or thinning silviculture.

2.2.2.2 Cable Yarding

Cable yarding uses wire ropes, to skid logs to a truck road or log landing. A yarder has a number of powered drums filled with wire rope, and a vertical tower or leaning boom that elevates the cables as they leave the machine. Three to eight wire rope guy lines hold the tower in position. With rare exception, cable systems yard logs up hill. Green Diamond utilizes cable yarding systems where the terrain is too steep (ground averaging over 35% slopes) to accommodate ground-based yarding systems such as shovel logging.

Cable yarding is usually skyline or high-lead, depending on the amount of lift required during yarding. High-lead logging essentially attaches logs directly to the end of the mainline that exits the top of the yarder tower. The only lift provided is the difference in elevation between the location of the log and the top of the tower to prevent logs from digging into the soil surface during yarding. This system is quick to implement and effective over short distances (generally <500 feet).

Skyline (or running skyline) is preferred over high-lead yarding and reduces drag since one end of the log is always elevated. This system is preferred over longer distances and significantly increases yarding speed and minimizes ground disturbance. In these circumstances, Green Diamond uses some form of skyline logging that provides sufficient lift. Skyline logging uses a skyline cable that extends from the top of the tower (or boom) to an anchor located at some elevated point beyond the edge of the logging area. This anchor is usually a stump or a suitable tree at the perimeter of the logging unit rigged to provide the necessary skyline elevation on an opposing hill slope. Logs are attached to a carriage that rides on the skyline. The yarder pulls the carriage to the landing with its mainline (also referred to as the skidding line in this application).

Depending on the skyline variant used, the yarder lowers the skyline to attach the logs and then raises it for lift, or the carriage can unwind its own skidding line and then lift the logs towards the skyline. Either way, the yarder provides enough lift to suspend the uphill end of logs above the ground. Green Diamond uses skyline cable yarding systems extensively throughout the Plan Area, which minimizes overall ground disturbance and mid-slope road building.

2.2.2.3 Helicopter Yarding

Aerial yarding (e.g., by helicopter or balloons) typically occurs when steep and/or unstable terrain or lack of road right-of-way prevents road construction for ground based or cable yarding systems. Balloon aerial logging uses cables or grapples suspended from long cables with the balloon providing lift and suspend the logs for transport to the landing. Aerial equipment lowers and releases logs to the loading area. Helicopter yarding utilizes a cable extending from the helicopter that is attached to the logs and fully suspends the logs to the landing area. These types of yarding generate virtually no soil disturbance. However, both require large landings to safely accommodate concurrent log landing, log sorting, truck loading operations, and log decking during peak production hours. Helicopters also require a separate service landing that is clean and rock-, debris- and dust-free to protect the engines from damage. The disadvantages of helicopter logging are its expense (roughly three times more expensive than cable yarding) and the fact that lack of vehicular access to the area compromises the landowner's ability to accomplish site preparation, reforestation, and other forest management activities in the future. Helicopter service landing areas are secondary to the THP area.

2.2.2.4 Landing Construction, Maintenance and Loading

Log landings are cleared areas or wide spots in roads to which logs are yarded, swung, skidded, lowered or forwarded for subsequent loading onto trucks for transport. They are constructed and maintained as part of the timber harvest and transport process. Landings must be located and constructed to complement the yarding system used to move the logs from the stump.

Logs yarded to a landing or roadside may need bucking into shorter segments, breakage removal and delimbing by hand or mechanically. A mechanical delimber is a tracked machine similar to an excavator with a long boom and moving cutting head that delimbs, accurately measures and bucks trees into log-length pieces.

At the landing or roadside, a shovel or front-end loader (a wheeled bucket loader equipped with log loading forks instead of a bucket) then loads logs onto log trucks. Shovels (or heel-boom loaders) can operate on small landings or, if side slopes are suitable, they can deck logs on the roadside and load trucks without leaving the road grade. In contrast, front-end loaders have a longer turning radius and require larger landings. Shovels are Green Diamond’s preferred loading equipment because they offer flexibility, utility and lower ground pressure.

2.2.3 Salvaging Timber Products

Dead, dying, and wind thrown trees are periodically salvaged. This salvage is primarily related to road maintenance or fire damage resulting from prescribed burns. Dead or dying trees are removed along roads if they can be easily salvaged and yarded to the road. Salvage of timber products is conducted through the annual filing of a property wide Exempt Notice, i.e., subject to the FPRs but exempt from THP requirements and THP processes. Removal of these products requires a licensed timber operator. If the volume to be salvaged exceeds 10% of the average existing timber volume per acre, a THP is required. Salvage harvesting is not permitted within floodplains or channel migration zones and is specifically limited in watercourse riparian management zones (RMZs) by Green Diamond's AHCP/CCAA (Green Diamond, 2007). Older, decaying or defective logs are retained on the landscape to provide valuable wildlife habitat structure (Section 5.2.2.2 and Appendix E, TREE).

2.2.4 Transporting Timber and Rock Products

Timber and rock materials are most commonly transported along private and public roads via truck and trailer. Helicopters may occasionally but infrequently be used to transport logs directly to sawmills. Using private and public roads for the transport of timber products, biomass products or rock products is a Covered Activity.

2.2.5 Road Construction, Maintenance, and Use

Roads on lands owned in fee by Green Diamond are constructed most commonly by felling and yarding timber along a predetermined road alignment that has been designated on the ground. This activity is followed by excavating or filling hillslope areas, using tractors or excavators. Road construction also commonly involves construction of watercourse crossings that use culverts, bridges, and occasionally fords. Roads also include vehicle turnouts and log landings that are wide spots used for yarded logs and loading log trucks. Road construction may also involve surfacing soil roads with rock, lignin, pavement or other surface treatments approved by NMFS and the Service under the AHCP/CCAA (Green Diamond, 2007).

Road maintenance typically includes surface grading, clearing bank slumps, repairing slumping or sliding fills, clearing ditches, repairing or replacing culverts and bridges, adding surface material, dust abatement and installing or replacing surface drainage structures. Road maintenance for fire prevention, public access, and timber management may include mechanical control of roadside vegetation. Mechanical control may include grading, hand cutting, using a brush buster-type mechanical device, burning, steaming and other experimental methods. Road construction and road maintenance activities are intended to provide for a well-designed and maintained transportation system used for long term access to harvest timber, haul logs and wood products, regenerate and maintain plantations, perform biological and geological study and assessments and allow for the general administration and protection of the Plan Area. All activities associated with the construction, maintenance and uses of roads serving the Plan Area (including roads over third parties where Green Diamond has a right or privilege of use) are Covered Activities.

2.2.6 Rock Pit Development and Use

Rock pits, also referred to as borrow pits, are locations where rock is excavated, crushed, blasted, or otherwise produced for eventual use as a road surface, fill or bank stabilization materials. Activities associated with the use of rock pits also include loading crushed rock into trucks for hauling, hauling of mined rock, and the construction and maintenance of rock pit access roads (see previous section). Under the AHCP/CCAA, Green Diamond also conducts an archaeological review for the development of any new rock quarry within the Plan Area to take account of any effects on historic properties under the National Historic Preservation Act (NHPA).

2.2.7 Water Drafting and Storage

Water drafting involves direct drafting of stream flow into a water truck which is then periodically sprinkled or otherwise applied to roads for dust abatement, road maintenance, road construction, surfacing or used to control prescribed fuel reduction burning or wildfire. Water may be diverted using gravity fed systems that provide water directly to storage reservoirs or tanks that are used to load water trucks for similar use. Occasionally, existing drafting locations within or adjacent to watercourses are excavated and cleaned of debris to increase their in-channel storage area for drafting purposes. Water drafting and storage management is covered under Green Diamond’s AHCP/CCAA (2007) in more detail and specificity under Green Diamond’s Master Agreement for Timber Operations (MATO) approved by CDFW on May 20, 2010, and in the WDRs for Discharges Related to Road Management and Maintenance Activities Conducted Pursuant to the Green Diamond Resource Company Aquatic Habitat Conservation Plan in the North Coast Region approved by the California North Coast Region Water Quality Control Board on June 10, 2010.

2.2.8 Equipment Maintenance

The use of falling, yarding, loading, trucking and road maintenance equipment requires fueling and maintenance. This maintenance is performed by Green Diamond and/or its contractors using maintenance trucks and generally occurs on or adjacent to roads and landings.

2.3 SILVICULTURAL REGIMES AND METHODS

Green Diamond's silvicultural practices are designed to enhance the productivity of its timberlands by ensuring both prompt regeneration of harvested areas and rapid forest growth. Treatments vary by stand age, stand condition, site class and species composition. Green Diamond does not apply all treatments to every site. Table 2–1 summarizes the treatments in approximate chronological order that Green Diamond includes as part of its forest management regime.

Table 2–1. Green Diamond's Forest Management Methods Based on Stand Age

Treatment	Stand Age (years)
Regeneration Harvest	45 and older
Site preparation	0 – 1
Tree Planting	0 – 1
Vegetation Management	0 – 10
Pre-commercial thinning	10 – 20
Commercial Thinning	30 – 40

Silvicultural activity involves specific methods used to harvest and regenerate forest stands over time to achieve desired management objectives. Typical management objectives include achieving maximum sustained yield, and the maintenance, alteration or creation of habitat. Examples of silvicultural methods for regeneration harvest include individual (single) tree selection, group selection, seed tree, shelterwood and clearcut. The first two methods regenerate uneven-aged stands and the latter-three regenerate even aged stands.

2.4 TIMBER STAND REGENERATION AND IMPROVEMENT

Timber stand regeneration and improvement includes activities necessary to establish, grow, and achieve desired species composition, spacing and rate of growth of young forest stands, including:

- Site preparation, prescribed burning and slash treatment
- Tree planting
- Vegetation management
- Precommercial thinning and pruning
- Commercial thinning
- Regeneration harvesting

Green Diamond manages timber in the Plan Area under a Maximum Sustained Production (MSP) plan prepared and approved in accordance with state law. Under the MSP plan, annual harvest levels are carefully scheduled to balance forest growth and timber harvest over a 100-year period and to achieve maximum sustained production of high quality timber products while protecting resource values such as water quality and wildlife. Stands are ready for harvest once they enter the 50-year age class (45 to 55 years old). However, state laws that constrain both the size of even-aged management units and the timing of adjacent even-age harvesting operations can delay the harvest of many stands until they reach the 70 year age class. Green Diamond currently uses the Forest Projection and Planning System (FPS), developed by the Forest Biometrics Research Institute (FBRI), for inventory tracking, growth modeling and long-term harvest scheduling. In 2008-9, this model was used to develop a 100-year projection of harvesting and growth to demonstrate MSP as required by the California FPRs under Title 14 *California Code of Regulations* 913.11(a). The rule requires the landowner to demonstrate achievement of MSP by satisfying the following five requirements:

- Producing the yield of timber products ... while accounting for limits on productivity due to constraints imposed from consideration of other forest values, including but not limited to, recreation, watershed, wildlife, range and forage, fisheries, regional economic vitality, employment and aesthetic enjoyment
- Balancing growth and harvest over time
- Realizing ... adequate site occupancy
- Maintaining good stand vigor
- Making provisions for adequate regeneration

The modeling used spatially explicit simulation of harvesting and growth of individual stand components over more than one rotation for 100 years, based on the GIS mapping of the standing inventory for Green Diamond's California timberlands as of January 1, 2008. This stand mapping and its projections included both harvested and unharvested areas retained for wildlife and fisheries protection. This portrayed projected stand ages and structure across the whole property at various times, e.g., at decadal intervals, throughout the simulation period. The MSP modeling resulted in a constant level of harvest for approximately 50 years, followed by an increase to a higher level for the last 50 years, with growth exceeding harvest at all times throughout the period, and with a concomitant increase in standing inventory throughout the whole period. With the exceptions noted below, Green Diamond plans to practice even-aged management in the Plan Area, using clear-cutting as the harvest/regeneration method. Clearcutting provides for prompt regeneration of redwood and Douglas-fir, the principal commercial tree species in these forests, and maintains these trees in a 'free-to-grow' state that is not compromised by competition from a predominate residual overstory influence of older trees or by the possibility of damage from the repeated site disturbance that is implicit in the application of other silvicultural systems. The growth potential inherent in the use of clearcutting in these forest types was assumed in the calculation of yields for Green Diamond's sustained yield (Option A document).[1]

The primary exceptions to clearcutting occur in the following situations:

- Areas where past use of selection or seed tree logging left residual mature timber that will be harvested in seed tree removal or overstory removal operations
- Areas where buffers along public roads or near urban development are harvested using the shelterwood or selection systems so that the visual impact of timber harvesting is ameliorated
- Overly steepened or unstable slopes where slope stability concerns take precedence over forest productivity
- RMZs, habitat retention areas (HRAs), single tree retention of trees possessing high value habitat features or other areas managed principally for fish and wildlife habitat.

As discussed in Section 5.2.2, clearcut management units will include the conservation measures designed to:

- Ensure that existing key habitat elements are retained on the landscape (snags, live legacy residual trees, key large residual hardwood trees, down old residual logs with rot and defect)
- Provide for the retention of vertical structure in the form of conifer and hardwood trees where existing key residual habitat elements do not presently exist

These retained trees, in conjunction with those left in RMZs, will cause a substantial portion of the area within even-aged harvesting units supporting post-harvest vertical structure to provide various habitat attributes for terrestrial and aquatic wildlife.

Because essentially all of Green Diamond's property has been harvested at some time in the past, the progress of timber harvesting across the ownership will always reflect to some extent the pattern of age classes imprinted on the landscape by the timing of prior logging activity. In areas where large ownership blocks were initially harvested in continuous logging operations during the railroad logging era (pre-WWII), harvesting operations will be more concentrated within these general watershed regions, although California FPR constraints will cause the dispersal of activities over time and space within these blocks during subsequent rotation periods. This is a product of the California FPRs adjacency harvesting constraints that are applied to even-aged harvesting units resulting in retention of many stands far past planned rotation age. If harvesting of a tract of mature timber is initiated around age 50, the harvesting of

[1] The Option A document contains confidential proprietary information that is protected from public disclosure under California law. This reference to the Option A document is explanatory and the Option A document has not been provided to the Service and is not intended to be part of the administrative record for Service action on this FHCP.

much of that tract will be constrained into the following decade, and the harvest of a few stands will be constrained past 70 years of age. This effect has been demonstrated in Green Diamond's long term operating plan.

2.4.1 Site Preparation, Prescribed Burning, and Slash Treatment

Site preparation may be required where accumulations of slash following timber harvesting constitute a physical barrier to effective planting, or where weed species (brush or non-merchantable trees) remaining on the site significantly compromise establishment of planted seedlings. In either situation, Green Diamond may use prescribed burning, machine piling, mechanical scarification, bio-mass harvesting, or a combination of these methods to prepare the site for hand planting and reduce fuel concentrations for fire safety.

Green Diamond may retain slash created by logging activity on site without treatment if it does not prevent replanting or represent excessive fuel concentrations that pose an unacceptable fire risk. The California FPRs require removal of accidental deposits of slash within Class I and Class II watercourses. Slash deposited into Class III watercourses must be removed unless it is stable within the channel. In all logging areas, slash developed on log landings from of yarding and truck loading activities may be piled and burned on the landing.

Site preparation occurs as soon as possible after completion of logging so that planting will not be delayed. Mechanical site preparation may occur concurrently with logging operations. If prescribed burning is required, it is scheduled during the first spring or fall following completion of timber harvesting. Prescribed burning is facilitated using two main techniques:

- Broadcast burning the harvest unit (excluding RMZs and other resource protection areas)
- Pile burning where logging debris and slash is accumulated and piled concurrent with harvesting operations and then ignited during the winter period under appropriate burning conditions

Piles of slash are accumulated by either cable yarders bringing debris to landings or by ground-based falling and shovel yarding equipment piling excessive accumulations of logging debris within the units or along the sides of adjacent roads and landings. Timing of prescribed burns is predicated upon temperature, wind, humidity and fuel moisture conditions that will cause low intensity burns. Such conditions minimize the probability of escape and allow retention of large woody debris and the finer organic matter concentrated at the soil/litter interface. Ignition patterns are designed to keep fire from intruding into RMZs.

Prescribed burning is used to reduce slash concentrations or to reduce vegetative levels or control species composition. This practice involves the introduction of fire under controlled conditions to remove specified forest elements with little risk of catastrophic fire damage. Prescribed burning is also used for slash control and the reduction of fuel concentrations for fire hazard abatement. The practice of using prescribed burning, especially broadcast burning, has been greatly diminished in recent years to comply with air quality regulatory standards.

Biomass harvesting techniques, developed and implemented over recent years, provide a successful and efficient alternative to broadcast burning. In areas where slash and other logging debris is accessible to ground based equipment, a portion of the logging slash is removed (harvested) from harvest units and landings as a site preparation and hazard abatement treatment. Advanced specialized harvesting equipment and techniques such as mechanized faller-bunchers, shovel logging and piling loaders, articulated off highway dump trucks and forwarders with low ground pressure capabilities, and high capacity mobile slash chippers and grinder equipment are used to gather up and process previously unused woody material. The biomass that is harvested is in the form of limbs, tops, chunks and slabs that were previously considered non-merchantable and uneconomical to retrieve from the landscape.

Where feasible and concurrent to harvesting operations, shovel logging operators are instructed to stack excessive slash into piles located along the roadway and in harvest units. Mechanized delimber operators stack tops and other debris in piles along the roadway, adjacent to landings and in units. After completing normal log harvesting operations, specialized biomass harvesting equipment (often a shovel loader with specialized tongs designed to pick up slash) gathers slash in untreated areas and deposits it into specialized articulated dump trucks capable of driving over uneven topography and slash. Alternatively, in areas with piles, the slash is loaded into the specialized dump trucks. These trucks deliver biomass to a centrally located landing where a mobile slash chipper grinds/chops the material into chips and then loads large trucks that deliver chips to conversion facilities such as paper chip utilizers or co-generation plants.

With development of specialized equipment, techniques, and new markets for biofuels, biomass harvesting has become a viable alternative in some areas to site preparation using broadcast burning. All operational constraints associated with topography, seasonal restrictions, and resource protection and retention of important aquatic and terrestrial wildlife habitat elements are comprehensively identified and documented in Green Diamond's AHCP/CCAA as well as in Green Diamond's TREE In areas where biomass operations occur, a residual layer of slash is retained throughout the unit to ensure needed ground cover is present for erosion prevention.

2.4.2 Tree Planting

Tree planting generally involves hand planting nursery-grown tree seedlings directly into the soil, ensuring good contact between the soil and roots. Tree seedlings are hand planted in even-aged management areas including landings during the first winter following completion of a THP. In general, the tree species selected for planting are chosen to best fit the site specific conditions of the area harvested.

Areas that exhibited pre-harvest high redwood composition are planted primarily with redwood seedlings. Some areas that are well stocked with redwood stump sprouts after harvest may be deemed unnecessary to replant except if it is necessary to fill areas void of regeneration. Areas exhibiting both redwood and Douglas-fir species before harvest will commonly be planted with a mix of both species often favoring one species over another depending upon the site specific conditions. In areas that are dominated by hardwoods, conifers (either redwood or Douglas-fir depending upon site conditions) are replanted with the purpose of increasing the conifer component while retaining important hardwood trees that provide benefits to wildlife species. In other locations on the ownership where elevation or growing site dictates, other tree species such as Ponderosa Pine or incense cedar may be selected for planting.

Planting will be postponed only if site preparation is necessary but cannot be completed before the planting season. The summer after initial planting, Green Diamond surveys planted areas to determine seedling survival rates and, where necessary to achieve desired stocking, will plant additional seedlings during the following winter. At age two, a more detailed stocking survey will be done, and if necessary, additional trees are planted. It is often common for some harvested sites to become stocked with additional volunteer tree species (western hemlock, Sitka spruce, red alder) that become established. Volunteers come from adjacent stands that provide seed sources. This is the most common process that allows for a wide variety of species across the landscape.

2.4.3 Control of Competing Vegetation

To provide successful establishment and continued, rapid growth of desired tree species, it is often necessary to control species that compete with desired species for water and sunlight. Control methods are mechanical cutting and chipping. Green Diamond is not seeking coverage of herbicide use for control of competing vegetation as a part of the ITP.

2.4.4 Precommercial Thinning and Pruning

Precommercial thinning involves thinning dense, young forest trees by mechanical means, including cutting individual trees or mechanically sawing or chipping rows or groups of trees. Pruning removes the lower limbs of desirable tree species to increase the eventual product value of the pruned trees. Between age ten and 20, precommercial thinning may occur to remedy overstocked conditions in planted stands so that crop trees will achieve optimum diameter growth. Currently, Green Diamond does not remove precommercial stems from the site because they are too small to meet current merchantable standards. This operation is performed only once in the life of a stand and only in those stands with an excess number of trees per acre. Although chainsaws are used to cut the noncrop trees, progress in the development of feller-bunchers may eventually lead to machines capable of executing this operation more efficiently and with less risk of injury to workers. Alternatively, improvements in markets for small wood and in the machinery used to harvest small stems may allow economic harvesting of the excess trees, thus converting precommercial thinning to commercial thinning as described below.

2.4.5 Commercial Thinning

Commercial thinning involves removing selected trees that may contain commercial value, to create additional growing space for crop trees. Thinning a portion of the competing trees allows for the release of the selected crop tree by providing more light, and in some cases, more nutrients and soil moisture when they are limiting factors. On Green Diamond's forest lands in the Plan Area, the most significant limiting factor in a young forest is typically sunlight. Commercial thinning on Green Diamond timberlands usually occurs when stands are identified as needing this treatment and when they are around the 30- to 40-year age class. The log size of these younger thinned stands is inherently smaller than those of an older stand ready for the final harvest stage of even-aged management. The harvesting systems however are fundamentally the same except the size of the yarding equipment can be significantly reduced to correspond with smaller payloads and logs. Both cable and ground based yarding systems are used to harvest the selected trees to be thinned with the goal of improving the growth potential of remaining stands and protecting residual trees from damage during the yarding process. During the planning and design stage of a thinning harvest, Green Diamond's registered professional foresters (RPFs) and professional biologists ensure key resource protection measures and mitigations included in a final clearcut harvest also apply to intermediate thinning harvest. This harvesting activity will comply with all measures covered under the AHCP/CCAA and measures in Section 5.2.2. Green Diamond 's goal is to ensure that important key resource values existing at the time of the thinning harvest are identified and protected to provide for a continuity of protection of sensitive habitats and habitat features throughout the harvesting cycles and the life of this FHCP.

2.4.6 Regeneration Harvest

Green Diamond uses clearcut and selection harvest as the two primary methods of forest stand regeneration. Other silviculture approaches described in Section 2.3 are used in minimal amounts when site specific conditions warrant and will be applied in future harvests under similar circumstances. Green Diamond plans to practice even-aged management in the Plan Area, using clearcutting as the harvest/regeneration method. Clearcutting provides for prompt regeneration of redwood and Douglas-fir, the principal commercial tree species in these forests, and maintains these trees in a 'free-to-grow' state that is not compromised by competition from a predominate residual overstory influence of older trees or by the possibility of damage from the repeated site disturbance that is implicit in the application of other silvicultural systems. The growth potential inherent in the use of clearcutting in these forest types was assumed in the calculation of yields for Green Diamond's sustained yield (Option A document).[1]

Selection harvesting involves choosing either individual trees or small groups of trees. This silviculture retains a significant component of the original stand with the intention of reentry after a prolonged period (approximately 10 years) to select another component of individual trees after the stand experiences subsequent regrowth and natural regeneration. On the north coast of California and within Green Diamond's ownership, selection harvest occurs where competing resource values take precedence over even-aged harvesting. Selection harvesting is an ideal method used to ensure robust retention of stands and individual trees within RMZs, geologically unstable areas and in locations where protection of other resource values is the foremost management factor. Areas designated for selection harvest are managed within that prescription for long periods to ensure the specific retention that is desired continues to persist on the landscape. Because riparian management zones and geologically unstable areas are key elements of both aquatic and terrestrial resource protection strategies, the key retention guidelines for these features are included in this FHCP Section 5.3.1.3 to ensure that long-term retention occurs across the landscape.

2.5 MINOR FOREST-PRODUCT HARVEST

Minor forest products include burls, stumps, boughs and greenery. Such products are collected, harvested and transported on Green Diamond ownership. These activities will comply with the measures in Sections 5 and 6. These activities are conducted by third parties subject to Green Diamond's permits with conditions that protect sensitive habitats and minimize the risk of any incidental take of Covered Species.

2.6 ADMINISTRATION, IMPLEMENTATION AND MONITORING ACTIVITIES

The activities needed to carry out the various aspects of the Conservation Program described in Section 5 include:

- Use of all-terrain vehicles and passenger vehicles on roads
- Use of hand tools and power tools for clearing and maintaining roads for access
- Surveys for Covered Species
- Data collection
- Tree marking and habitat improvement activities (e.g., cavity creation)
- Observation, capture and marking of Covered Species

Section 3. Biology of Species Considered in this FHCP Alternatives

TABLE OF CONTENTS

3.1 INTRODUCTION

Numerous animal species, with varying abundance and sensitivity to Green Diamond's timberland management operations, inhabit this FHCP Plan Area. For example, this includes:

- Aquatic species in the Plan Area managed under Green Diamond's AHCP/CCAA
- Terrestrial species, in particular the NSO, in the Plan Area managed on Green Diamond lands under the NSO HCP since 1992

Other sensitive species such as the bald eagle (*Haliaeetus leucocephalus*) and marbled murrelet (*Brachyramphus marmoratus*) are present in the Plan Area, but Green Diamond manages its lands and conducts its operations without incidental take of those species. Appendix A includes a summary description of these and other sensitive species that do not warrant further consideration in this FHCP development.

In developing this FHCP, Green Diamond considered conservation strategies for the following five species:

- NSO
- Fisher
- Red tree vole
- Sonoma tree vole
- Marten

These species are or could be sensitive to Green Diamond's operations over this FHCP term. Each of the five species was addressed in at least one of the primary alternatives for this FHCP described in Section 8. This section provides biological information on the five species considered under those FHCP alternatives. Of the five species, all except the marten are Covered Species under the proposed FHCP. Although the marten could be sensitive to timberland management activities, it is absent from nearly all of the IPA. Accordingly, the Conservation Program in FHCP Section 5 focuses on conservation of the remaining four as Covered Species, with potential, incidental benefits for the marten should it eventually inhabit the Plan Area.

The five species considered in this FHCP alternatives use a wide range of forest stand conditions based on their specific habitat requirements and biological adaptations. However, where they occur within a managed landscape, they all share the need for structurally complex forest habitat elements. The following sections generally describe each of the species considered in this FHCP alternatives. Appendix B provides a more detailed description of these species with complete references.

3.2 SPECIES CHARACTERISTICS

3.2.1 Northern Spotted Owl (*Strix occidentalis caurina*)

3.2.1.1 Species Description

The NSO is a medium-sized owl. The largest of the three subspecies of NSO (Gutiérrez et al., 1995), it is approximately 46 to 48 centimeters (18 inches to 19 inches) long. The sexes are dimorphic, with males averaging about 13% smaller than females. They are dark brown with a barred tail and white spots on their head and breast, with dark brown eyes surrounded by prominent facial disks. Plumage characteristics distinguish the four age classes (Forsman, 1981; Moen et al., 1991). The NSO closely resembles the barred owl, a congeneric species with which it occasionally hybridizes (Kelly and Forsman, 2004).

3.2.1.2 Range and Distribution

Although no estimates exist of the population size before modern European settlements in the mid-1800s, NSO probably inhabited most old-growth forests throughout the Pacific Northwest including northwestern California (USFWS, 1989). The current NSO range extends from southwest British Columbia through the Cascade Mountains, and coastal ranges and intervening forested lands in Washington, Oregon, and as far south as Marin County, California (USFWS, 1990b). Within the United States, the NSO range distributes into 12 physiographic Provinces based on recognized landscape subdivisions exhibiting different physical and environmental features (Thomas et al., 1993). These Provinces include:

- Washington – Eastern Cascades, Olympic Peninsula, Western Cascades, Western Lowlands
- Oregon – Coast Range, Willamette Valley, Western Cascades, Eastern Cascades, Klamath
- California – Coast, Klamath, Cascades

Green Diamond does not know the actual number and distribution of currently occupied NSO locations across the range because of limited areas surveyed on an annual basis. However, incomplete surveys and anecdotal observations suggest that while NSO continue to occupy the majority of their presumed historical range, many historical sites are no longer occupied because barred owls displace NSO, and timber harvest and severe fires displaced their suitable habitat. They are very rare in certain areas including British Columbia, southwestern Washington and the northern coastal ranges of Oregon. Populations in most of their remaining range declined to various degrees.

3.2.1.3 Life History and Habitat

The NSO is a primarily nocturnal predator that forages mostly on small mammals. NSO diets vary geographically and by forest type with flying squirrels, the predominant prey in Washington and Oregon Douglas-fir and western hemlock forests (Forsman et al., 1984). Dusky-footed woodrats comprise a major part of the diet in the Oregon Klamath, California Klamath and California Coastal Provinces (Forsman et al., 1984, 2001, 2004a; Ward et al., 1998; Hamer et al., 2001). NSO are relatively long-lived, territorial and typically monogamous. Despite a long reproductive lifespan and high adult survivorship, NSO fecundity is relatively low due to a rather small clutch (average of two eggs), variability in nesting (typically do not nest every year) and delayed onset of breeding (most breed for the first time at 2 or 3 years). Home-range sizes vary across the species' range with a generally decreasing trend from north to south (USFWS, 1990b). Estimates of median annual home range size vary from 2,955 acres in the Oregon Cascades (Thomas et al. 1990) to more than 14,000 acres on the Olympic Peninsula (USFWS, 2008a). Home range sizes vary depending on the primary prey available in a given region. For example, NSO have larger home ranges where flying squirrels are the predominant prey and smaller home ranges where wood rats are the predominant prey (Zabel et al., 1995).

NSO generally begin courtship in February or March with females typically laying eggs in late March or April. Nesting and fledging time vary with latitude and elevation (Forsman et al., 1984).

After fledging in late May or June, juvenile NSO depend on their parents until they hunt on their own, with parental care continuing from fledging into September (Forsman et al., 1984; USFWS, 1990b). Juvenile NSO dispersal from their natal territories typically begins in September and October, with a few individuals leaving as late as November and December (Miller et al., 1997; Forsman et al., 2002). Median natal dispersal distances (straight line distance from natal site to adult territory) are approximately ten miles for males and 15.5 miles for females (Forsman et al., 2002).

NSO inhabit a variety of forest types including Douglas-fir, western hemlock, grand fir, white fir, ponderosa pine, Shasta red fir, mixed evergreen, mixed conifer hardwood and redwood (Forsman et al., 1984). The transition to subalpine forest, characterized by relatively simple structure and severe winter weather, generally corresponds to the upper elevation limit for NSO occurrence (Forsman, 1975; Forsman et al., 1984). NSO generally rely on older forest habitats because they contain the structural characteristics necessary for nesting, roosting, foraging and dispersal (Carroll and Johnson, 2008). Nesting and roosting habitat typically include forested habitats with:

- Moderate to high canopy closure (60 to 90%)
- Multi-layered, multi-species canopy with large overstory trees (>30 inches diameter at breast height [dbh]); numerous large trees with various deformities, e.g., large cavities, broken tops, mistletoe infections, and other evidence of decadence
- Large snags
- Large accumulations of fallen trees and other woody debris on the ground
- Sufficient open space below the canopy for owls to fly (Thomas et al., 1990)

Foraging habitat generally contains attributes similar to those in nesting and roosting habitat, but may not offer high enough quality to support nesting pairs (USFWS, 1992b). At a minimum, dispersal habitat consists of forests with adequate tree size and canopy closure to provide protection from avian predators and at least some foraging opportunities (USFWS, 1992b).

In the southern Oregon Coast and California Klamath Provinces, landscape-level analyses suggest that a mosaic of late-successional habitat interspersed with other seral stages may benefit NSO more than large homogeneous older forest tracts (Meyer et al., 1998; Franklin et al., 2000; Zabel et al., 2003). Younger forests that possess some of the structural characteristics of older forests may also support NSO. In coastal northwestern California, younger redwood and mixed conifer-hardwood forests support considerable numbers of NSO, particularly in areas where hardwood species and larger residual trees provide a multi-layered canopy and added structural diversity in younger forest stands (Thomas et al., 1990; Diller and Thome, 1999).

3.2.1.4 Listing Status and Threats

The Service completed a status review for the NSO in 1990 (USFWS, 1990a) and officially listed the owl as threatened under the Endangered Species Act (ESA) on June 26, 1990. The Service prepared a draft recovery plan in 1992, but never finalized it (USFWS, 1992a). Following completion of the 1992 draft recovery plan, in a final ruling on January 1, 1992, the Service designated Critical Habitat for the NSO that encompassed 6,887,000 acres of federal lands in California, Oregon, and Washington (USFWS, 1992b). In 2004, the Service completed a five-year review of the NSO’s status and concluded that it should remain listed under the ESA as a threatened species (USFWS, 2004a). On May 13, 2008, the Service completed and signed a final recovery plan for the NSO (USFWS, 2008a). Subsequently, the Service issued a final ruling for a revised Critical Habitat on August 13, 2008 (USFWS, 2008b). After a court challenge in 2010, the Service agreed to revise the 2008 final recovery plan and critical habitat designation. A revised recovery plan was published in June 2011 (USFWS, 2011a) and a new designation of critical habitat for NSO was adopted on December 4, 2012 (USFWS, 2012a). On September 4, 2012, the CFGC received a petition to list the NSO as threatened or endangered pursuant to the CESA (EPIC, 2012). On August 25, 2016, the CFGC listed the NSO as threatened pursuant to CESA.

The Service listed the NSO as a threatened species throughout its range “due to loss and adverse modification of suitable habitat because of timber harvesting and exacerbated by catastrophic events such as fire, volcanic eruption and wind storms” (USFWS, 1990b). At that time, the Service thought loss of habitat, and population isolation and decline represented the greatest concern range-wide to NSO conservation (USFWS, 1990b, 1992b). Following their Five-year Status Review in 2004, The Service modified the threat assessment with competition from barred owls deemed a primary and imminent risk. The Service also considered the threat of increased habitat loss due to catastrophic wildfire since the 1990 listing (USFWS, 2004a). The most recent threat assessment, included in the revised recovery plan, identified barred owl competition, past habitat loss, and current habitat loss, i.e., timber harvest and wildfire, as the three most significant risks. The revised recovery plan also stated “… it is becoming more evident that securing habitat alone will not recover the spotted owl. Based on the best available scientific information, competition from the barred owl (*S. varia*) poses a significant and complex threat to the spotted owl" (USFWS, 1992b).

Due to their slightly larger size and apparently more aggressive behavior (Van Lanen et al., 2011), barred owls were recognized as a potential threat to spotted owl populations as early as 1990 when the Service listed the NSO as a threatened species (USFWS, 1990b). In a critical review of all available information on the status of the species, Courtney et al. (2004) reported that barred owls were believed to be a greater threat than previously anticipated. Barred owls are considered habitat and prey generalists (Mazur and James, 2000; Hamer et al., 2001). However, their similarity in size, overlapping diet and broader range of habitat use compared to spotted owls supports current hypotheses and competition theory predictions that they will substantially compete for resources (Hamer et al., 2001, 2007; Gutiérrez et al., 2007). Barred owls also have comparatively smaller home ranges (Hamer, 1988), and potentially greater reproductive output, and are known to become numerically superior in favorable habitats (Wiens et al., 2011). Occasional hybridization between the two species is documented (Hamer et al., 1994; Kelly and Forsman, 2004) but not considered to be a serious threat to spotted owl populations.

Barred owls may negatively affect detection probability of NSO during surveys, site occupancy, reproduction, and survival. A negative effect of barred owls on detectability of NSO was reported by several studies (Dugger et al. 2009; Olson et al. 2005; Crozier et al. 2006; and Wiens et al., 2011). Kelly et al. (2003) found that NSO occupancy was significantly lower in territories where barred owls were detected within 0.8 kilometer of the territory center. Pearson and Livezey (2003), and Gremel (2005) also reported relationships between barred owl presence and reduced site occupancy by NSO. In a related study, Olson et al. (2004) found the presence of barred owls negatively affected reproductive success in NSO. A telemetry study of barred owls and NSO in coastal Oregon provided compelling evidence that interference competition for territorial space limited availability of old forests to NSO, their preferred habitat (Wiens et al., 2014). This interference competition with barred owls for territorial space constrained the availability of critical resources, which resulted in low survival rates and no successful reproduction for NSO that were within 1.5 kilometers of nesting barred owls.

While some uncertainties remain when projecting the outcome of interactions between barred owls and NSO throughout its entire range, substantial evidence suggests that barred owls are contributing to the population decline of the NSO with declines of 31 to 77% documented in 11 demographic study areas in Washington, Oregon and California (Dugger et al., 2016). Collectively, this provides increasingly overwhelming evidence that lacking some form of intervention, barred owls likely will replace or seriously influence NSOs throughout all or major portions of their range, and reduce the likelihood that the species will be recovered (USFWS, 2011a).

Note: Appendix B includes a more detailed description of the NSO with complete references.

3.2.2 Fisher (*Pekania pennanti*)

3.2.2.1 Species Description

The fisher is a seldom seen, secretive, medium-sized forest carnivore in the Mustelidae family that includes other small and medium-sized carnivores such as weasels, martens, mink, otters, badgers and wolverine. Fisher body size displays pronounced sexual dimorphism with females weighing between 2 to 2.5 kilograms (4.4 to 5.5 pounds) and ranging in length from 70 to 95 centimeters, while males weigh between 3.5 to 5.5 kilograms (7.7 to 12.1 pounds) and range from 90 to 120 centimeters long (Powell, 1993). Fisher have a slender weasel-like body with relatively short legs and a long well-furred tail (Douglas and Strickland, 1987). Fisher are mostly dark brown with white or cream patches distributed on their undersurfaces, but they appear uniformly black from a distance (Powell, 1993). They have a sharp muzzle with small rounded ears giving their head a somewhat bear-like appearance.

Although Goldman (1935) recognized three North American fisher subspecies, others indicate that subspeciation is not appropriate and all fisher in North America are one group, *Martes pennanti* (Grinnel, 1937; Hagmeier, 1956). Recent genetic research has led to a reclassification of the fisher into the genus *Pekania* (Sato et al., 2012) and shows that fisher are more closely related to the taya (*Eira barbara*) and wolverine (*Gulo gulo*) than to other species in the genus *Martes* (Nyakatura and Bininda-Emonds, 2012; Sato et al., 2012; USFWS, 2014a). Furthermore, other genetic studies demonstrate evidence of population subdivision in fisher, especially among populations in the western US and Canada (Drew et al., 2003; Aubry and Lewis, 2003; Wisely et al. 2004). In the West Coast population, evidence demonstrates that genetic diversity follows a latitudinal gradient from British Columbia to the southern Sierra Nevada, with genetic diversity decreasing from north to south (Wisely et al., 2004). In California, fisher haplotype frequencies differ strongly between the northern population and southern Sierra population (Drew et al., 2003; CDFG, 2010). Preliminary analyses also suggest the two fisher populations in California (northern California and southern Sierra Nevada) separated thousands of years ago (CDFG, 2010). In 2015, the California Department of Fish and Wildlife determined that the Southern Sierra Nevada and Northern California fisher populations are two distinct evolutionary significant units under the CESA (CDFW, 2015). Future work on genetics may provide critical information on current fisher distribution in California.

3.2.2.2 Range and Distribution

Fisher occur throughout a large swath of coniferous and mixed forests throughout Canada and the northern United States. This includes Canadian areas from Labrador to the southern Yukon Territory and American areas from the Appalachian Mountains to central California (Powell, 1993). Over trapping, predator control, and alterations of forested habitats drastically reduced fisher range during the 1800s (Douglas and Strickland, 1987; Powell, 1993; Powell and Zielinski, 1994; Lewis and Stinson, 1998). As a result of trapping closures, changes in forested habitats, and reintroductions, fisher distributions recovered in portions of their central and eastern United States historic range (Brander and Books, 1973; Powell and Zielinski, 1994).

In the western range, fisher distributions remain seemingly restricted relative to their historic range. Powell and Zielinski (1994) noted continued fisher population decline in the West. Fisher were extirpated in lower mainland British Columbia, but they may still occur in low densities at higher elevations. In Pacific states, fisher historically and frequently inhabited low to mid-elevation forests (Grinnell et al., 1937; Schempf and White, 1977; Aubry and Houston, 1992). Based on a few detections in Washington, Oregon, and the northern Sierra Nevada in recent decades, it appears there was fisher population extirpation or significant reduction (Aubry and Houston 1992; Zielinski et al. 1995; Aubry and Lewis, 2003).

Fisher were previously thought distributed throughout most of the Sierra Nevada, Southern Cascade, and northern Coast Ranges in California (Grinnel, 1937). However, recent genetic analyses suggest the southern Sierra Nevada and Northwestern California populations separated thousands of years ago, with the historical gap present in northern Sierra Nevada (CDFG, 2010). Fisher now occur in two isolated populations in California: one on the west slope of the southern Sierra Nevada and the other in the Klamath Mountains and Coast Ranges of northwestern California. These populations are approximately 270 miles apart (430 kilometers) (Zielinski et al., 1995). Fisher apparently no longer inhabit much of the Coast Range, including habitats in Marin, Sonoma, and most of Mendocino County, and generally are absent between the Pit River in the northern Sierra Nevada/Cascades to the Merced River in the southern Sierra Nevada. Range losses are likely the result of exploitative trapping in the early 1900s. CDFW hypothesized that habitat modification from timber harvesting, other human-caused factors and fisher limited dispersal capability hindered successful recolonization (CDFG, 2010).

3.2.2.3 Life History and Habitat

Although fisher are adept climbers well-known for their arboreal habits, most hunting probably takes place on the ground (Douglas and Strickland, 1987). Fisher are generalist predators that feed opportunistically with diverse diets, including: mammalian and avian prey, carrion, vegetation, insects, and fungi (Grenfell and Fasenfest, 1979; Powell, 1993; Martin, 1994). Although their diet shares some general similarities with fisher across the continental range, California fisher tend to consume a broader food array than those found elsewhere in North America (Golightly et al., 2006). In addition, coastal regions appeared to have greater diet diversity than interior regions (Martin, 1994; Zielinski et al., 1999; Zielinski and Duncan, 2004; Golightly et al., 2006). Unlike fisher elsewhere in their range, reptiles comprise a regular fisher diet component in California (Golightly et al., 2006). Dietary studies from across North America show that fisher often specialize on porcupine and/or snowshoe hares (Powell, 1993; Martin, 1994; Weir et al., 2005). However, in California, both populations show extremely low occurrences of lagomorphs and porcupine in diets (Golightly et al., 2006; Zielinski et al., 1999; Zielinski and Duncan, 2004). In northern California, fisher diet appeared to vary with proximity to the coast, with sciurids favored at interior sites and woodrats (*Neotoma sp.*) favored at coastal sites (Golightly et al., 2006).

Like other mustelids, the fisher’s reproductive cycle involves delayed implantation. Fertilized eggs remain inactive for approximately 10 months, followed by an active 30- to 36-day pregnancy. Fisher kit birth typically occurs in late March or early April after this almost 12-month gestation, followed by 7 to 10 days where females can breed (Powell, 1993; Mead 1994; Frost et al. 1997). Average litter size is two to three kits born with eyes and ears closed and weighing between 40 and 50 grams (Powell 1993; Powell and Zielinski, 1994). The kits' eyes open at seven to eight weeks and they remain dependent on milk until 8 to 10 weeks. However, they mature quickly and are capable of killing their own prey at about four months (Powell 1993; Powell and Zielinski, 1994). Juvenile fisher are sexually mature and begin establishing their home ranges at about one year (Wright and Coulter 1967; Arthur et al., 1993).

Fisher have low annual reproductive capacity (Heinemeyer and Jones, 1994; Lewis and Stinson, 1998). Because of delayed implantation, females cannot birth for the first time until reaching at least two years-old. In a meta-analysis of regional fisher studies, Truex et al. (1998) found that reproductive success appears to vary from year to year, with various studies reporting from 14 to 73% of females lactating during various years. In addition, a study in the Northern California Hoopa Valley reported 62% (29 of 47) of denning opportunities from 2005 to 2008 resulted in weaning at least one kit (Higley and Mathews, 2009).

The fisher is a late successional forest habitat specialist (Buskirk and Zielinski, 2003). However, in California, fisher may select late successional forest structures for resting and denning, but they may select younger age forest characteristics for foraging (Zielinski et al., 1999). Forest habitats suitable for resting and denning are not necessarily late-successional forests, but may be younger forests that contain remnant structures suitable for denning or resting (Klug, 1997; Thompson, 2008). Forest cover may provide many benefits to fisher, including protection from predators, reduced energy expenditures due to proximity of foraging and resting sites, favorable microclimates, and increased prey abundance and vulnerability (Buskirk and Powell, 1994; Powell and Zielinski, 1994).

Fisher use a variety of forest types in California, including redwood, Douglas-fir, Douglas-fir – tanoak, white fir, mixed conifer, mixed conifer-hardwood, and ponderosa pine (Klug, 1997; Truex et al., 1998; Zielinski et al., 2004b). Forest structures that provide successful foraging while still offering resting and denning sites may be more important than actual tree species composition (Buskirk and Powell, 1994). Important forest structures should provide high prey diversity, lead to increased prey vulnerability, and offer denning and resting sites (Powell and Zielinski, 1994). Forest canopy cover might be one of these important structural components, as moderate and dense canopy cover is an important fisher occurrence predictor at the landscape scale (Truex et al., 1998; Carroll et al., 1999; Zielinski et al., 2004b; Davis et al., 2007). At the stand and site scale, fisher tend to benefit from numerous structural attributes, including diverse tree sizes, canopy gaps and under-story vegetation, and decadent structures (Powell and Zielinski, 1994).

3.2.2.4 Listing Status and Threats

The Service published a 12-month fisher status review in April 2004 for the fisher West Coast Distinct Population Segment (DPS) following a petition to list the fisher in 2000, and a court order to issue a 90-day finding in 2003. The Service found that listing the DPS was warranted, but precluded by higher priority actions to amend the Endangered and Threatened Wildlife and Plants lists due to higher priority actions (USFWS, 2004b). This established the fisher's federal status as a candidate species. In a November 2009 review of candidate species, the Service found the magnitude of fisher threats remained high for the West Coast DPS, but the threats were not considered imminent and the species remained a candidate. In 2011, the Service settled multiple listing lawsuits by agreeing to either propose the fisher for listing in fiscal year 2014 (which would result in a fiscal year 2015 listing) or issue a notice that listing is not warranted. On March 18, 2013, the Service issued a notice reinitiating a status review of the fisher in anticipation of its decision on a potential listing and critical habitat designation for the Pacific fisher under the ESA. On October 7, 2014, the Service proposed listing of the West Coast fisher as a threatened species. On April 18, 2016, the Service withdrew the proposed listing and determined that the fisher was not threatened with extinction. (USFWS, 2016)

In California, fisher status under state law received much scrutiny in recent years. The California Fish and Game Commission (CFGC) received a petition in January 2008 to list the fisher under the CESA. In August 2008, CFGC voted to reject the petition based on CDFW's recommendation and input from other stakeholders and the public (CDFG, 2008). However, in March 2009, CFGC reversed its decision and voted to accept the petition. CFGC placed the fisher on California's candidate species list, initiating a 1-year status review process in April 2009. Following extensive review, CDFG maintained its recommendation of not listing the fisher and CFGC voted to reject the petition in June 2010. In November 2010, the Center for Biological Diversity filed a lawsuit challenging the CFGC decision not to list the fisher for protection under the CESA. On July 23, 2012, the decision not to list the fisher under the CESA was found invalid and the matter has been remanded to CFGC for further review. On June 8, 2015, CDFW completed a new status review for fisher and determined that the Southern Sierra Nevada and Northern California fisher populations are two, distinct evolutionary significant units. The CDFW recommended listing of the Southern Sierra Nevada ESU for protection under the CESA, and, on August 5, 2015, CFGC listed the Southern Sierra Nevada ESU of fisher as a threatened species under the CESA. Fisher in the Plan Area are within the Northern California ESU, which was not listed under the CESA.

Numerous threats can affect California fisher populations. The most significant of these three threats are loss of habitat due to timber harvest activities, stand replacing fire and small populations. Of these threats, loss of habitat due to timber harvest is more prominent in the northern California population, while small population and catastrophic fire affect the southern Sierra Nevada population (CDFG, 2010).

Reduced late-seral forest habitat in California due to timber harvest is well-documented. Laudenslayer (1985) reported that National Forest late-seral forests declined by 50% in California, from an estimated four million acres in 1900 to two million acres in 1985. Beardsley et al. (1999) conducted a comparative study of late-seral forests in the Sierra Nevada, and reported that only 11% of the Sierra Nevada timber was currently late seral, mostly at high elevations. CDFW considers late-seral forest harvest, especially removal of key late-seral habitat elements, a fisher threat. Although many younger seral stage forests with high canopy cover may provide suitable foraging habitat, they are not likely to provide denning and resting unless they also provide late seral habitat elements necessary to sustain those activities, i.e., large trees and snags with cavities, (CDFG, 2010). Two northwestern California fisher studies indicated timber harvest resulting in habitat modification reduce fisher density and survival (Buck et al., 1994; Truex et al., 1998). However, documentation demonstrates that fisher occur and reproduce at relatively high densities in heavily managed landscapes with long histories of timber harvest in coastal northwestern California (Klug, 1997; Thompson, 2008; Higley and Matthews, 2009). While timber harvesting can negatively affect several fisher habitat aspects at various scales, the extent to which studies have demonstrated that harvesting has negatively affected fisher populations or created large, e.g., size of fisher home range, areas of unsuitable habitat in northern California is unknown (CDFG, 2010).

Catastrophic wildfire can affect fisher populations in a variety of ways, including direct mortality, habitat destruction prey species impact, and isolation and fragmentation of suitable fisher habitat (Green et al. 2008). Habitat destruction and isolation in the southern Sierra Nevada will synergistically interact with diminished population and low genetic variability to increase southern Sierra Nevada fisher population risk (Spencer et al., 2008). With the possible exception of the coastal redwood zone, wildfire may also threaten northwestern California fisher (CDFW, 2015) like it does NSO in the interior region (Courtney et al., 2004). Recent fire data compilations suggest larger fuel loads and increased high intensity fire areas caused by decades of fire suppression in the North Coast Ranges (Stuart and Stephens, 2006), Klamath Mountains (Skinner et al., 2006) and Southern Cascades (Skinner and Taylor, 2006). Extensive timber management created forests more prone to high severity fires in these regions (Frost and Sweeney, 2000; Stuart and Stephens, 2006). Together, these two factors put northern California fisher populations at risk (CDFG, 2010).

Anticoagulant rodenticide poisoning has emerged as a new threat to fisher populations in California (Gabriel et al., 2012). Anticoagulant rodenticides (ARs) are used to eradicate or suppress rodent pest populations in agricultural areas, urban settings, and illegal marijuana cultivation sites to minimize economic losses (Berny, 2007; Gabriel et al., 2012). ARs bind and inhibit enzyme complexes responsible for recycling of vitamin K necessary for the production and activation of clotting factors. Exposure to ARs can cause direct mortality and potentially increases a fisher's susceptibility to other diseases and predation (Gabriel et al., 2012). Gabriel et al. (2012) found that 46 of 58 (79%) fisher carcasses in California were exposed to one or more anticoagulant rodenticide compounds. In northern California, 13 of 18 (72%) fishers were exposed to AR compounds. To date, four of the 58 tested fishers in California have died as a result of lethal toxicosis from AR exposure. In addition to the direct mortality risks, ARs pose a potential indirect risk of depleting the fisher's rodent prey base (Gabriel et al., 2012).

Even with these primary threats identified, current scientific information provides no direct evidence about the factors limiting the California fisher population. In addition, we do not know whether the local or regional population is increasing or decreasing. The current preliminary information in the Hoopa region and in the southern Sierra Nevada suggests the fisher population is stable to slightly increasing. The southern Sierra Nevada population is small and isolated, but most importantly, the population may be limited by space as its only route or link for expansion is north up along the central Sierra Nevada. To help alleviate this problem, a coalition of state, federal and private cooperators initiated a translocation effort in 2009 to relocate fisher from the northwestern California population to the central Sierra Nevada. Initially, the coalition planned to translocate 40 fisher (16 male, 24 female) over a three year period (Powell, 2010). In December 2009 and January 2010, the coalition captured 19 fisher in Siskiyou, Shasta, and Trinity Counties, and translocated 15 to private timberlands in northeastern Butte County between December 2009 and February 2010 (CDFG, 2010). The coalition will monitor the introduced population intensively, documenting survival, reproduction and habitat use during the first five years following release. Early translocation results are positive. This may open more fisher reestablishment opportunities in other parts of their historical range.

Note: Appendix B includes a more detailed description of the fisher with complete references.

3.2.3 Red Tree Vole and Sonoma Tree Vole (*Arborimus longicaudus* and *A. pomo*)

3.2.3.1 Species Description

Tree voles (*Arborimus* spp.) are unique, almost exclusively arboreal, and nocturnal microtine rodents. They live in Pacific Northwest coniferous forests feeding almost exclusively on conifer needles (primarily Douglas-fir), nest-building and feeding in the same trees. They feed by stripping resin ducts from these needles, creating potentially large discarded masses of hair-like resin ducts, as a unique feature of their nests. The tree voles have long, soft coats that vary in color from rich brown to bright reddish orange, with a generally light gray underbody. They have small eyes, a long well-haired tail, and pale almost hairless ears (Howell, 1926). They range in size from approximately 158 to 206 millimeters total length, and generally weigh between 25 and 47 grams (Maser et al., 1981). There are two tree vole species, the Sonoma tree vole (*Arborimus pomo*) in California and the red-tree vole (*Arborimus longicaudus*) in Oregon and northern California (Johnson and George, 1991; Bellinger et al., 2005).

3.2.3.2 Range and Distribution

Voles of the genus *Arborimus* have a limited geographical distribution, occurring from the Columbia River in northern Oregon south to Sonoma County, California (Taylor, 1915; Maser et al., 1981). The red tree vole occurs throughout western Oregon, from the Columbia River south to the California border, and continuing into northwestern California to approximately the Klamath River (Bellinger et al., 2005; Johnson and George, 1991). Until recently, research indicated red tree voles only occurred west of the Cascade Crest. However, Forsman et al. (2009) documented red tree voles in the headwaters of the Lake Branch of the Hood River, on the eastern slope of the Cascade Range. The Sonoma tree vole occupies the region immediately south of the red tree vole in California, stretching south along the Coast Range to Sonoma County, California (Bellinger et al., 2005; Johnson and George, 1991).

3.2.3.3 Life History and Habitat

Tree voles are one of the most specialized small mammals in North America (Maser et al., 1981). They also have secretive habits, making them one of the most poorly understood mammals endemic to the Pacific Northwest (Forsman et al., 2004b). Tree voles primarily build nests in Douglas-fir trees, but may also use a variety of other tree species (Maser et al., 1981; Thompson and Diller, 2002). They may also occasionally build ground nests (Thompson and Diller, 2002). Active tree vole nests are generally located within the live canopy of the nest tree, typically situated against the bole of the tree on a whorl of branches in younger trees and away from the bole on larger branches in older trees (Maser, 1966; Thompson and Diller, 2002). Although tree voles construct most nests by themselves from small twigs cut from the nest tree and surrounding canopy, they will also occupy nests abandoned by birds, squirrels, and woodrats. Tree voles line their nest inner chamber with resin ducts remaining after they consume non-resinous portions of the conifer needles (Maser, 1966).

The majority of tree vole's very specialized diet is Douglas-fir needles (Maser, 1966). They also consume other conifers needles and eat the tender bark and sometimes the pithy center of fresh twigs (Forsman et al., 2009; Maser, 1966). Recent studies indicate that tree voles may spend very little time foraging away from their nest. Instead, they harvest most twigs during short foraging bouts and promptly return them to the nest for later consumption (Forsman et al., 2009). Tree voles cut fresh conifer twigs at night, and although they may feed some while away from the nest, they promptly bring most twigs back to the nest for stockpiling (Maser et al., 1981; Forsman et al., 2009). When feeding, tree voles bite individual needles off at the base, then strip the resin ducts from each needle side one at a time, before consuming the remainder of the needle (Benson and Borell, 1931; Maser et al., 1981). They discard these resin ducts to accumulate in the nest or use them to line the nest's inner chambers. Tree voles probably obtain most of their required moisture from their food, but may also lick moisture off foliage when available (Taylor, 1915; Maser, 1966).

Tree voles typically spend their time alone with one adult vole occupying each nest, except when females are receptive (Howell, 1926; Maser, 1966; Forsman et al., 2009). Swingle and Forsman (2009) determined that most individuals occupy a single nest tree and adjacent foraging trees with interconnecting branch pathways with the nest tree. A smaller portion of tree voles used two or more nests that were a mean distance of 45 meters apart. Estimates of mean and median home range were 1,732 and 760 square meters, respectively. Although home range size varied considerably, gender, or vole or forest age failed to explain much of it. However, females occupied fewer nests and made fewer movements between nest trees than males. Male home ranges were larger than females during late winter and spring during the peak breeding period (Swingle and Forsman, 2009).

Tree voles typically breed within 24 hours of giving birth, which may occur anytime throughout the year (Benson and Borell, 1931; Maser et al., 1981; Forsman et al., 2009). Litter size varies from one to four young, with two or three as the norm (Maser et al. 1981). Young are altricial and develop slower than ground-dwelling voles, remaining in their nursery nests until they disperse at 1 to 2 months (Hamilton, 1962; Maser et al., 1981; Swingle, 2005; Forsman et al., 2009).

There are few detailed studies of tree vole habitat requirements. However, general habitat requirements are available from numerous studies focused on other aspects of tree vole ecology and occurrence. Tree voles are almost exclusively arboreal and generally associated with coniferous forest habitats, including both mature and immature forests (Taylor, 1915; Howell, 1926; Benson and Borell, 1931; Maser, 1966; Thompson and Diller, 2002; Forsman et al., 2009). Although tree voles do occur and nest in younger forests, they are generally more abundant in older forests (Corn and Bury, 1986, 1991; Aubry et al., 1991; Thompson and Diller, 2002). Although they are found in a variety of forest types (Douglas-fir, redwood, Sitka spruce), Douglas-fir trees are typically present in the immediate vicinity since the needles are their preferred food (Maser, 1966; Thompson and Diller, 2002).

Trees that contain tree vole nests are generally larger, in both girth (dbh) and height, than surrounding trees that do not contain nests (Gillesberg and Carey, 1991; Meiselman and Doyle, 1996; Thompson and Diller, 2002). Although studies indicated tree voles spend some time on the ground (Corn and Bury, 1986, 1991; Raphael, 1988; Gilbert and Allwine, 1991; Swingle and Forsman, 2009), this time is not substantial, as they move quickly from tree to tree when interconnecting branches are not available (Swingle and Forsman, 2009). Howell (1926) suggested that considerable land expanses without suitable trees are potential barriers to tree vole movements. However, more recent data in early successional forest stands (Corn and Bury, 1986; Verts and Carraway, 1998), and observations on the ground (Swingle, 2005) suggests that small forest gaps may not necessarily impede tree vole movements.

3.2.3.4 Listing Status and Threats

The ESA protects neither the red tree vole nor the Sonoma tree vole in the Plan Area. However, the Service recently reviewed the dusky tree vole (*A. longicaudus silvicola*), a subspecies of the red tree vole found in the northern Coast Ranges of Oregon north of the Siuslaw River, for listing as threatened or endangered under the ESA (USFWS, 2008c). The Service issued a 12-month finding, and based on the best scientific and commercial information available, determined that listing the North Oregon Coast population of the red tree vole as a distinct population segment (DPS) was warranted but precluded by higher priority listing actions. However, the species will be added to the Service list of candidate species due to these higher priority actions (USFWS, 2011a). Within the range of the species to be covered in this HCP, the

Oregon Department of Fish and Wildlife (ODFW) classifies the red tree vole as Sensitive-Vulnerable (ODFW, 2008) in southern Oregon, while the CDFW classifies the Sonoma tree vole as a Species of Special Concern in northern California (CDFG, 2011). This HCP will discuss tree vole species together and refer to them as such due to their similar ecological niches and historical variation in taxonomy. This HCP will provide specie specific information where appropriate.

Tree vole ecology and habitat requirements are not well understood. Consequently, species threats are not well documented. Two primary threats to tree vole population persistence are habitat loss and habitat fragmentation. The primary cause of habitat loss is timber harvest. Wildfire threat in the coastal mountains is generally not as great as in interior forests. Because tree vole distribution is often patchy, timber harvest can potentially remove entire colonies. Timber harvest may also reduce habitat quality through removal of structural components important to tree voles, e.g., deformed trees, large live trees and snags. Local tree vole populations experience increased predation threat and poor dispersal ability to other suitable habitats as occupied habitat harvest, removal or degradation occurs.

Forest fragmentation may threaten tree vole persistence as they do not disperse long distances (Dunk and Hawely, 2009). Timber harvest or other disturbances, e.g., wildfire, windthrow, fragments landscapes, making tree vole dispersal and colonization dispersal more difficult. It is unknown if the time required for new tree vole site colonization is due to delayed suitable stand structure development or if it relates to time necessary for vole dispersal from adjacent stands. Thompson and Diller (2002) reported anecdotal observations of vole nests in stands ten to 16 years-old. They suggested that the source distance of colonizing voles may increase the time for colonization beyond the age when stands are structurally suitable for occupation. Fragmentation may limit dispersal and colonization of suitable habitats. This may leave long-term tree vole viability, in some regions, dependent on colony long-term survival in occupied stands.

Note: Appendix B includes a more detailed description of tree voles with complete references.

3.2.4 Humboldt Marten (*Martes caurina humboldtensis*)

3.2.4.1 Species Description

The marten is a seldom seen secretive small forest mustelid, sharing the same genus as the fisher, and is similar, but smaller. Martens have long, slender bodies with relatively large rounded ears, short limbs, and bushy tail (Clark et al., 1987). Their triangular faces feature muzzles less pointed than fisher. Like fisher, they exhibit sexual dimorphism, with males 20 to 40% larger than females (Buskirk and Zielinski, 1997). Their total length is 500 to 680 millimeters (20 to 24 inches) and adults weigh 0.5 to 1.4 kilograms (1.2 to 3.4 pounds), depending on sex and subspecies (Buskirk and McDonald, 1989). Their long, silky, dense fur is pale yellowish buff, tawny brown or almost black. The head color is usually lighter than the body, with darker legs and tails. A characteristic throat and chest bib is pale straw to vivid orange (Clark et al., 1987).

Although there is considerable recent scientific debate, the American marten currently is a single species (Clark et al., 1987; Hall, 1981; Powell et al., 2003). There are 14 subspecies of marten (Hall and Kelson, 1959). Traditionally, there are two morphologically distinct subspecies separated into groups: the *americana* group and the *caurina* group (Stone et al., 2002; Powell et al., 2003; Hagmeier, 1961). The *americana* group includes subspecies from Montana and Idaho northward to Alaska and eastward to the Atlantic Coast. The *caurina* group includes subspecies from the Pacific Northwest and the Great Plains (Carr and Hicks, 1997; Stone et al., 2002). Two of the purported *caurina* group subspecies, the Humboldt marten and Sierra marten (*M. a. humboldtensis* and *M. a. sierrae*) occur in California. When compared to the Sierra subspecies, the Humboldt marten has a darker and richer golden tone, less orange and yellow throat patch, smaller skull (Grinnell and Dixon, 1926), and smaller and less crowded premolars and molars (Buskirk and Zielinski, 1997).

In 1996, track-plate stations in northwestern California detected martens within the historical range of the Humboldt subspecies (Zielinski et al., 1998) for the first time in approximately 50 years (Zielinski and Golightly, 1996). Slauson et al., (2009) compared mitochondrial DNA sequence of coastal and Sierra subspecies and historical and contemporary martens within the Humboldt subspecies range. The analysis indicated Oregon coastal martens and historical and contemporary martens within the Humboldt subspecies range all share common haplotype, not found in martens from the Oregon Cascades. These results may suggest a single subspecies occurs along the California and Oregon coast (Slauson et al., 2009). Currently, there is a more definitive genetic analysis underway with a larger sample of various potential marten subspecies. Green Diamond adopted the scientific law of parsimony and refers to martens in the Plan Area as American martens, lacking timely genetic or geographic evidence of separation between the purported Humboldt and coastal marten subspecies.

3.2.4.2 Range and Distribution

Marten inhabit forested regions throughout boreal North America with populations extending southward to the southernmost extent in the California Sierra Nevada Mountains and the southern New Mexico Rocky Mountains (Gibilisco, 1994). In California, martens occur in the far northwestern Coast Range, east through the Salmon-Trinity Mountains to the Cascades, and south throughout the Sierra Nevada (Zielinski et al., 2001). In the far western United States, marten populations also occur in the coastal and interior Oregon and Washington mountains (Zielinski et al., 2001). Within north coastal California, the Humboldt subspecies historically occurred in the coast redwood zone from the Oregon border south to Sonoma County (Grinnell and Dixon, 1926; Grinnell, 1933). Marten surveys since 1995, conducted in much of this region, suggest they no longer occupy much of their historical California range (Zielinski et al., 2001; Slauson, 2003). Currently, only one small portion of martens occurs in southern Del Norte and northern Humboldt Counties, <5% of their historical range in this part of the state (Slauson, 2003).

3.2.4.3 Life History and Habitat

Few published papers address marten life history and habitat requirements in northwestern California. Information included here describes martens in general, with information specific to northwestern California where available.

Martens are opportunistic predators with a diverse diet that includes mammals, birds, carrion, eggs, insects, and vegetation, e.g., fruits, berries, nuts, fungi, lichens, grass, (Buskirk and Ruggiero, 1994; Martin, 1994; Zielinski and Duncan, 2004). Voles (*Microtus* spp. and *Clethrionomys* spp.), squirrels (*Tamiasciurus* spp. and *Spermophilus* spp.), and chipmunks (*Tamias* ssp.) are also important marten food (Martin, 1994). In the California Sierra Nevada, Zielinski and Duncan (2004) noted 34 distinguishable plant taxa and animals as marten food, with mammals as the most important, followed by insects and plants. Well-documented dietary seasonal variations occur with berries (Buskirk and Ruggiero, 1994) and insects, e.g., bees and wasps, (Zielinski and Duncan, 2004) peaking in late summer and fall.

Based on scat analysis, including 420 samples collected from summer 2000 through fall 2003, marten diets in northwestern California primarily include mammals (93%), berries (85%), birds (21%), insects (20%), and reptiles (7%). Sciurids and Murid voles (*Clethrionomys* and *Arborimus*) were the most common mammal species in the diet. The frequency of berries and birds in the diet in northwestern California is the highest reported for American martens (Hamlin et al., 2010).

Marten mating generally occurs in July or August (Strickland et al., 1982) with kit births occurring in late March or April the following year, due to delayed embryo implantation (Buskirk and Ruggiero. 1994). Kits are helpless and completely dependent at birth, but rapid growth and weaning occur at about 6 weeks (Buskirk and Ruggiero, 1994). Martens reach sexual maturity at approximately one year, but due to delayed implantation, effective breeding may not occur before they are three years-old (Powell et al. 2003). Martens live relatively long, but have low reproductive rates (Buskirk and Ruggiero, 1994), producing an average fewer than three young per female with one litter per year (Strickland et al., 1982). Females provide all care for their kits until they disperse in late summer or autumn (Strickland et al., 1982).

In Maine, median dispersal distances were 8.9 miles (range = 3 to 21.7 miles) and 7.5 miles (range = 3.4 to 16.8 miles) for 13 juvenile male and 13 juvenile female martens, respectively (Phillips, 1994). In northeastern Oregon, three juvenile fisher (two male, one female) averaged 20.7-mile dispersal distances (range = 17.4 to 26.8 miles) (Bull and Heater, 2001). In Ontario, Canada, most juveniles remained within 3.1 miles of their first capture site, with no significant male and female dispersal differences detected (Johnson et al., 2009). There is no information available for juvenile marten dispersals in northwestern California.

Marten home ranges include an array of forest stands that provide for their year-round needs (Slauson et al., 2007). In a review of marten studies, Buskirk and Ruggiero (1994) found marten home ranges three to four times greater than predicted for a terrestrial carnivore its size. Buskirk and Ruggiero (1994) also reported a considerable variation among male marten home range size, with the largest reported in the upper Midwest (3,880 acres [15.7 square kilometers]) and the smallest in Montana (200 acres [0.8 square kilometer]). Thompson and Colgan (1987) found home range size varied due to prey abundance. Based on home ranges reported in the literature, male home ranges are significantly larger than female. However, male home ranges tend to vary significantly among study sites, while female home ranges are relatively consistent among different study sites (Buskirk and McDonald, 1989). Martens exhibit intrasexual territoriality allowing for male home ranges to overlap with females (Powell et al., 2003). Male home ranges are usually two to three times larger than female home ranges (Douglas and Strickland, 1987), which means the home range of a single male may overlap the home ranges of several females. Little information is available regarding marten home ranges in northwestern California. However, Slauson and Zielinski (2009) estimated 100% MCP seasonal (summer-fall) home ranges for five adult male martens (1,321.7 acres ± 719.6 acres; $\bar{x}$ ±SE), one adult female (315 acres), and three juvenile females (1,490.8 acres ± 795.7 acres).

Typically, American martens inhabit closed-canopy, late-successional, coniferous forests that contain a complex physical structure near the ground. This provides a selection of protective thermal microenvironments and protection from predators (Buskirk and Ruggiero, 1994). Near-ground structures include living tree large lower branches, decadent tree boles, coarse woody debris, shrubs, rock piles, and boulder outcroppings (Buskirk and Zielinski, 1997, Slauson et al.

2007). The distribution of mature forest stands at the landscape-scale may be the primary determinant of marten distribution (Kirk and Zielinski, 2009), while marten populations may be limited by lack of late successional forest characteristics considered important for den sites, e.g., large diameter logs, medium and large diameter snags, and high overhead canopy, at smaller scales (Ruggiero et al., 1998).

In the western United States, martens are strongly associated with late-successional coniferous forests, but may occur in younger seral stages that contain remnant structures of late-successional forest, such as large logs and stumps (Baker, 1992). Martens generally avoid non-forested areas, including prairies and clearcuts that lack overhead cover (Buskirk and Ruggiero, 1994). Powell et al. (2003) reviewed numerous habitat studies in Maine, Utah, and Quebec and suggested that martens tolerated an upper limit of 25 to 30% openings within their home range, including clearcuts and natural forest openings. Slauson et al. (2007) found martens in northwestern California often used serpentine soil habitats that contained expanses of dense shrub cover but little forest canopy.

Historical records suggest martens in northwestern California were closely tied to late-successional coast redwood forests (Slauson et al., 2003). However, the one remnant population in this region occurs in an area dominated by Douglas-fir and tanoak forest associations, with coast redwood associations limited to the western edge of the currently occupied range (Slauson et al., 2007). This population uses two structurally distinct forest types, with one occurring on serpentine soils and one on more productive non-serpentine soils (Slauson, 2003; Slauson et al., 2007). In northwestern California, martens occupy low elevation areas with little or no snowfall and select forest habitats with some features, e.g., dense, extensive shrub cover, distinctly different than those used by martens in the Sierra Nevada (Slauson et al., 2007, 2009). Serpentine habitats occupied by martens have open tree canopies, dense shrub cover, and many boulder piles. Non-serpentine sites have closed, multi-layered tree canopies and dense shrub cover, and are in the oldest seral stages. Evidence suggests that shrub layers may provide necessary overhead cover, as some serpentine sites lacked trees (Slauson, 2003). On serpentine sites, boulders and rocky outcrops provide habitat for prey species, and may be used for escape cover where trees are sparse (Slauson, 2003, Slauson, et al. 2007).

Martens appear to select habitat features at the following four spatial scales: microhabitat, stand, home-range, and landscape (Bissonette et al., 1997). Martens select different habitat features that provide one or more important life-history requirements at each scale:

- Microhabitat scale selection for specific foraging, resting, or denning opportunities
- Landscape scale selection for areas unoccupied by same-sex conspecifics for dispersing juveniles
- Stand level selection driven by seasonal needs such as prey populations or available rest structures
- Home range selection for an array of stands providing year-round needs (Slauson, 2003)

Martens selected the largest available patches of late-successional forest or serpentine habitats in north coastal California. Slauson et al. (2007) found that the minimum patch size of late-successional and serpentine habitats present at locations where martens were detected were similar, suggesting that marten occupancy may be limited by some minimum patch size of suitable habitat. Slauson et al. (2007) also found that the probability of detecting martens increased with increases in the largest contiguous patch of late-successional forest, total amount of late-successional forest, and total area of serpentine habitat (Slauson, 2003). The mean patch size occupied by martens in north coastal California was 447 acres, while the minimum patch size occupied was 205 acres (Slauson et al., 2007).

Dense shrub cover was the most consistent habitat feature at sites selected by martens in both serpentine and non-serpentine stands in north coastal California (Slauson et al., 2007). Martens showed the strongest selection for conifer stands with >80% shrub cover and selected against stands with <60% shrub cover (Slauson and Zielinski, 2007b). Shrub layers typically included shade tolerant, long-lived, mast and berry producing ericaceous species (salal [*Gaultheria shallon*]*,* evergreen huckleberry [*Vaccinium ovatu],* Pacific rhododendron [*Rhododendron macrophyllum*]), shrub oak (huckleberry oak [*Quercus vaccinifolia*]*,* and bush tanoak [*Lithocarpus densiflorus* var. *echinoides*]). Dense stands of mature shrubs provide beneficial functions, including protection from predators and cover for prey and food, e.g., berries and acorns, for prey and martens (Slauson and Zielinski 2009). Thick shrub layers also provide nesting and foraging opportunities for birds, which may be important based on the high frequency of berries and birds in the diet of the martens in this region (Hamlin et al., 2010).

3.2.4.4 Listing Status and Threats

On September 28, 2010, the Service received a petition requesting they consider for listing the (then classified) Humboldt marten (*Martes americana humboldtensis*) or the (now recognized) subspecies Humboldt marten (*Martes caurina humboldtensis*) or the Humboldt marten DPS of the Pacific marten (*Martes caurina*) as threatened or endangered under the ESA and designating critical habitat concurrent with the listing (CBD, 2010). On January 12, 2012, the Service published a 90-day finding that the petition presented substantial information indicating that a listing may be warranted and initiated a status review (USFWS, 2012b). On June 23, 2014, the Service published a scoping notice that summarized the uncertainty of the current taxonomic classification of marten subspecies and announced its intent to conduct an evaluation of a potential DPS of marten in coastal California and coastal Oregon for the 12-month finding (USFWS, 2014b). On April 7, 2015, the Service published a 12-month finding and concluded that their review of the best available scientific and commercial information indicates that the coastal marten is not in danger of extinction (endangered) nor likely to become endangered within the foreseeable future (threatened), throughout all or a significant portion of its range and that listing the coastal DPS of the Pacific marten as an endangered or threatened species under the ESA was not warranted (USFWS, 2015). According to CDFW, the American marten has no special status in California, but the U.S. Forest Service (USFS) lists it as sensitive. However, CDFW does consider the Humboldt marten a Species of Special Concern (CDFG, 2011). On June 8, 2015, CFGC received a petition to list the Humboldt marten as an Endangered Species under the CESA (EPIC, 2015). On February 16, 2016, CFGC found the petition to be worthy of further consideration and the Humboldt marten was thereby deemed to be a candidate species subject to protection under the CESA.

Loss, modification and fragmentation of habitat are significant ongoing threats to the remaining population of martens in northwestern California. Martens were extirpated from as much as 99% of their historical distribution in northwestern California. Past timber harvest activities eliminated much of the late-seral forests in coastal northern California. Due to marten specialized habitat requirements, such as large diameter live trees, snags and logs, it will likely take decades for habitat to regenerate with the necessary structural characteristics supporting marten. With approximately 38% of the occupied range in northwestern California located on lands currently available for timber harvest, it is unlikely that these lands will support a viable marten population without a management strategy to maintain key habitat elements. Wildfire that removes structural components such as overstory canopy, large logs or dense understory shrubs may greatly alter essential marten habitat. Roads may fragment suitable habitats and provide corridors for potential predators, e.g., bobcats and coyotes. Trapping martens remains legal in coastal Oregon, while trapping martens has been illegal in California since 1941. In California, incidental marten capture while targeting other species may still create a risk to the species, and should be monitored to assess that risk. Management activities that encourage growth of other mesocarnivore populations may also threaten marten populations, as some of these species, e.g., fisher and bobcat, may opportunistically kill martens (Hamlin et al., 2010).

While there are no region-wide surveys to monitor marten populations, there were extensive surveys in north coastal California since the mid-1990s. Most of these surveys designed to detect both fisher and martens included federal and state lands with some private lands. Except for the small marten population apparently isolated primarily on USFS land in north coastal California detected in 1996, none were found within their historical coastal California range. Recent marten population monitoring suggested that it declined from 2001 to 2008 based on occupancy surveys (Slauson et al., 2009). However, at the time the north coastal core marten population apparently declined, martens appeared for the first time west of the core population in the Plan Area in 2004 and 2006. In addition, a marten appeared further west in Redwood National and State Parks in 2009 and 2010. While these survey results are not definitive assessments of a coastal marten population trend, it appears clear the marten population remains small and isolated to a small portion of its historical range.

Note: Appendix B includes a more detailed description of the marten with complete references.

Section 4. Forest Habitat Conditions and the Status of Covered Species and the Marten

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4.1 INTRODUCTION

This section describes the region's forest habitat conditions and the current status of Covered Species and marten in the Plan Area. It includes information about extensive biological studies of the Covered Species and marten conducted by Green Diamond dating back to 1989. It provides a basis for analyzing other commercial timberlands in the Eligible Plan Area (EPA). Appendix C includes details regarding the objectives, methods, results, discussions and conclusions of Green Diamond's studies.

4.2 FOREST CONDITIONS WITHIN THE PLAN AREA

As described in Section 1.4.2, this FHCP is the terrestrial counterpart to Green Diamond's 2007 AHCP. Accordingly, this FHCP describes forest conditions using the AHCP Hydrographic Planning Areas (HPAs) framework.

This FHCP IPA and Adjustment Area (AA) (collectively the EPA) includes four HPA Groups (Table 4-1). This approach integrates conservation planning efforts for both aquatic and terrestrial resources interconnected through watershed and ecological processes. The EPA occurs primarily within the northern extent of the California Coast Physiographic Province and the northwestern extent of the California Klamath Physiographic Province (Revised NSO Recovery Plan [USFWS, 2011a]) (Map 4-1). It also occurs within three major Ecological Regions (Ecoregions) as described by USFS (Miles and Goudey, 1997):

- **Northern California Coast** – This Ecoregion is characterized by mountains, hills and valleys of the northern Coast Ranges and portions of the Klamath Mountains that are close enough to the Pacific Ocean for the climate to be greatly modified by the marine influence. The predominant forests include redwood, Douglas-fir/tanoak, Oregon white oak, tanoak and Coast live oak. Elevations range from zero to 3,000 feet above sea level and precipitation varies from 20 to 120 inches. The area has a long growing season of 225 to 310 days, with fog very common during summer and winter. This Ecoregion encompasses approximately 81% of the area within the four HPA Groups.
- **Northern California Coast Ranges** – This Ecoregion includes the interior portion of the California Coast Range Mountains that also has a marine influence but to a much smaller degree. Elevations range from just above sea level to 8,000 feet. The growing season is 80 to 250 days, and summer fog is generally limited to low elevations and major watercourses. The predominant plant communities include Douglas-fir/tanoak, Oregon white oak, mixed conifer and white fir. This Ecoregion encompasses about 9% of the area within the four HPA Groups.
- **Klamath Mountains** – This Ecoregion is located between the Southern Cascades and Coast Range Mountains. It is characterized by greater temperature extremes and elevations from 200 to over 9,000 feet above sea level. The predominant forest types are Douglas-fir, Douglas-fir/tanoak, Douglas-fir/pine, mixed conifer, white fir, Jeffrey Pine, red fir, canyon live oak and Oregon white oak. This Ecoregion has the shortest growing season of the three, and encompasses about 10% of the area within the four HPA Groups.

There are 13 Ecological Subregions within these major Ecoregions, and HPA groups are comprised of a unique suite of Ecological Subregions (Table 4-1). Each HPA group includes a wide range of forest age classes (Table 4-2) but in general, the current distribution results from the timing of initial harvest in the region. The two southern HPA groups (Korbel, Humboldt Bay) contain the greatest percentage of young age classes (younger than 30 years) and consequently lower percentages of forests entering the commercially viable age classes (older than 30 years) due to more recent harvesting of the mature second growth stands. The northern HPA groups (Smith River and Klamath) consist of a greater percentage of stands entering the commercially harvestable forest age classes (older than 30 years).

Table 4-1. Hydrographic Planning Area (HPA) groups and United States Forest Service Ecological Subregions used to describe forest habitat conditions within this FHCP Eligible Plan Area.

HPA Group	HPAs in Group	HPA Group Acreage	Ecoregions	Ecological Subregions
Smith River	Smith River	181,384	Northern California Coast, Klamath Mountains	Crescent City Plain, Northern Franciscan, Western Jurassic, Gasquet Mountain Ultramafics
Coastal Klamath	Coastal Klamath Blue Creek	188,327	Northern California Coast, Northern California Coast Ranges, Klamath Mountains	Northern Franciscan, Western Jurassic, Gasquet Mountain Ultramafics, Eastern Franciscan, Siskiyou Mountains
Korbel	Interior Klamath Redwood Creek Coastal Lagoons Little River North Fork Mad River Mad River	547,789	Northern California Coast, Northern California Coast Ranges, Klamath Mountains	Northern Franciscan, Wiregrass Ridge, Humboldt Bay Flats and Terraces, Central Franciscan, Western Jurassic, Gasquet Mountain Ultramafics, Pelletreau Ridge, Rattlesnake Creek, Eastern Franciscan, Central Franciscan
Humboldt Bay	Humboldt Bay Eel River	345,857	Northern California Coast	Humboldt Bay Flats and Terraces, Central Franciscan, Coastal Franciscan

Table 4-2. Forest Age Class Percentage within the Initial Plan Area by Hydrographic Planning Area Group as of 2010.

Forest Age Class (years)	Smith River (Percentage)	Coastal Klamath (Percentage)	Korbel (Percentage)	Humboldt Bay (Percentage)
0-9	10.1	5.4	12.7	17.1
10-19	15.7	4.3	8.4	21.6
20-29	7.0	18.9	14.0	22.5
30-39	23.6	35.1	10.0	8.0
40-49	20.6	21.4	20.1	4.3
50-59	13.8	8.2	14.1	15.2
60-69	2.7	1.0	8.1	4.3
70-79	1.2	0.2	3.9	1.4
80+	1.5	2.6	4.9	4.5
Non-Forest	3.7	2.8	3.7	1.1

4.2.1 Smith River HPA Group

The Smith River HPA group occurs within the Northern California Coast and Klamath Mountains Ecoregions, which are further divided into four Ecological Subregions (Table 4-1).

4.2.1.1 Geology

The topography of the Smith River HPA group is highly variable but in general is relatively steep and sharp-featured compared to other HPA groups within close proximity to the coast. The coastal plain is another unique feature of this group. The group is bisected by the South Fork Mountain Thrust (The Coast Ranges Thrust), which separates Franciscan Central Belt from the Klamath Mountains and Eastern Franciscan Belt bedrock. Both of these geologic terrains underlie Green Diamond's ownership in the Smith River group. The Franciscan Bedrock is composed of a mixture of sandstone and mudstone and the Klamath Mountains Bedrock is composed of volcanics and ultramafic intrusive rocks.

4.2.1.2 Climate

This HPA group is one of California's wettest areas. Average annual rainfall varies from about 60 inches at Point St. George to over 125 inches at higher inland areas. Precipitation is orographic, increasing with elevation and usually greater on the windward (southwest) slopes. About 75% of precipitation occurs between November 1 and March 31 (90% between October 1 and April 30). Average annual snowfall ranges from 28 inches at 1,700 feet (Elk Valley) to 126 inches at 2,420 feet (Monumental). Marine air masses and cold air drainage from higher elevations primarily influence the climate in this area. The area has a temperate, humid climate with abundant summer fog. Occasionally, drier air masses associated with east winds influence the climate.

4.2.1.3 Forest Types

Except for the Crescent City Plain supporting agricultural and urban development, the Smith River HPA is heavily forested. Green Diamond's current ownership in this Group is almost entirely (>95%) within the Northern Franciscan subregion. Redwoods dominate this area, with Douglas-fir becoming a principal constituent of many stands in the more inland, xeric portions of the HPA. On western aspects near the coastal plan, Sitka spruce is a major stand component. Dominant hardwoods are red alder, California bay, big-leaf maple and tanoak. Red alder dominates along the riparian zones, north aspects and areas with natural or anthropogenic surface disturbance. Western hemlock, western red cedar and grand fir also occur as minor stand components on lower slopes near the coast. Tanoak and madrone are common on drier sites toward the interior, particularly upper slopes with south to west aspects. Stand age varies from recently planted harvest units to 60-year-old second-growth forests. Green Diamond's remaining 5% ownership in this group occurs within the Crescent Coastal Plain and the Gasquet Mountain Ultramafics subregion. Sitka spruce, redwood and alder dominate the Coastal Plain forest types. The Gasquet Mountains subregion is quite different from the coastal forest types and is dominated by Douglas-fir, pine and cedar.

4.2.2 Coastal Klamath HPA Group

The Coastal Klamath HPA group contains five Ecological Subregions (Table 4-1) and includes the Blue Creek and Coastal Klamath HPAs spanning all three Ecoregions. Green

Diamond's ownership in this group occurs within the Northern Franciscan and Gasquet Mountain Ultramafics Ecological Subregions. The EPA contains minor land amounts (approximately 5%) occurring within the Eastern Franciscan subregion.

4.2.2.1 Geology

Generally steep, rugged terrain topography is the distinguishing landscape characteristic and primary reason for this HPA group. This HPA group is bisected by the South Fork Mountain Thrust (the Coast Ranges Thrust), which separates the Franciscan Central Belt from the Klamath Mountains and Eastern Franciscan Belt bedrock. The Central Belt Franciscan Complex is generally described as a complex mixture of meta-sandstone and mudstone, with inclusions of other rock types. Klamath Mountain bedrock in the HPA is composed of Josephine Ophiolite intrusive and extrusive volcanics, which includes partially to completely serpentinized ultramafic rocks, gabbro, diorite, pillow lava and breccia.

4.2.2.2 Climate

A wide range of climatic conditions occur within this large and geographically diverse HPA group. In general, this group experiences dry summers with hot daytime temperatures to wet winters with low to moderate temperatures. The main air temperature factor is the coastal marine climate, with daily high temperatures from 40 to 70 degrees Fahrenheit annually. Precipitation is very seasonal, with approximately 90% falling between October and March. Annual amounts vary from 20 inches to over 100 inches depending on location. High intensity rainfall occurs during December through February, causing occasional flooding. Snow occurs at higher elevations and some areas receive up to 80 inches annually. Precipitation in the Blue Creek headwaters averages 100 inches annually, with 75% falling between November and March (Helley and LaMarche, 1973). During the summer, the climate is moderated by coastal fog, which reduces solar radiation and contributes moisture by fog drip.

4.2.2.3 Forest Types

Green Diamond's ownership in this group is dominated by the Northern Franciscan Ecological Subregion (more than 98%) with the remaining acres occurring in the Gasquet Mountains Ecological Subregion. Redwood and redwood/Douglas-fir forest dominate, with Sitka spruce occupying a narrow strip of westerly aspects along the coast and some lower slopes for a short distance inland. The redwood/Douglas-fir forests also include grand fir, western red cedar and western hemlock on lower slopes and in riparian zones. Red alder is the most common hardwood in riparian zones. Tanoak is the most common mid- to upper-slope hardwood, with madrone occurring as a minor stand component on drier sites. As distance from the coast increases, the proportion of redwood stands decreases and Douglas-fir and tanoak become more prevalent. Ridge tops and upper south to west slopes in the most inland reaches can support nearly pure Douglas-fir or tanoak/madrone stands. A distinct ecotone occurs around 2,500 to 3,000 feet. Redwood and Douglas-fir forest rapidly give way to non-forest landscape dominated by manzanita, with knobcone pine, ponderosa pine and Port Orford cedar at the transition and persisting upslope in the bottom of many watercourses. This ecotone results from a band of serpentinaceous soils on the Red Mountain/Rattlesnake Mountain ridge that divides Terwer Creek and Goose Creek in the Smith River HPA group. A few isolated small stands of old growth exist on the IPA in addition to those in state and federal parks within a few miles of the coast. Blue Creek's elevation range (50 to 5,700 feet) and location at the inland edge provide diverse association of forest types. At the mouth of Blue Creek, coastal redwood/Douglas-fir forest predominates, and redwood persists nearly to Green Diamond's property line approximately seven miles upstream. The federal government (Six Rivers National Forest) owns the entire HPA above Green Diamond's property. The forest there progresses from Douglas-fir/tanoak at lower elevations to a montane conifer forest more typical of the Klamath Mountains at higher elevations, with Douglas-fir and white fir the primary overstory species. As in the Coastal Klamath HPA group, serpentinaceous soils on South Red Mountain generate a vegetative cover above 2,500 to 3,000 feet dominated by manzanita, with knobcone pine, ponderosa pine and Port-Orford-cedar at the transition and persisting upslope in the bottom of many watercourses. This same soil-vegetation complex occurs over much of the Slide Creek subwatershed, mostly within the National Forest on the south slope of Blue Creek.

4.2.3 Korbel HPA Group

The Korbel HPA group is the largest and most diverse HPA group, spanning all Ecoregions and intersected by nine Ecological Subregions. Green Diamond’s IPA includes seven of the nine Subregions dominated by those occurring in the Northern California Coast region (by more than 95%). The EPA contains relatively minor areas (<2%) in the two Subregions (Western Jurassic and Gasquet Mountain Ultramafics) not represented by the IPA.

4.2.3.1 Geology

The Korbel HPA group is transected by numerous faults, including the Mad River Fault Zone, the Bald Mountain Fault, the Grogan Fault and the South Fork Fault, which separates the Coast Range province from the Klamath Mountains province. Bedrock in this HPA is primarily composed of the Coast Ranges Franciscan Complex with Klamath Mountain bedrock present in limited areas at the eastern margin. The inactive South Fork Fault is the HPA’s major structural feature. Franciscan Central Belt and Eastern Belt Bedrock include sandstone, mudstone and mélange, with schist underlying most of the HPA. There are limited occurrences of Wildcat group equivalent and younger bedrock within the Mad River Fault Zone and along the coast of the Korbel HPA group. There are also limited occurrences of volcanic and ultramafic rocks of the Western Jurassic Belt of the Klamath Mountains province in the eastern margin of the Interior Klamath HPA.

4.2.3.2 Climate

The Korbel HPA group has a weather pattern typical of most northern California coastal watersheds, with wet winters and dry summers. Summer temperatures are mild, with a commonly occurring marine fog layer. At least 90% of precipitation occurs between October and April. The coastal area receives about 40 inches annually, while interior parts of the watershed receive over 90 inches annually. Although most precipitation falls as rain, snow fall occurs at higher elevations and may persist on the ground for up to four months. The freeze-free period ranges from about 100 to over 300 days.

4.2.3.3 Forest Types

This HPA group spans the transition from Sitka spruce and coastal redwood forests along the coastal face to more mesic interior landscapes dominated by Douglas-fir/tanoak forests, with grasslands appearing on some drier ridge tops and south to west aspects. Minor amounts of grand fir, western red cedar and western hemlock occur on lower slopes near the coast and in riparian zones. Red alder is the most common hardwood in riparian areas and northern slopes with tanoak and madrone more common inland or on drier sites. Aspect affects the distribution of redwood within some watersheds. Redwood may persist roughly half way up the west side of the drainage, but only one-third of the way up the east side. In some specific areas in the redwood zone, Douglas-fir exists as pure or nearly pure stands due to underlying soil characteristics. Higher elevations at the eastern boundary of this HPA group (4,000 to 4,500 feet) support montane conifer forests dominated by Douglas-fir and white fir with golden chinquapin as a stand component on more xeric sites. Oregon white oak is common at the margins of grasslands, with California black oak also found on drier soils.

4.2.4 The Humboldt Bay HPA Group

This HPA group exists entirely within the Northern California Coast Ecoregion and includes three Ecological Subregions (Table 4-1). Green Diamond's ownership includes lands within all Ecological Subregions, but approximately 60% occurs within the Coastal Franciscan Subregion. The Coastal Franciscan (43%) and the Central Franciscan Ecological Subregions (41%) dominate the EPA.

4.2.4.1 Geology

This HPA group is entirely within the Coast Ranges province. It is split by numerous fault zones, including the Freshwater Fault, Little Salmon Fault and Russ/False Cape faults. The eastern portion of the Group is underlain by sandstone and melange associated with the Central belt of the Franciscan Complex. The Freshwater fault delineates the western boundary of the Central belt and separates it from the rocks of the Wildcat formation (Overlap Assemblage), and the Yager Terrane (argillite, shale, sandstone and conglomerate associated with the Coastal belt of the Franciscan Complex). The Russ/False Cape fault zone roughly delineates the region southern boundary, separating Pliocene/Pleistocene materials from a strip of Coastal belt (Yager terrane) rock located just within the southern margin of the region. Most of Green Diamond ownership is underlain by the Wildcat Group geologic units.

4.2.4.2 Climate

The watersheds draining into Humboldt Bay are influenced by the coastal weather patterns of Northern California. A dense, often persistent, band of marine fog may extend 20 to 30 miles inland. Typically, most precipitation falls as rain between November and April with snowfall occurring sporadically at higher elevations. Eureka receives about 35 to 40 inches of rain annually, whereas inland areas of the basin may receive 60 inches or more per year. During the summer the climate is moderated by coastal fog, which reduces solar radiation and contributes moisture by fog drip. Like most of Northern California, wet winters and dry summers characterize the Eel River basin. Nearly 80% of the annual precipitation falls between November and April. The average annual precipitation varies from <40 inches to >110 inches.

4.2.4.3 Forest Types

The Humboldt Bay portion of the group is entirely within the summer fog zone, and all vegetative types reflect a strong coastal influence. Redwood/Douglas-fir forests dominate and persist to the eastern boundaries. Spruce is common near the coast, and minor amounts of grand fir, western red cedar and western hemlock occur on lower slopes and in riparian zones. Red alder dominates many riparian zones, and tanoak is the most common mid to upper slope hardwood. Above the Eel River and Van Duzen River alluvial plains, there is the usual progression of redwood/Douglas fir forests near the coast to Douglas-fir and Douglas-fir/tanoak forests in the interior. Spruce is also common on coastal faces and at the coastal plain margins. Grand fir, western red cedar and western hemlock occur on lower slopes and in riparian zones. Red alder dominates many riparian zones, and tanoak is the most common mid- to upper-slope hardwood. Other common hardwoods are California laurel (pepperwood), Pacific madrone, and California black oak. Extensive prairies are prevalent in this Group's most inland portions, dominating many southern to western slopes and ridge tops.

4.3 COVERED SPECIES: HABITAT, STATUS AND PROJECTED TRENDS WITHIN THE PLAN AREA

4.3.1 Northern Spotted Owl

This FHCP and its conservation program are unique in that they are based on over two decades of property-specific surveys, studies and habitat monitoring. For example, Green Diamond first began surveying NSO on its property in 1989. As a result of this extensive and long-standing research effort, and its experience implementing the 1992 HCP, Green Diamond has a comprehensive understanding of NSO presence and use of its lands, and how to manage its commercial timberlands in a way that both minimizes adverse impacts and maximizes conservation values for the species. However, despite this knowledge and Green Diamond's ability to manage habitat, other threats exist that contribute to the decline of NSO.

4.3.1.1 Distribution

Green Diamond first surveyed NSO on its north coastal California lands in 1989. Although that first survey did not cover the entire ownership, it demonstrated that NSO occur throughout the majority of Green Diamond's property, and their population density was unusually high in some regions. Green Diamond then surveyed all main contiguous land blocks every year since 1989. Results indicated Green Diamond located virtually all resident NSO by 1994. The pattern indicated that NSO were located throughout the ownership, but there were substantial differences in the density of NSO sites. In general, densities were highest in regions with a mixture of mature second growth and young regenerating stands (high diversity of forest seral stages). There was also a pattern of high density of NSO sites distributed lower on slopes along rivers and major creeks. A study based on 1990-1997 surveys indicated two regions (Korbel and Mad River) had the highest densities reported anywhere within the species' range (Diller and Thome, 1999) (Map 4-2).

4.3.1.2 Habitat: Early Assumptions and Current Research-Based Conclusions

The NSO HCP was based largely on rather simple assumptions about NSO habitat in the redwood region (Green Diamond, 1992). Nearly 20 years later, extensive research on Green Diamond's lands and elsewhere in the redwood region has enabled Green Diamond to craft this new FHCP, based on detailed analyses of actual NSO habitat uses and needs.

When the NSO HCP was developed, little research was available regarding NSO use of the coastal redwood region. The basis for this HCP was primarily three years of site-specific surveys. As a result, only simplistic definitions of habitat existed, with suitable habitat defined as forest stands older than 30 years old, because at least some stands in this age class were known to be used by NSO for foraging, roosting, and nesting (Folliard, 1993). At the time, it was assumed recently regenerated stands (younger than 7 years) had no direct value to owls. Stands 8-30 years were known to be woodrat habitat (Hamm, 1995) and therefore potential NSO foraging habitat. Foraging, roosting, and occasional nesting occurred in stands 31 to 45 years-old, and forest stands older than 45 years old were considered prime nesting and roosting and foraging habitat.

In developing the 1992 HCP, timber harvest and growth modeling predicted NSO habitat would increase on Green Diamond land through 2022, as then-existing stands aged and age class distribution changed over time. A GIS analysis showed NSO habitat defined in the 1992 HCP increased 38%, from 64,375 hectares (159,075 acres) in 1992, to 88,870 hectares (219,602 acres) in 2002 (Appendix C, page C-57). The largest gain in owl habitat during that 10-year period resulted from young stands (<30 years-old) growth into the 31- to 45-year age class. Older stands also matured into the *prime* nesting habitat category (older than 46 years, the age class where timber harvesting occurs), so only a modest net increase (approximately 12.5%) in this category occurred over the same time period.

Since the 1992 HCP, extensive research has been performed on NSO habitat requirements. Most of this research has focused on analyzing the structural characteristics, areal and spatial requirements of nesting, roosting and foraging habitat (Forsman et al., 1984; Carey et al., 1990; Solis and Gutiérrez, 1990; Ripple et al., 1991; Lehmkuhl and Raphael, 1993; Hunter et al., 1995, Buchanan et al., 1995; Zabel et al., 1995). Most of those studies occurred in landscapes with significant amounts of mature or old forests, which are the principal habitat for NSO in most areas studied (Courtney et al., 2004).

However, as early as 1990, the coastal region of northern California was recognized as being somewhat unique for NSO (Thomas et al., 1990). In this region, NSO were known to frequently nest in relatively young managed stands, a phenomenon not commonly occurring elsewhere in the range. This is due to several factors. Habitat structure develops more rapidly in the moist coastal region due to the rapid regeneration of redwoods and other conifers, but it is the coppice growth from the stumps of several hardwood species (e.g. tanoak, madrone and California bay) that produces high structural diversity in these managed even-aged stands. The occurrence of dusky-footed woodrats also contributes to habitat quality in this region. Woodrats are the primary prey of NSOs in this region and they occur in high abundance in young regenerating stands (Sakai and Noon, 1993; Hamm, 1995; Hughes, 2005). Consequently, a certain amount of timber harvesting, which then produces young regenerating stands, may benefit NSO by increasing prey abundance (Carey et al., 1992; Carey and Peeler, 1995; Franklin et al., 2000; Olson et al., 2004). In this region both the rapid development of forest structure and the resulting abundance of woodrats contribute to early post-harvest development of suitable habitat. As a result, NSO occupy landscapes composed of stands as young as 30 years-old (Folliard et al., 2000).

To better define and quantify the unique site-specific habitat use of NSO in the redwood region, Green Diamond conducted extensive research and monitoring that culminated with a more sophisticated and spatially explicit definition of NSO habitat (Appendix C.2). Green Diamond first sought to determine what habitat NSO used during their period of nocturnal activity. A radio telemetry study of 28 NSO from 1998-2000 was conducted, and the resulting data was used to construct 95% kernel distributions based on locations the NSO actually used versus a random selection of available points within the same area. These data were then used to develop a resource selection function for NSO nighttime activity. The top model indicated that NSO tended to be found low on the slope in areas composed of approximately 70% age class 41 years or older, with a high percentage of hardwood. Furthermore, selection was highest if the nearest stand to the NSO's location was either 6 to 20 or 21 to 40 years old, and lower if the nearest stand was either 0 to 5 or more than 41 years old. In other words, at night, NSO on Green Diamond's ownership were most likely to be found in older, more complex forest stands that were in proximity to younger stands, i.e., stands with more potential prey.

To further refine the analysis of NSO habitat in the redwood region, Green Diamond then studied the habitat selected for nesting by NSO on its managed timberlands. Green Diamond identified 182 successful nests (fledged at least one owlet) from 1990-2003, then estimated a resource selection function to characterize the habitat of an average successfully nesting NSO. The top model for managed timberlands indicated that the relative probability of locating a successful nest increased with age of the stand and open edge density within 600 meters of the nest. In addition, selection was greatest in stands with approximately 55% basal area of residual older trees, 30% hardwood basal area, and a large amount of good nighttime activity habitat within 400 meters. In other words, for nesting, NSO were selecting older more complex stands that were in fairly close proximity to potential foraging areas. Using projections of future habitat created by in-growth and harvesting patterns, Green Diamond projected that the best nesting habitat would increase from 20% of its ownership in 1992 to 54% by 2022. This increase in high quality NSO nesting habitat is primarily due to decreases in clearcut size and management of large riparian areas pursuant to the AHCP (Green Diamond, 2007), which will greatly increase habitat heterogeneity.

4.3.1.3 Evaluation of Biological Value of 1992 NSO HCP Set-Asides

Given the uncertainty associated with the original habitat definitions, the NSO HCP established 40 special conservation areas or set-asides on Green Diamond lands. The NSO HCP precluded timber harvesting within these mature forest areas "to protect existing owl sites in select areas (thereby avoiding take) and to promote development of suitable owl habitat following harvesting in other areas…" The NSO HCP stated "the set-asides were selected based on their current and potential function as nesting and roosting habitat, their size, their location in relation to known owl sites immediately adjacent to Simpson property, and their location in relation to planned timber harvests on Simpson property" (Green Diamond, 1992).

The set-aside strategy was premised on the assumption that NSO habitat lost through timber harvest would be replaced by in-growth of new habitat as young stands matured. Habitat models at the time projected an increasing amount of NSO habitat in the Plan Area over time, and various measures were implemented to accelerate the development of such habitat, e.g., habitat retention areas, tree clumps in clearcut units, increased retention in stream zones. However, the 1992 NSO HCP did not clearly articulate that the state of the science on NSO at that time did not provide support for the premise that NSO habitat could be regenerated in as little as 45 to 50 years. Therefore, static set-asides were created as a more conventional NSO conservation strategy for protection of NSO habitat. It was recognized at the time that future research might reveal that these set-asides were unnecessary and one of the primary questions of the comprehensive 10-year review required by the HCP was to "provide a detailed analysis of efficacy of and continued need for the set-asides…"

As part of the 10-year review, Green Diamond conducted NSO survival and fitness analyses in which the position of NSO nest sites or activity centers relative to set-asides was included as a covariate (Section 4.3.1; Appendix C). Specifically, NSO sites were characterized as being within, adjacent to (<0.5 mile) or outside of (>0.5 mile) set-asides. With respect to survival, NSO at sites that were adjacent to set-asides had the highest survival, followed by those within and finally those outside set-asides.

With respect to fecundity, NSO adjacent to set-asides had the highest fecundity, followed by those outside and those within set-asides. However, Green Diamond believes this result may have been biased by how fecundity was estimated. Fecundity was assigned for each observed female by dividing the number of fledged young by two. However, if a female was not observed in a territory during a given year, no fecundity value was assigned, which was described as a null value (Anthony et al., 2006). Green Diamond hypothesized that this null value creates a positive bias to fecundity estimates, as experience has shown that non-nesting females are more difficult to locate. Although it was possible that some females that could not be found in given years had moved to new locations and successfully nested, it was much more likely that females not detected in a given year were not nesting and did not show strong affinity to any particular activity center/nest site. This was particularly true since much of the study area was a density study area where Green Diamond surveyed 100% of the habitat every year. Green Diamond investigated this phenomenon relative to set-asides and discovered that null fecundity values occurred at 15.9, 24.1 and 32.1% of perennial owl sites within, adjacent and outside set-asides, respectively. Green Diamond's interpretation of this trend was that NSO in set-asides or adjacent with no harvest had greater habitat stability relative to those NSO outside set-asides where harvest activities displaced selected NSO pairs. Presumably, Green Diamond was more likely to find females in set-asides relative to those outside regardless of their reproductive status, which would have biased the fecundity estimates. Assuming all null fecundity values were zero fledged, mean fecundity estimates for all NSO (includes territories too close to the study edge to include them in the fecundity analysis) were 0.264, 0.266, and 0.199 for NSO within, adjacent and outside set-asides, respectively. This suggests NSO within or near set-asides have the highest fecundity, and those outside have the lowest.

Although the specific ecological mechanism associated with being adjacent to a set-aside requires further investigation, it is still apparent that the set-asides had an important impact on the vital rates of NSO in the Plan Area. Green Diamond's data indicated that high quality foraging habitat occurs along the edge between young and mature forests (Section 4.3.1; Appendix C), which most commonly occurs in areas of active timber harvesting. Set-asides were areas of mature forests with no timber harvest that were selected primarily because the areas were being used for nesting and roosting by NSO. Therefore, Green Diamond believed the primary biological value of the set-asides related to providing a stable core area for roosting and nesting of NSO that were either in or adjacent to set-asides. The high site fidelity that NSO showed to occupied set-asides provided additional support for the hypothesis that NSO benefitted from stable core areas.

To further investigate the effects of set-asides on survival, Green Diamond did a post hoc analysis in which a set-aside covariate was constructed from capture histories used in the 2009 NSO meta-analysis (Forsman et al., 2011) and fit it into the top survival model from the meta-analysis (Section 4.3.1; Appendix C). The effect of the set-aside covariate was slightly negative (survival of birds associated with set-asides was slightly lower than that of other birds), but it was not statistically significant. Similar post hoc analyses with both the fecundity and lambda models indicated no difference between set-aside versus non-set-aside NSO.

From these particular analyses, there was no evidence that demographic parameters were influenced by an NSO being associated with a set-aside, but this was a post hoc analysis and the results should be interpreted with caution. Furthermore, forcing a single habitat-related variable into a model without the potential for other interacting habitat variables to enter the model is questionable and may have produced spurious results.

It should also be noted that while set-asides were presumed to have a positive influence on both survival and fecundity, i.e., fitness, of NSO in the Plan Area, not all set-asides were beneficial to NSO. Set-asides that were initially selected because they were occupied by NSO tended to continue to support NSO. However, property-wide surveys were incomplete when the NSO HCP was being developed and some set-asides were selected because they appeared to have suitable habitat and helped achieve spacing requirements. The set-asides that appeared to be initially unoccupied in 1992 continued to be unoccupied by NSO throughout the elapsed years of the NSO HCP. The most important lessons learned from monitoring the set-asides since 1992 is that places selected by the NSO for roosting and nesting have special qualities that tend to result in repeated generations of NSO being tied to the same general location for their nest sites or activity centers. However, unoccupied locations that were selected because they appeared to have suitable habitat were very unlikely to ever be used by NSO (Green Diamond, 1992). In other words, despite all the data collected and models developed, the specific site selection criteria of a NSO remains unknown to humans.

4.3.1.4 Habitat Fitness

Fitness, the ability to survive and reproduce, has traditionally been considered an individual attribute, but the quality of the habitat occupied by a particular individual also influences its fitness. Therefore, habitat fitness is habitat quality relative to its impact on the fitness of individuals occupying it (Franklin et al., 2000). Combining the influence of habitat on both survival and reproduction provides the ultimate measure of habitat quality such that areas with high habitat fitness are capable of supporting a stable or increasing source population while areas of low habitat fitness are associated with habitat sinks.

Pursuant to the NSO HCP, Green Diamond conducted a long-term demographic study that enabled it to assess the impacts of timber harvesting on NSO (Green Diamond, 1992). Green Diamond’s geographically referenced, relatively detailed forest stand information was used to directly relate habitat characteristics to survival and fecundity in order to estimate habitat fitness. Green Diamond used capture-resight data from 1990 to 2003 to estimate survival and nesting data over the same period to estimate fecundity. Finally, Green Diamond estimated habitat fitness as a function of average survival and fecundity at a location through a site-specific projection matrix.

The top survival model estimated negative effects on survival for increased days of precipitation during the early nesting season and for locations more than 0.5 mile from a designated set-aside (relative to locations inside a set-aside). Positive effects on survival were associated with increased temperatures during early nesting, increased nest site selection values and for locations near (<0.5 mile) to a set-aside (relative to locations inside a set-aside). The top fecundity model estimated negative effects on fecundity for locations inside a set-aside, sites where take, i.e., displacement of NSO from a site due to timber harvest, had occurred and for increased precipitation in the early nesting season. Positive effects were estimated for:

- Locations <0.5 mile from a set-aside (relative to locations outside a set-aside)
- Even number years
- Adult females relative to S2 females
- Natural log of the percent of 41- to 60-year-old stands in a 600-meter radius buffer
- Natural log of the percent of 21-to 40-year-old stands in a 600- to 921-meter annulus
- Average nighttime activity selection values in a 600-meter radius buffer
- Average open edge density in a 600-meter buffer

From the average survival and fecundity at a specific location, the growth rate or largest Eigenvalue of the Leslie projection matrix was computed and defined to be the habitat fitness of the site. Relative to other categorical variables, habitat fitness was most sensitive to the location of the nest site/activity center relative to a set-aside. Habitat fitness values were highest in the 0.5-mile buffer surrounding a set-aside with all other covariates being realistically equal. While considerably lower relative to the magnitude of the effect, sites that went from non-take to take were the second most important categorical variable relative to habitat fitness. Relative to continuous variables, habitat fitness was most sensitive to changes in precipitation during the early nesting period such that increases in the total number of days of measurable precipitation within the early nesting period caused habitat fitness to decline. The second most important continuous variable was open edge density, where increases in this variable resulted in higher values of habitat fitness. Relative to latent variables, habitat fitness was most sensitive to changes in survival followed by changes in fecundity and nesting habitat.

4.3.1.5 Trend in Habitat Fitness

Following modeling of survival, fecundity and habitat fitness potential, Green Diamond projected the trend in future habitat on its lands using the 1992 landscape as the baseline. Green Diamond used projections of future habitat created by in-growth and harvesting patterns to predict the proportion of its future ownership falling within various habitat categories. The total area in the best survival, fecundity and habitat fitness potential class, which were all set at 20% in 1992, increased to 37, 57 and 45% of Green Diamond's study area, respectively.

Since non-habitat variables, e.g., weather and take, and set-asides were set at constant median values throughout the projections, they did not contribute to the changes. Based on the sensitivity analysis, the habitat variable that likely contributed the most to the trend was open edge density. The proportion of older stands (41 to 60 years old) adjacent to younger stands (6 to 20 and 21 to 40 years old) would have also contributed to the trend. Riparian and geologic protection areas mandated by Green Diamond's 2007 AHCP will create a future landscape in which an estimated 25% of the landscape will be in some type of protected area. Along with smaller clearcuts, the net effect will be much greater overall open edge density and a higher overall level of habitat heterogeneity, which appears to be highly beneficial to NSO in the redwood region.

To estimate habitat fitness further into the future, Green Diamond used the known 2009 landscape with the anticipated harvest plans over the next 10 years. Green Diamond then projected harvests derived through a newly developed harvest schedule model to project spatially explicit stand conditions at 10 year intervals from 2010 to 2060. Assuming important non-habitat variables, e.g., weather and barred owls, remained at some mean value, the spatially explicit estimates of habitat fitness on Green Diamond's study area were extended at 10 year intervals from 2010 to 2060. The changes in habitat fitness across

Green Diamond's ownership can be seen by decade on Map 4-3. The map indicates the dynamic nature of habitat fitness across the ownership, where specific areas wax and wane in their relative habitat value for NSO. However, Figure 4-1 shows that overall the proportion of the ownership in the highest categories of habitat increase through time. The proportion of Green Diamond's ownership in the highest category of habitat fitness (more than 1.05, which indicates habitat capable of supporting an increasing population of NSO) increased from 95,899 acres (35% of ownership) in 2010 to 179,959 acres (64% of ownership) in 2060. In 2060, a total of 87% of Green Diamond's ownership is projected to be in the two highest categories of habitat fitness, which would support stable or increasing populations of NSO if other non-habitat variables, e.g., weather and barred owls) remain within acceptable limits.

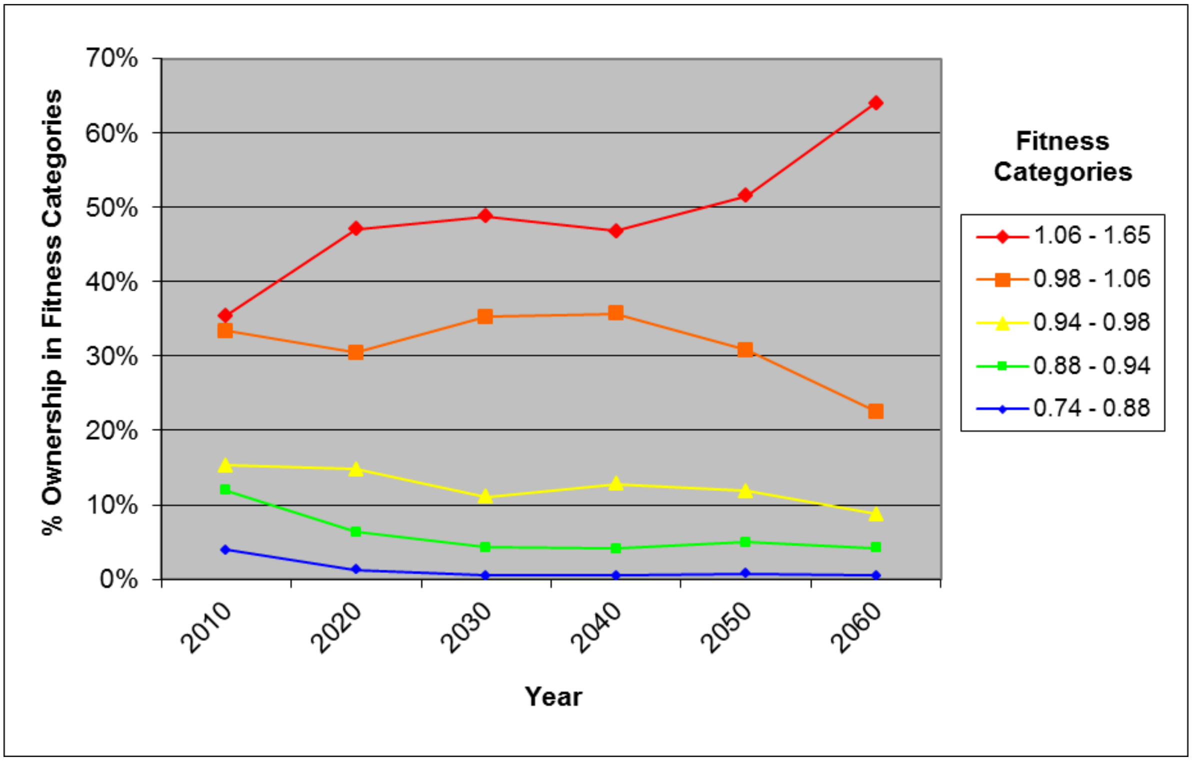

Figure 4-1. Percentage of Green Diamond Resource Company ownership in different projected decadal Northern Spotted Owl habitat fitness categories. Fitness values <1.0 represent habitats projected to have declining populations while those ≥ 1.0 are projected to support stable or increasing populations of owl.

As noted above, the highest category of habitat fitness for NSOs increased from 1992 (start of the NSO HCP) to 2022 (original termination date of the NSO HCP [Green Diamond, 1992]). This FHCP required projections to 2060. Green Diamond's studies show that this upward trend in the highest quality of habitat fitness was projected to continue to increase. Based on a sensitivity analysis of habitat fitness, the habitat variable that most likely contributed to the trend was open edge density. The proportion of older stands (41 to 60 years old) adjacent to younger stands (6 to 20 and 21 to 40 years old) also contributed to the trend. Both of these variables are related to creating more habitat heterogeneity that is projected to increase mostly due to implementation of Green Diamond's AHCP (Green Diamond, 2007) and the FPR. These projections of habitat fitness provided a very positive assessment of future habitat for NSO. Compared to habitat in the past, the modeled habitat on Green Diamond's ownership is predicted to be able to support a stable or increasing population of NSO assuming other non-habitat variables, e.g., weather and barred owls) remain within acceptable limits.

4.3.1.6 Demographic Trends – 2014 Meta-analysis

Green Diamond initiated mark-recapture studies throughout its ownership in 1990 to estimate key demographic parameters and trends in the population. Along with 11 other rangewide demographic studies of NSO, Green Diamond participated in four meta-analyses in 1998, 2004, 2009 and 2014. Although not the longest running demographic study, as of 2013, Green Diamond had the largest NSO dataset with 982 non-juvenile NSO banded, 4,733 total encounter histories and 1,998 assessments of nesting (fledging) success. This section includes the key results published from this most recent meta-analysis (Dugger et al., 2016), but Green Diamond's results were unique, because it was the first dataset to include the effects of a barred owl removal experiment. Initiated in 2009, this was a before-after-control-impact (BACI) experiment in which Green Diamond's demographic study area was divided into treated areas (barred owls lethally removed) and untreated control areas (barred owls not disturbed). Some barred owl results were included in Dugger et al., (2016), but the full results of the barred owl removal experiment are summarized below in Section 4.3.2.

Territory occupancy rates were declining in all study areas throughout the range of the NSO. As seen on Figure 4-2, occupancy of NSO territories not part of the barred owl removal areas (i.e., control areas where barred owls were allowed to increase) showed a marked decline in occupancy from 92% in 1999, to 55% in 2013 in Green Diamond's study area. The most consistent pattern in NSO territory occupancy dynamics was the strong positive association between the presence of barred owls and territory extinction rates of NSO in all 11 study areas (Dugger et al., 2016).

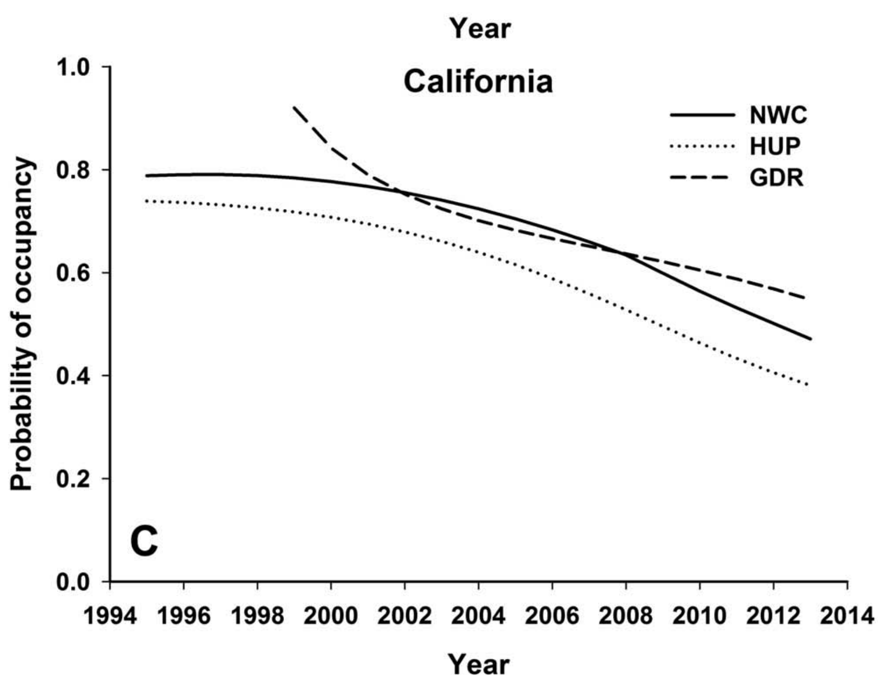

Figure 4-2. Estimates of the probability of territory occupancy for NSO on the Green Diamond (GDR), Hoopa (HUP) and Northwest California (NWC) study areas (Dugger et al., 2016). Green Diamond estimate did not include NSO territories in barred owl removal areas.

Based on the best statistical model, there was a negative log-linear time trend on mean adult apparent survival for the combined Green Diamond dataset. Before any barred owl removals, estimates of mean survival were virtually identical for treatment (0.857) and control areas (0.858), and they also were similar to the nearby Hoopa and Northwest California (Willow Creek) study areas. However, after removals were initiated in 2009, apparent survival was higher in treated areas (0.870) compared to those in untreated control areas (0.804). The estimate for the treated areas (0.870) matched the highest estimates of mean survival for any of the study areas (Dugger et al., 2016).

There was high annual variation in reproduction for NSO throughout their range (Dugger et al., 2016). For many study areas, this annual fluctuation took on an even-odd year pattern as can be seen for the California study areas during the 1990s (Figure 4-3), but aside from this, the covariates associated with the variation in fecundity among the different study areas tended to be highly variable and complex. For the Green Diamond study area, mean minimum winter temperature (lower = lower fecundity) and total winter precipitation (higher = lower fecundity) were included in the top or competitive fecundity models. The top model with a linear time trend for the Green Diamond study had a negative slope indicating an overall decline in fecundity (Figure 4-3). Because of this overall decline, apparently driven primarily by weather effects, mean estimates of fecundity derived from the first 18 years of the study (0.308 and 0.302, treatment and control respectively) before initiation of barred owl removal were greater than the estimates from the last 5 years of the study (0.212 and 0.182, treatment and control respectively) that included the removal experiment.

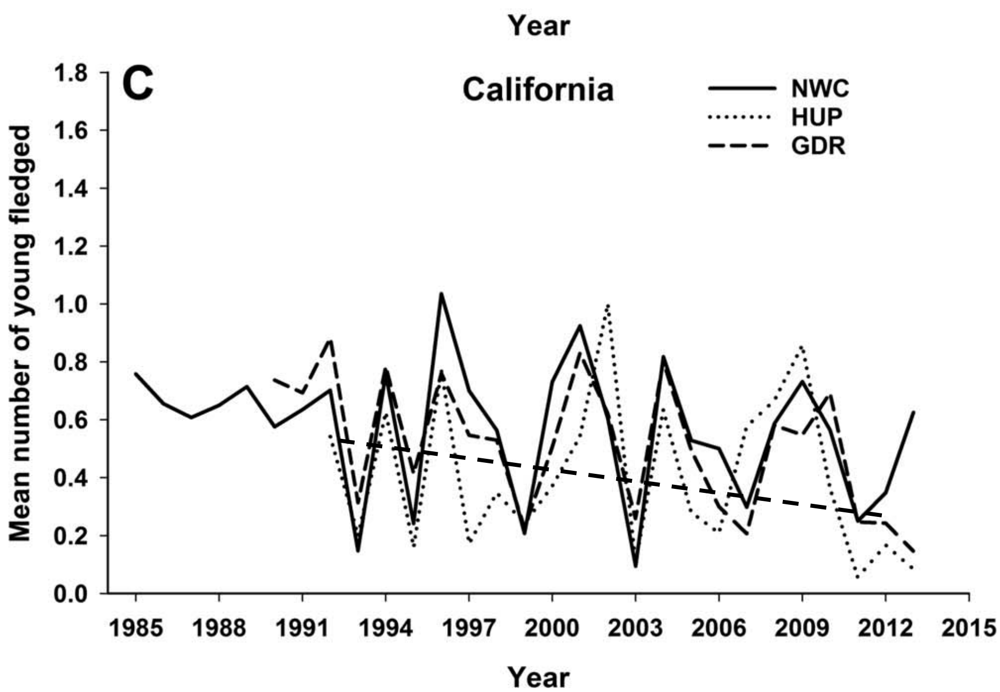

Figure 4-3. Annual fluctuations in mean fecundity (number of female owlets fledged per female) of adult NSO on the Green Diamond (GDR), Hoopa (HUP) and Northwest California (NWC) study areas (Dugger et al., 2016). The straight dashed line

represents an approximate overall trend in fecundity for the Green Diamond study area.

Mean estimates of lambda suggested declining population trends (lambda <1.0) in almost all study areas (Figure 4-4). For the Green Diamond study area, mean lambda for the treatment (barred owls removed) and control areas (barred owls not removed) in the 18 years prior to the removal experiment was 0.961 (SE = 0.018; 95% CI = 0.926-0.996) and 0.988 (SE = 0.009; 95% CI = 0.970-1.006), respectively. In the 5 years after the experiment was initiated, mean lambda was 1.030 (SE =0.040; 95% CI = 0.952-1.108) and 0.878 (SE = 0.070; 95% CI = 0.741-1.015) for the treatment and control areas, respectively. Among all the study areas throughout the range of the NSO, the only estimate of lambda that suggested an increasing population was observed in the Green Diamond treatment areas after barred owl removals began in 2009, although the 95% CI widely overlapped 1.0 indicating reduced statistical support for this conclusion (Dugger et al., 2016).

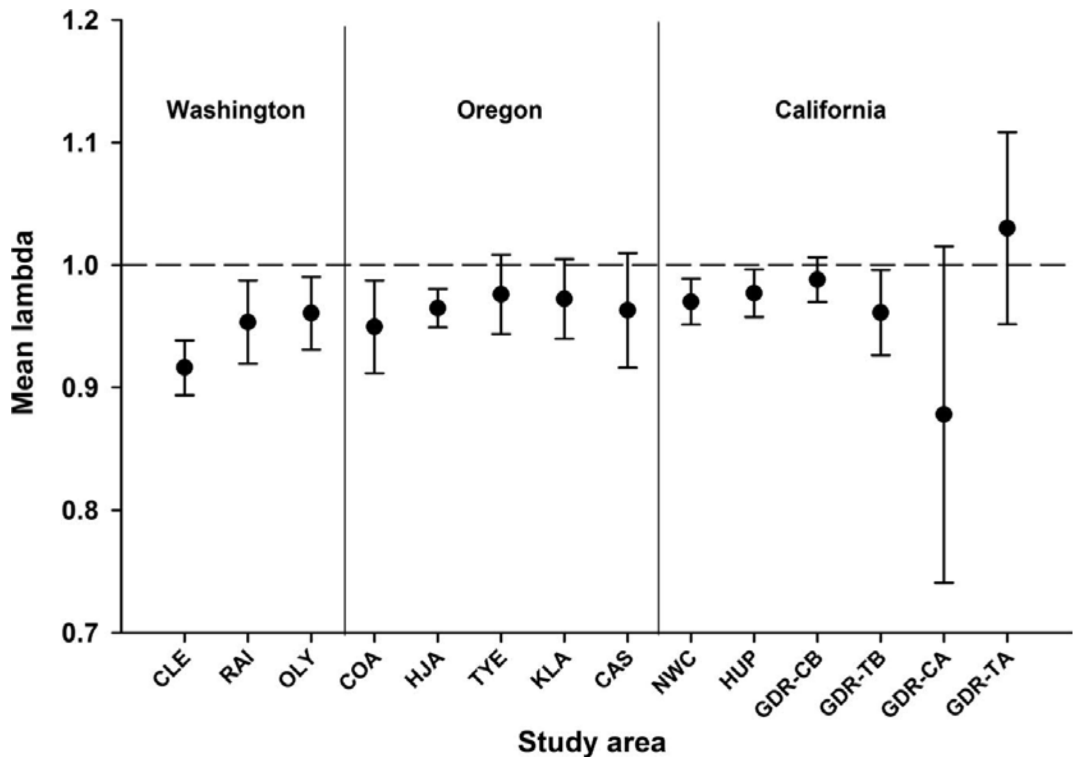

Figure 4-4. Estimated mean rates of population change and 95 percent confidence intervals for NSO in each of 11 study areas in Washington, Oregon, and California 1985–2013 (Dugger et al., 2016). Estimates for the Green Diamond (GDR) study area are presented separately for control and treatment areas before (1990–2008) and after (2009–2013) barred owls were removed (GDR-CB = control before removal, GDR-TB = treatment before removal, GDR-CA = control after removal, GDRTA = treatment after removal).

Another metric of population change through time is the realized rate of population change, which portrays the population trajectory in each year of the study relative to the population size in the first year where it was estimated. Estimates of realized population change indicated that populations in Washington declined by 55 to 77%, 31 to 68% in Oregon, and 32 to 55% in California, except in the treatment areas for Green Diamond, where the estimated overall population decline was only 9% (Dugger et al., 2016). Looking at the trend through time in more detail for Green Diamond (Figure 4-5), there was a clear pattern of a stable or increasing population for treatment of control areas prior to the early 2000s when NSO began to decline in all areas. The decline continued for the untreated control areas, but was reversed and the population began to increase in the treated areas immediately following the initiation of barred owl removal in 2009.

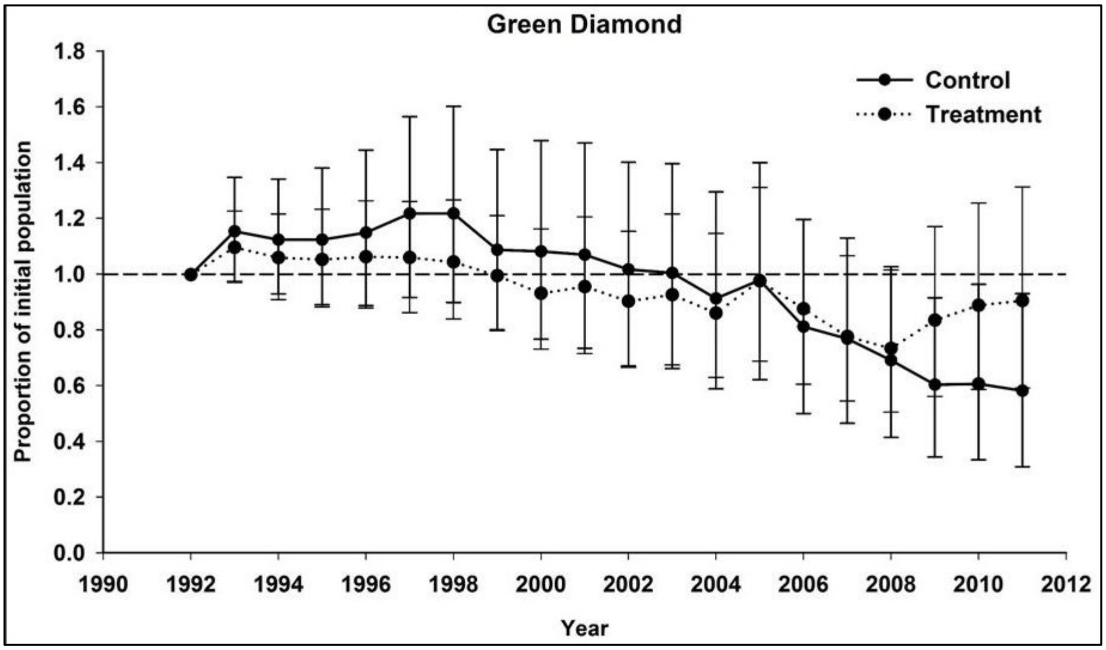

Figure 4-5. Estimates of realized population change with 95% confidence intervals for NSO on the Green Diamond study area, 1992-2011 (Dugger et al., 2016). (Note: Although mark-recapture data were available through 2013, an estimate of realized population change cannot be obtained for the last two years.)

The conclusion from Dugger et al., (2016) was that competition with barred owls was likely the primary cause of NSO population declines across their range, but habitat and climatic patterns also were related to survival, occupancy, recruitment, and, to a lesser extent, fecundity. However, an additional important conclusion from this study was that barred owl densities may now be high enough across the range of the NSO that, despite the continued management and conservation of suitable owl habitat, the long-term persistence of NSO may be in question without additional management intervention of barred owls (Dugger et al., 2016).

The meta-analysis was not designed to fully analyze the results of the barred owl removal experiment, but it provided compelling evidence that barred owls were responsible for much of the decline seen in NSO on the Green Diamond study area. It also indicated that barred owl removal could slow or reverse the declines of the NSO in at least Green Diamond's study area where barred owl densities were relatively low compared to most of the demographic study areas (Dugger et al., 2016).

4.3.1.7 Lower Mad River Case Study

The best example verifying the dynamic nature of habitat within a given region (Section 4.3.1.4) and the prediction of an overall increase in NSO habitat comes from the Lower Mad River Tract. The Lower Mad River Tract of the Plan Area is an area of approximately 22,000 acres that is primarily composed of third growth redwood forests between 15 to 30 years old, except for approximately 2,000 acres of 70- to 80-year-old second growth contained mostly within nine set-asides that occur within or overlap at least partially with this region. Clearcut harvesting of the second growth within this tract started in 1979 and continued at or near the maximum rate allowed by California FPRs for approximately 20 years until adjacency constraints slowed the rate of harvest on small amounts of the remaining second growth stands. By the late 2000s, virtually all non-constrained stands had been harvested. The pattern of harvesting in the Lower Mad River differs somewhat from future harvesting since the area was harvested in the 1980s and early 1990s when retention of overstory trees on most streams was at the minimum requirement and maximum clearcut size was 80 acres. These practices will not be repeated in the future, and instead, a pattern of small clearcuts of different ages scattered across the landscape interconnected with substantial older riparian stands is expected. So although the Lower Mad River example will not be duplicated in the future, the pattern observed in future similar tracts should foretell an even more optimistic future trend in the NSO population in the Plan Area.

A complete NSO survey of the Lower Mad River Tract was initiated in 1990 and it has been continued until the present. The number of sites was slightly lower in 1990 relative to 1991, because it was the first complete survey and Green Diamond may have missed one or two NSO sites (Figure 4-6). In 1989, approximately 40% of the area had been recently harvested, which created ideal habitat heterogeneity in some areas. However, the pattern of harvesting had almost completely removed all mature second growth from other areas, which would have displaced any NSO that were in those areas. Operating under the 1992 NSO HCP, two additional sites were taken by timber harvest in the Mad River (one in 1999 and one in 2000), but six other sites that were in commercially valuable stands were not available for take since they occurred within set-asides.

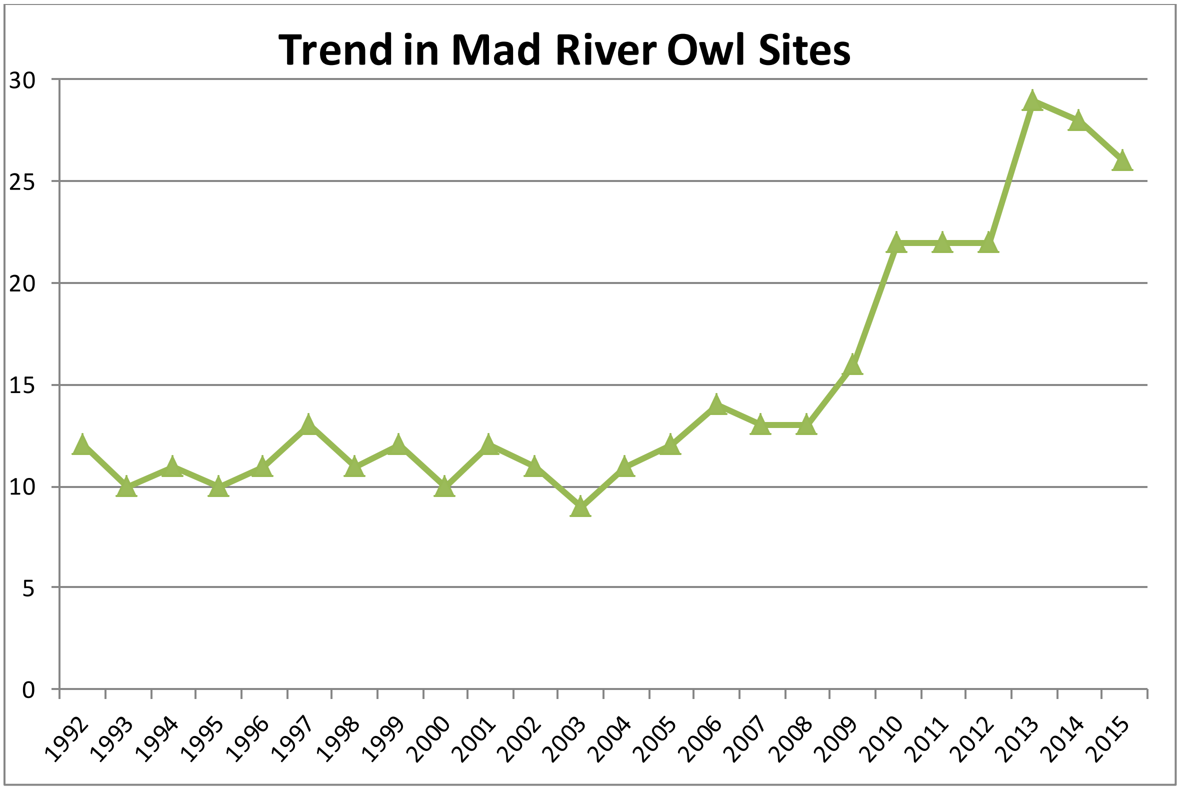

Figure 4-4. Trend in the Number of Known Occupied northern spotted owl Sites in the Lower Mad River Tract, 1992-2015.

The Lower Mad River Tract also happens to occur within the Korbel/Mad River treatment area of the Green Diamond barred owl removal experiment and all barred owls have been removed from the area beginning in 2009. This probably facilitated NSO to begin recolonization of the area based on newly emerging habitat suitability. In the spring of 2009, there were 13 occupied sites within this area, and from that time until the spring of 2015, 13 new sites have been colonized in the area. The barred owl removal experiment may have contributed to a very sharp increase in NSO sites, which potentially would have been more gradual if the barred owl numbers had not been allowed to increase beginning in the early 2000s. Nevertheless, with 26 NSO sites in an area of approximately 22,000 acres, the region may probably soon be at its maximum carrying capacity with NSO densities higher than anything reported in the literature. This Mad River example, although not directly comparable to future landscape dynamics, which will have a higher proportion of retained riparian zones, provides evidence that the number of future occupied NSO sites will be dynamic in any given sub-basin with the low portion of the cycle extending for 15 to 20 years of the average 50-year cycle. But most importantly, it provides evidence that if the barred owl threat is removed, NSO can and will respond favorably to improving habitat conditions.

Note: A more detailed review of NSO habitat and population trends with complete references is provided in Appendix C.2.

4.3.2 Response of NSOs to Experimental Removal of Barred Owls:

In 2006, Green Diamond assisted the California Academy of Sciences (CAS) in obtaining a small collection of barred owls in California. To maximize the scientific value of the individuals collected, CAS targeted barred owls to be collected from sites that were historically occupied by NSO. Thus, these initial collections provided an opportunity to do preliminary removal case studies that would document the response of individual NSO to the removal of barred owls. Seven barred owls were collected from four different historical NSO sites during May and June 2006 on Green Diamond's ownership in Humboldt County. Although based on just four case studies, these initial collections of barred owls raised the possibility of future expanded removal studies, because it indicated that barred owls could readily be removed and it suggested that NSO were quick to recolonize their former territories following removal of barred owls.

A 2008 meta-analysis of NSO populations, including study areas from across the subspecies' range, concluded that the population on the Green Diamond study area was apparently stable or increasing until 2001, when it began to decline (Forsman et al., 2011). The 2008 meta-analysis could not determine cause and effect relationships. However, the presence of barred owls was negatively associated with fecundity and apparent survival of NSO and the apparent decline in NSO coincided with an increase in barred owl numbers.

Although the increase in barred owl was the most probable hypothesis for the decline of NSO on the Green Diamond study area, experimental studies had not been conducted to isolate the effect of barred owls from other potential sources that may contribute to NSO population declines. A panel of scientists reviewed potential experimental designs and concluded that a demographic approach with a paired BACI experimental design where removal of barred owls was the treatment provided the greatest inference and statistical power (Johnson et al., 2008).

As part of the implementation of the draft NSO recovery plan, a Barred Owl Work Group was formed to consider implementation of a suite of barred owl removal studies (USFWS, 2008a). The Barred Owl Work Group evaluated a proposal to do an additional barred owl study on Green Diamond's ownership and provided full support for the study, because it was consistent with barred owl objectives of the draft recovery plan and the subsequent revised final NSO recovery plan (USFWS, 2011a). It also was designed to be complementary to, and provide supporting data for other removal experiments that were being planned for mostly public lands in Washington, Oregon and California. Ultimately, with assistance from Green Diamond's pilot data, the Service completed an EIS to conduct four barred owl removal experiments throughout the Pacific Northwest (USFWS, 2013).

In addition to its complementary role to the NSO Recovery Plan (USFWS, 2011a) and EIS (USFWS, 2013) to conduct additional barred owl removal experiments throughout the Northwest, in 2009, Green Diamond realized the value of the pilot removal experiment to support this FHCP, which was already in the developmental process. Furthermore, Green Diamond recognized that the barred owl threat was likely to persist far into the future such that some type of management actions would be necessary throughout the life of the proposed FHCP. Therefore, when the pilot removal experiment was initiated in 2009, it was identified as Phase One of a long-term barred owl research program with the additional phases implemented after this FHCP is approved.

When the Phase One Pilot Barred Owl Removal Experiment was initiated in 2009, the Green Diamond NSO demographic study area was partitioned into areas of approximately equal total acreage where barred owls were to be lethally removed (treated) and control areas where barred owls would be undisturbed (untreated). To account for geographic variation in habitat and both NSO and barred owl population densities, Green Diamond's demographic study area was subdivided into three treated (Salmon Creek, Korbel/Mad River/Little River and Wilson/Hunter/Terwer Tracts) and three untreated control areas (Ryan Creek, Redwood Creek and Bald Hill/County Line Tracts, Figure 4-7). The objectives of this experiment were to determine the cost and feasibility of doing lethal removal of barred owls; estimate the impact of barred owls on NSO occupancy, fecundity, survival, and rate of population change; and assess the effectiveness of barred owl removal to allow recovery of NSO in the Plan Area. The results of this experiment were analyzed, peer-reviewed and published in two scientific manuscripts. The first focused on the cost and feasibility (Diller et al., 2014), and the second reported on the demographic response and potential for NSO recovery following barred owl removal (Diller et al., 2016).

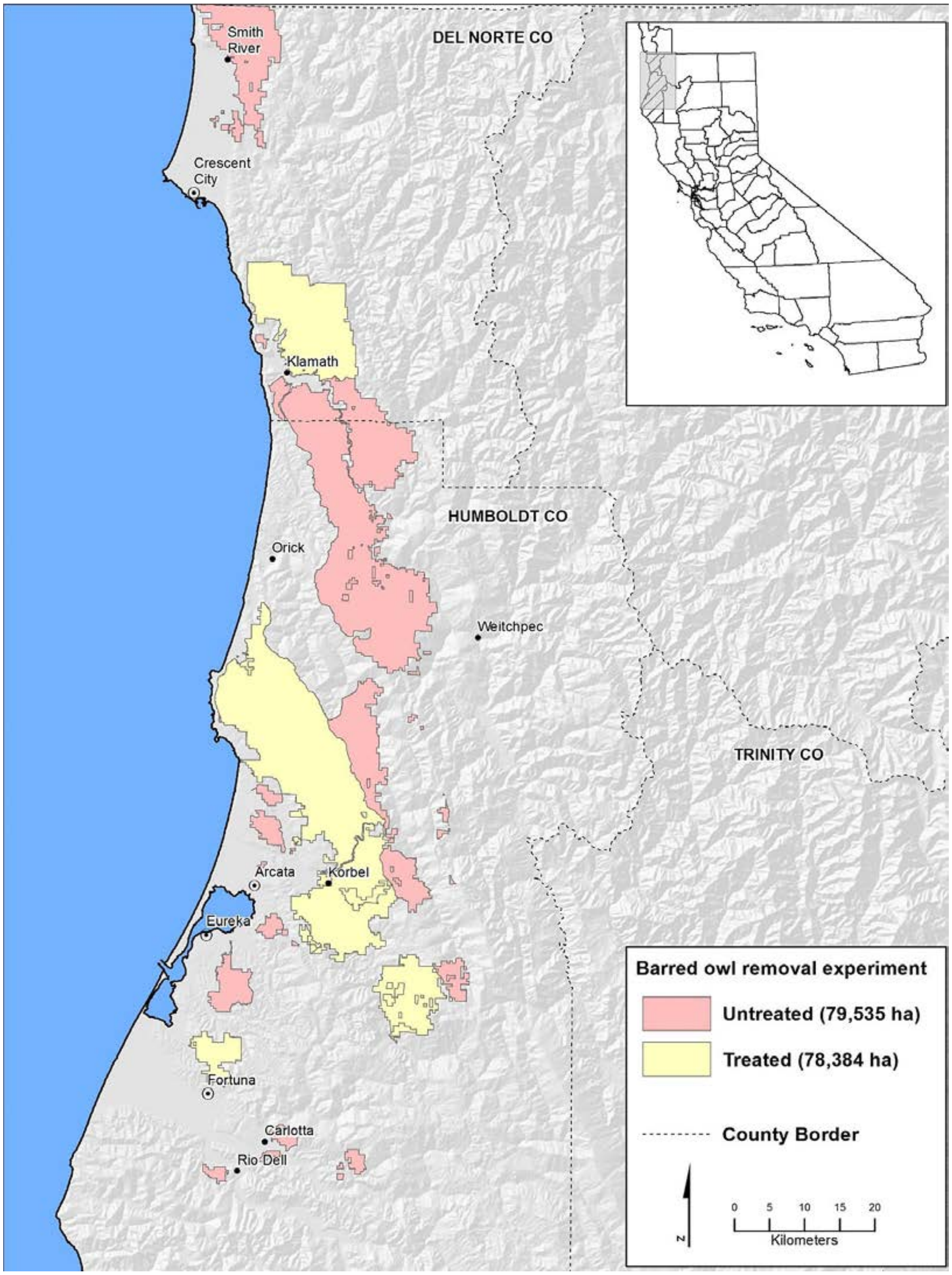

Figure 4-7. Treated (barred owls lethally removed) and untreated (barred owls undisturbed) areas on Green Diamond's NSO demographic study area in north coastal California.

4.3.2.1 Cost and Feasibility (full publication in Appendix C.2)

Lethal removal of vertebrates is often quite controversial for social and ethical reasons, but it is also often criticized for reasons related to cost, feasibility and ability to achieve the desired results. Lethal removal of barred owls had never been done, so the first objective of the pilot removal experiment was to document whether removals could be conducted efficiently and effectively using practical, humane techniques, and at reasonable cost and staffing levels. This portion of the experiment was conducted from 2009 through 2012.

The pilot barred owl removal experiment within the NSO demographic study area was initiated on 15 February 2009, working under a permit to California Academy of Sciences that allowed 20 barred owls to be collected. Following an evaluation by the Service of our removal data from this pilot study, we were authorized to continue lethal removal in 2010 of a maximum of 70 barred owls over a 3-year period, with no more than 30 individuals removed in any given year.

We attempted to lethally remove all barred owls continuously in treatment areas that behaved in a territorial manner except barred owls that potentially had dependent nestlings or fledglings. The basic field methods involved locating barred owls in the treatment areas with broadcast calls, luring the barred owl into proximity, and lethally removing the owl with a shotgun. Prior to 2009, Green Diamond detected barred owls as a byproduct of standard surveys to locate NSOs as part of Green Diamond's demographic study. However, since these surveys were reported to underestimated the number and location of barred owls (Wiens et al., 2011), we began barred owl-specific surveys in 2009. If a territorial barred owl was detected in a removal area during any survey, we returned to the site to locate it. If that location was in a historical NSO territory, we first broadcast NSO calls. If NSOs were present, Green Diamond did not attempt to lure barred owls. If NSOs did not respond within approximately 400 meters of the working site, it was assumed there were no NSOs present at the local site. We then broadcast a repertoire of barred owl lure calls using commercially available remotely controlled digital caller to lure the owl to within 20 to 30 meters (the preferred shooting range). Once a positive identification of a barred owl was made while it perched on a branch, we collected the individual(s) using either a 20- or 12-gauge shotgun equipped with an illuminated aimpoint. The distance and appropriately sized shot (#8 or 6) was used to insure a quick and humane death while retaining a good specimen for scientific purposes.

The cumulative time of all visits to a site to collect barred owls was calculated to depict effort. Green Diamond recorded the total removal time as beginning with arrival by vehicle at a location at or near the owl site and ending when leaving the location. Activities at the site potentially included the following: walk to the actual collection site, set up the equipment and initiate calling, kill and recover the barred owl(s), conduct initial field processing (e.g., collect oral, cloacal and blood samples, and record basic field data), and broadcast additional lure calls after owls were processed to determine whether other territorial barred owls were in the area. Thus, we considered the time from arriving at a site until leaving that site as a "visit." We did not record the time needed to conduct general NSO surveys for Green Diamond's NSO demographic study.

One person made 122 field visits to collect 73 of 81 barred owl detected from 2009 to 2012. It took an average of 2 hours, 23 minutes (range = 5 to 295 minutes per barred owl collected) to collect and field process the 73 barred owls for scientific specimens. The eight owls not collected after initial detection were never detected again during 16 repeat visits, averaging 3 hours, 7 minutes suggesting the owls had abandoned their territories. Most owls (79.5%) were collected at dusk or after dark, but daytime collection at known owl sites was also effective and efficient. The mean time from arrival to making the shot (killing the owl) was 52.1 (SE = 7.47) minutes for females, which was significantly less than the mean of 80.5 (SE = 10.99) minutes for males. The time taken to collect an owl upon arrival at a site was positively skewed for both females and males; that is, the majority of females and males were collected within 30 and 90 minutes of arrival, respectively. During the first year of the study, the majority of the owls collected were residents (birds present at a site for less than one breeding season prior to removal). In subsequent years most birds were colonizers (apparent new barred owls occupying a site following removal of birds from a site.

The results of this study indicate that removing barred owls can be both efficient and cost-effective, from which we concluded that removal experiments should not be technically challenging, but costs will vary depending on the context of the removal experiment (i.e., travel costs and need to do additional NSO and barred owl surveys). Removal experiments will require maintenance control as previously suggested, but the cost of maintenance removal should be less than the cost of original removal. The primary cost of doing a removal experiment will likely not be dependent on the actual cost of removing barred owls, but more likely on the costs associated with detection surveys of owls and other factors associated with conducting a field experiment. For example, we estimated that the direct costs of removing barred owls was less than 1% of the total survey costs associated with conducting the removal experiment and estimating the NSO demographic response. In summary, the results of this study indicated that barred owl removal was both technically feasible and cost-effective, and that conducting removal experiments on existing NSO demographic study areas would be most cost-effective because demographic histories and locations of most NSOs are known (Diller et al., 2014).

4.3.2.2 Demographic Response of NSO to Barred Owl Removal (full publication in Appendix C.2)

Green Diamond's long-term NSO demographic study provided almost 2 decades of the largest pretreatment dataset from which to estimate the demographic response of NSO to barred owl removal. The fundamental approach of Green Diamond's classic BACI experiment was to determine if trends in any of the NSO demographic parameters changed between treated and untreated areas following treatment (barred owl removal). Specifically, we estimated occupancy parameters (rates of site occupancy, extinction and colonization), fecundity, survival and rate of population change pre- and post-treatment to determine if the relationship among any of these demographic parameters changed post treatment relative to pretreatment. Based on the theoretical underpinnings of a BACI experiment, any statistically significant post treatment changes in the parameters of interest can be attributed to the treatment effect (barred owl removal). The extent to which the treatment reversed negative impacts of barred owls on NSO can also provide compelling evidence relative to the potential for barred owl removal to allow for the recovery of the NSO population on Green Diamond's study area.

Field methods included monitoring NSO by surveying the Green Diamond study area from 1990 to 2013 using vocal imitations or playback of owl calls. The objectives of the surveys were to document occupancy status of owl territories, locate and confirm previously banded owls, band unmarked owls, and document the number of young produced by each territorial female. The number of surveys of each potential owl territory (i.e., owl site) in each study area was normally three or more per year. The field methods to capture, mark, and resight individual owls and to determine number of young fledged per female was the standard protocol used in all the NSO demographic study areas (Forsman et al., 2011; Dugger et al., 2016).

The pilot barred owl removal experiment within our NSO demographic study area was initiated on 15 February 2009, working under a permit to California Academy of Sciences that allowed 20 barred owls to be collected. Following an evaluation by the Service of our removal data from this pilot study, we were authorized to continue lethal removal in 2010 of no more than 70 barred owls over a 3-year period, with a maximum of 30 individuals removed in any given year.

As described in Section 4.3.2.1, we initially detected barred owls as a consequence of standard surveys to locate NSOs from 1990 to 2009, but later began barred owl-specific surveys in 2009. Following removal of barred owls from a site as described above, we conducted additional barred owl-specific surveys to assess recolonization by barred owls at removal sites. All territorial barred owls were continuously removed from the treated areas regardless of their proximity to known NSO territories. However, some barred owls occupied the same territory core, and sometimes even used the same nest site, from which the NSOs were apparently displaced. These NSO sites were evaluated as case studies if the criteria were met in which a former NSO territory was occupied by barred owls that inhabited the same territory center (nest or primary roost sites). In these situations, the site was surveyed at least once per month following the removal of the barred owls to determine the timing of potential re-occupancy by either NSO or barred owls.

Most of the analytical methods followed Dugger et al. (2016) with the exception that specific analytical techniques were employed to assess a treatment effect on the various demographic parameters of interest. Specifically, for occupancy parameters, fecundity, survival and rate of population change, different analytical techniques were used to assess statistical model support or significant changes in treated and untreated areas pre- and post-treatment (barred owl removal).

Some of the important demographic results were that NSO site occupancy was declining in both treated and untreated areas, but following treatment, occupancy stabilized and began to increase in the treated areas while it continued to decline in the untreated areas (Figure 4-8A). Potentially the cause for this was that barred owls caused more than a four-fold increase in the estimate of NSO site extinction (i.e., probability that a NSO site will be abandoned), but following barred owl removal, the extinction rate in the treated areas returned to a level comparable to sites where barred owls were never present (Figure 4-8B). This provides compelling evidence that barred owls were responsible for increases in NSO extinction rates and that removal efforts were effective at removing this impact.

Apparent survival in both treated and untreated areas was declining 2% per year prior to removal, but following treatment, mean apparent survival increased to 0.859 in the treated areas, but remained low at 0.822 for the untreated areas. The mechanism by which barred owls affected apparent survival in NSO is not known, but we believe it was unlikely that it was due to direct effects on NSO mortality rates. It is known that barred owls can displace NSO from their territory (Wiens et al., 2014). We also made anecdotal observations of NSOs that no longer vocalized following occupation by barred owls at or near their territory core, but we could still observe them when they flew up to take a proffered mouse. Thus, we hypothesize that release from barred owl influence creates the appearance of increasing apparent survival by allowing displaced NSOs in the floater population to regain a territory and become more readily detected. Our empirical observations of NSOs recolonizing sites within as little as 13 days provide support for this hypothesis.

Probably the most dramatic demographic result was that prior to treatment, mean lambda was declining 3.6% for all areas, but post treatment, mean lambda was 1.029 (2.9% annual increase) and 0.87 for treated and untreated areas, respectively (Figure 4-9). Just as with survival, the mechanism by which the treatment effect influenced lambda is not known. If the sharp increase in lambda seen in this study were the result of increases in fecundity and actual survival within the treated population, we would have expected a delay or lag of several years in the lambda response. Instead, the immediate increase suggested that similar to the effect on survival, much of the increase was probably due to displaced NSOs in the floater population regaining territorial status and being detected. Furthermore, creating an area free of barred owls may have increased the probability that floater NSOs rebuffed in adjacent untreated areas could colonize the treated areas.

Fecundity was the only demographic parameter for which there was no significant treatment response. The lack of evidence of an effect of barred owl removal on NSO fecundity was likely to be at least partly caused by the high annual variation in fecundity. Furthermore, the competitive interaction between barred owls and NSOs often results in the displacement of NSOs (Wiens et al., 2014), and when this occurred, we were generally unable to detect the female NSO. This manifested itself as a reduction in occupancy in the untreated versus treated areas, but females that were not detected in a given year were by protocol excluded from an estimate of fecundity. So although we did not find evidence of a change in the number fledged per breeding female that we could detect, the total productivity did appear to change in treated compared to untreated areas. Empirical counts of the number fledged at active NSO sites post treatment (2009 to 2014) indicated that only 36 fledglings were documented from an annual mean of 49.8 active owl sites in the untreated areas. In contrast, during the same period, 133 fledglings were observed from an annual mean of 104.2 active sites in the treated areas.

Although based on a small number of case studies (n = 7), the empirical observations of NSO recolonization suggested that NSOs were likely to re-colonize their former territories following removal of barred owls. The very rapid recolonization of four sites by the original resident NSOs also indicated that, at least in some cases, the resident owls apparently remain in the vicinity of, or regularly investigate their former territory for years after being displaced by barred owls. These results also suggest that barred owls are not simply colonizing areas vacated by declining NSO populations, but rather that barred owls are actively displacing NSOs as described by Wiens et al. (2014). The high and sometimes rapid rate of re-colonization by both original resident and new NSOs following barred owl removal suggests that at least in some cases, barred owls were keeping the NSOs from preferred, high quality sites. The sites that were colonized by barred owls also had high continuous occupancy by pairs of NSOs with high reproductive success before barred owls invaded, which is further evidence that these sites were in high demand by NSOs. For our study area, located within an intensively managed landscape where many of our NSOs occupy young-growth sites that differed relative to other demographic study areas, the barred owls tend to occupy the sites with more classic late seral habitat elements.

The overall conclusion from this initial experiment was that barred owls were primarily responsible for negative impacts to most, if not all, NSO demographic parameters. Furthermore, lethal removal of barred owls allowed the recovery of the NSO population in the treated portions of Green Diamond’s study area. However, removal experiments may be more difficult to implement and recovery may be slower in other areas where barred owls have been present in large numbers for a longer period of time and the population of NSOs has been more suppressed. Nevertheless, this experiment provides evidence that barred owl management will be vital to NSO conservation efforts associated with Green Diamond's FHCP and future management options may be developed to assist in the recovery of the NSO outside Green Diamond's ownership in at least the southern portions of its range (Diller et al., 2016).

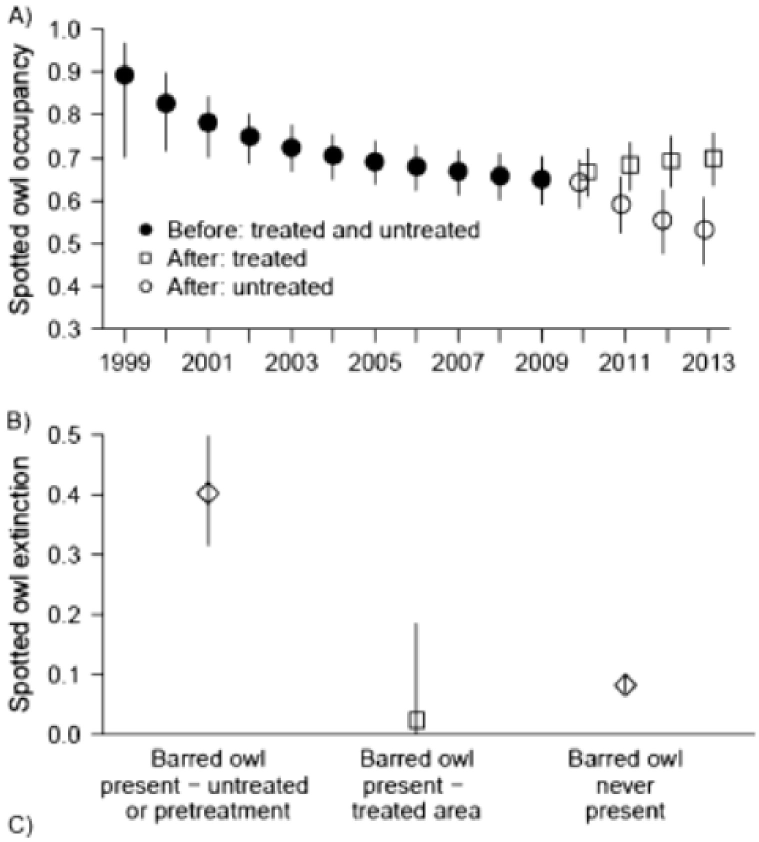

Figure 4-8. Changes in NSO occupancy and extinction probability on Green Diamond's demographic study area in north coastal California. (A) Trend in NSO occupancy in treated and untreated areas before and after treatment (barred owl removal). (B) NSO extinction rates when barred owls are present and not removed, barred owls are present and removed, and barred owls were never present.

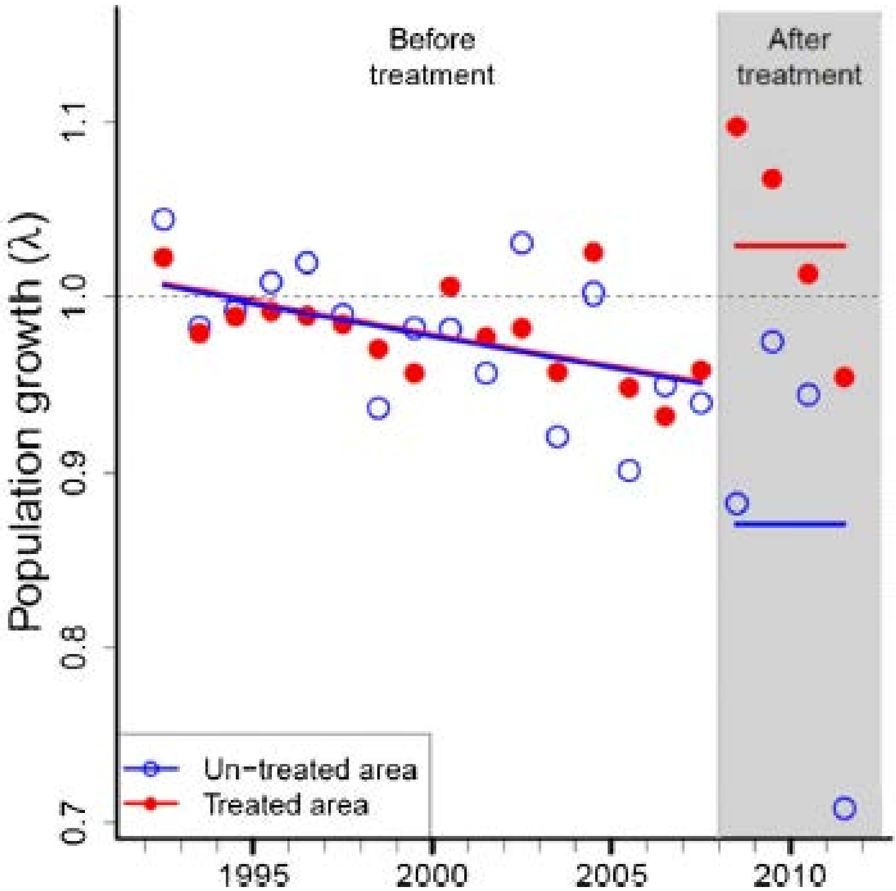

Figure 4-9. Estimates of the rate of population change from 1990 through 2013 on Green Diamond's NSO demographic study area in north coastal California. Dashed line represents a stable population, lambda = 1.0.

Note: A more detailed review of the barred owl removal experiment with complete references is provided in Appendix C.2.

4.3.3 Fisher

Like the NSO, Green Diamond has conducted extensive studies of fisher on its lands, dating back to 1994.

4.3.3.1 Distribution

The first surveys for fishers on Green Diamond's ownership were track plate surveys conducted in 1994 and 1995. These surveys were part of a Masters study to determine the distribution and habitat associations of fishers across the ownership. A total of 99 and 139 fisher detections were obtained in 1994 and 1995 respectively. At least one fisher detection occurred at 71 different stations during the 1994 and 1995 surveys. Fisher were detected on 26 of the 40 (65%) survey segments during both surveys combined. Fisher were the third most frequently detected mammalian species with only gray fox and spotted skunks detected in higher numbers. The distributional pattern of detections across the study area indicated that almost all survey segments in the more interior Douglas-fir and mixed redwood-Douglas-fir had detections, while there were few detections in the more coastal redwood areas and southern regions near Humboldt Bay and the Eel River drainage. There were also few detections in the northern region near the Oregon-California border, but Green Diamond's ownership in that area only included coastal redwood stands.

Vegetation type was the only variable to be selected by the logistic procedure to predict fisher occurrence in stands. The highest detection ratios (roughly equivalent to fisher population density) was in the Douglas-fir zone followed by the mixed Douglas-fir/redwood and redwood zone Green Diamond found no relationship between fisher detections and stand age, canopy cover or topographic position. The average age of stands in which fishers were detected was 42.6 years compared to 43.6 years of stands in which they were not detected. A forward stepwise logistic procedure indicated that presence of fishers at the station level was best predicted by elevation, volume of logs, basal area of conifer 52 to 90 centimeters dbh, percent slope and distance to the coast.

This study indicated that although fishers were generally well distributed across Green Diamond's ownership, detections occurred more frequently at higher elevations, further from the coast and in stands with a predominant Douglas-fir component. Greater amounts of hardwood and greater volume of logs were also associated with the occurrence of fishers. Another study over a similar but larger geographic region including Redwood State and National Park and Humboldt Redwood State Park also indicated that fishers were generally less frequently detected in areas closer to the coast (Beyer and Golightly 1996). In addition, this broader survey also showed a pattern with few fishers detected in the northernmost (Smith River watershed) and southernmost (Eel River watershed) portions of the study area. Contrary to the notion that fishers are associated with late successional forests, the mean stand age in which fishers were detected in this study was 42.6 years and there was no difference in stand age between stations with and without fisher detections. A survey of Redwood National and State Parks provided corroboration relative to fisher habitat selection in the redwood region (Slauson et al., 2003). An analysis of track plate surveys throughout old growth and second growth portions of the park indicated that fishers were found more than expected in second growth and less than expected in old growth. However, this study also found that fishers were associated with structurally complex portions of the second growth stands.

While the track plate surveys were not specifically designed for monitoring long term trends, Green Diamond saw the opportunity to repeat the surveys at 10-year intervals to provide an estimate of potential changes in distribution or abundance of fishers throughout the ownership. In 2004, Green Diamond repeated the exact survey as it was conducted in 1994 and 1995. In addition, Green Diamond randomly selected 18 of the 40 original segments and surveyed them in 2006. This additional survey in 2006 was prompted when the Hoopa Tribal forestry's fisher study reported a potential decline in fisher numbers (Higley and Matthews, 2006). These additional surveys confirmed that the distribution of fishers across the ownership remained unchanged. (The implications of these additional surveys relative to fisher population trends will be discussed in the following sections.) A summary of all the fisher detections across Green Diamond's ownership that resulted from track plate surveys and incidental sightings is depicted on Map 4-5.

4.3.3.2 Den and Rest Site Habitat

Although foraging habitat has to be critical to any predator, it is commonly assumed that habitat used for denning and resting is most likely to be limiting on a managed landscape.

Green Diamond conducted a radio telemetry study to quantify denning and resting areas used by fishers in 1996 and 1997. The specific objectives of the study were:

- Capture and radio collar fishers to locate rest and den sites
- Quantify structures used for resting and denning
- Quantify vegetation around the sites
- Compare vegetation at rest and den sites to vegetation data collected at track plate stations where fishers were detected

This information was used to evaluate management practices currently being applied under the NSO HCP to determine if habitat provided under the HCP might also be beneficial to fishers (Green Diamond 1992).

Of the 11 adult females captured, 9 showed evidence of having been reproductive based on lactating or swollen teats when captured, or they were located in natal or maternal dens. A total of nine dens were found for five of six females outfitted with radio transmitters. These consisted of four natal (where the young were born) and five maternal (temporary refuge sites for the kits) dens. The dens were located in four highly decadent live hardwoods, one sound hardwood and four conifer snags. Natal dens were all in cavities in two tanoaks, one chinquapin and one Douglas-fir snag. The mean diameter at breast height (dbh) was 76.5 centimeters (standard deviation = 15.6, range 62.5 to 95.3 centimeters). Maternal dens were also all cavities: three appeared to be cavities excavated by pileated woodpeckers and two appeared to have been created by fire. The cavities were in two tanoaks, two Douglas-fir snags, and one western red cedar snag with a mean dbh of 112 centimeters (standard deviation = 45.8, range 62.5 to 184.4 centimeters). Comparisons with other trees in the stand indicated that den trees tended to be the largest trees available.

Green Diamond located 35 fisher rest sites in a variety of tree species and structures. Live hemlock was the most common tree species in which rest sites were located followed by live Douglas-fir and cedar. The most common structures used as rest sites were dwarf mistletoe clumps in hemlocks (10), lateral branches and other mammal nests in Douglas-fir trees (7), and mostly cavities in cedars (6). Although Green Diamond did not collect specific data on use versus availability, general observations throughout the ownership indicate hemlock with dwarf mistletoe is not a major component of most stands. This suggests fishers were showing high selectivity for hemlock with its propensity to be infected with dwarf mistletoe. Green Diamond found other rest sites in fir snags and logs, a variety of structures in hardwood species and broken top redwoods. The mean dbh of trees with rest sites was 33.3 inches, with a range of 8.8 to 68.9 inches. Trees with rest sites spanned the full range of available dbh size classes, but smaller trees were less likely to have suitable rest structures compared to larger trees.

In summary, larger hardwood and conifers with cavities were particularly important to fishers for den sites. Fisher use a wider range of structures for rest sites and these can be found in a broad range of tree sizes compared to den trees. In contrast to den sites that occur in cavities, rest sites tend to be in open structures such as mistletoe or debris platforms. In general, on Green Diamond’s ownership, fishers were using the same types of structures in trees for den and rest sites as those used by NSO for roosting and nesting on Green Diamond’s ownership. The primary difference is that fishers show a strong selection for cavities for reproductive sites, while NSO show relatively little use of cavities for nesting.

4.3.3.3 Foraging Habitat

As noted above, track-plate surveys were conducted in 1994-1995 as part of a Humboldt State University graduate study to determine distribution and habitat associations of fishers. Later in 2004 and 2006, these same survey segments were repeated to identify potential trends in fisher distribution and abundance. The habitat associated with track plates could best be described as foraging habitat, because the fisher was most likely moving through its environment foraging when it detected the scent and entered the track plate box to eat the bait. All of these individual track plate stations provided presence/absence data from which Green Diamond estimated site occupancy models (MacKenzie et al., 2006) that characterized foraging habitat affinities of an average fisher on Green Diamond's ownership. These models were also used to predict the probability of future occupancy by a fisher, which will be discussed in Section 4.3.3.6.

The initial model building procedure resulted in selection of a year covariate that indicated a decrease in occupancy for year 2004 relative to the other years that were surveyed. This will be discussed in Section 4.3.3.6, but for purposes of understanding habitat associated with fisher occupancy, the final site occupancy model of fisher track plate detections did not include a year covariate and was based on 577 sites that satisfied the interior criterion for all buffer sizes. The following variables in the order in which they entered the model were:

1. Elevation (positive coefficient)
2. Percentage of an 800-meter (2,624-foot) buffer containing stands of trees 6 to 20 years old (negative coefficient)
3. Percentage of whitewood tree species within the stand (positive coefficient)

Holding other variables constant, the odds of occupancy by a fisher was estimated to increase with increasing elevation at the site, decrease with increasing amounts of 6- to 20-year-old stands in the 800-meter buffer and increase with increasing percentage of whitewood tree species within the stand where the track plate was located.

The positive relationship between the probability of fisher detection (occupancy), elevation and amount of whitewood tree species was consistent with previous studies on Green Diamond that showed increasing detections with increasing elevation and amount of Douglas-fir forest (Klug 1997). The increase in occupancy rates with increasing elevation and whitewood tree species is likely a result of various factors such as increased prey diversity and potentially greater abundance of sites for resting and denning. Studies of fisher prey base have not been done locally to document this assumption, but anecdotal observations indicate a wider variety of potential prey species at higher elevations in Douglas-fir/hardwood areas of the ownership. The whitewood stands on Green Diamond ownership are also represented by a greater hardwood and hemlock/cedar component which has been shown to be important for denning and resting sites.

Previous studies of fishers on Green Diamond's ownership did not evaluate the spatial component of forest age classes at a variety of scales as was done in this study. Green Diamond constructed the age class covariates in the occupancy model from resource selection modeling done for NSO (Appendix C). Green Diamond used the same age class breaks for the fisher occupancy model since these age classes represent biologically significant stages in the development of forest structure. (Hamm, 1995; Hamm and Diller, 2009) and Hughes (2005) documented that the young forests have high densities of dusky-footed woodrats (*Neotoma fuscipes*), a key prey species for NSO (Courtney et al., 2004) and fishers in the redwood region (Golightly et al., 2006; Slauson et al., 2011). These young forests also support numerous other prey species used by fishers, which suggests young forest may be important as foraging habitat for fishers in a similar manner as they are hypothesized to be used by NSO in the southern portion of its range. The older managed stands with late seral structure are the primary areas used for resting and reproduction for both NSO and fishers in this region (Courtney et al., 2004). If fishers and NSO use managed forests in similar ways in the redwood region, one would not expect the negative relationship between fisher occurrence and increasing amounts of 6- to 20-year-old forests. However, despite the abundance of prey, fishers may be avoiding this age class for reasons not readily applicable to NSO. Green Diamond hypothesized that fishers may be avoiding young stands due to increased risk of predation, increased human activity associated with producing young stands on a managed landscape or other factors that are beyond current knowledge of fisher ecology.

NSO are noteworthy for their tolerance of human activity. They will allow people to approach to a very close distance, and observations within Green Diamond's study area indicate they show no apparent avoidance of areas with high levels of harvesting activity. The same does not appear to be true for fishers. While doing fisher telemetry work reported previously, it was common to have fishers leave their rest site while an approaching field biologist with a radio receiver was still hundreds of meters away. It appears that fishers simply do not tolerate human activity in close proximity. If fishers avoid areas with high levels of human activity associated with timber harvesting, it would seem that the 0- to 5- rather than the 6- to 20-year-old age class would enter the top occupancy model with a negative coefficient. Green Diamond believes the 0- to 5-year-old age class likely gets even less use by fishers than the 6- to 20-year-old age class, but because it only spans a 5-year period, the total area within a given sub-basin in this age class tends to be limited. To understand why, it is necessary to understand the pattern of timber harvesting on Green Diamond's ownership. The initial logging of old growth forests in this area tended to create whole watersheds or sub-basins of similar aged stands. As the stands within a given area reach merchantable age, typically Green Diamond initiates even-age harvesting. This harvesting continues within the constraints of the California FPR, which limits harvest unit size and provides adjacency constraints, i.e., adjacent timber stands cannot be harvested for 3 to 5 years following the even-age harvest of the first unit. Therefore, once started, logging activities are ongoing at a relatively constant rate for 20 to 30 years until most of the unconstrained harvest units have been logged in a given area. This steady rate of harvesting results in an initial increase in the amount of young age classes (0 to 5 and 6 to 20) until the rate of harvest matches the rate of ingrowth (stands moving from a younger into an older age class). Therefore, the amount of 0- to 5-year-old age class reaches a plateau at approximately one third the amount of 6- to 20-year-old age class, which explains why the latter age class is a better covariate for the amount of harvesting activity within a given area. The results from the Hoopa study (Higley and Matthews, 2009) do not appear to support this disturbance hypothesis, since they found fishers selecting for stands that had been recently harvested. However, Hoopa Tribal Forestry is not subject to California FPR, and they have developed their own forest management plan. Their timber harvesting is not concentrated in selected sub-basins so presumably their disturbance is more dispersed.

4.3.3.4 Trend in Habitat

Although Green Diamond cannot quantify future potential fisher denning and rest site habitat, implementation of Green Diamond's 2007 AHCP will result in an overall increase in the amount of older stands that will develop as part of riparian and geologic protection areas. Figure 4-8 shows the trend in stand age class distribution, which indicates that approximately 25% of the Plan Area is in riparian management zones and that the average age of these stands increases from 44 to 94 years-old by the end of the permit period. Presumably, this will result in an overall increase in potential denning and resting habitat for fishers, but it is an untested hypothesis that age alone is sufficient to create this type of habitat for fishers.

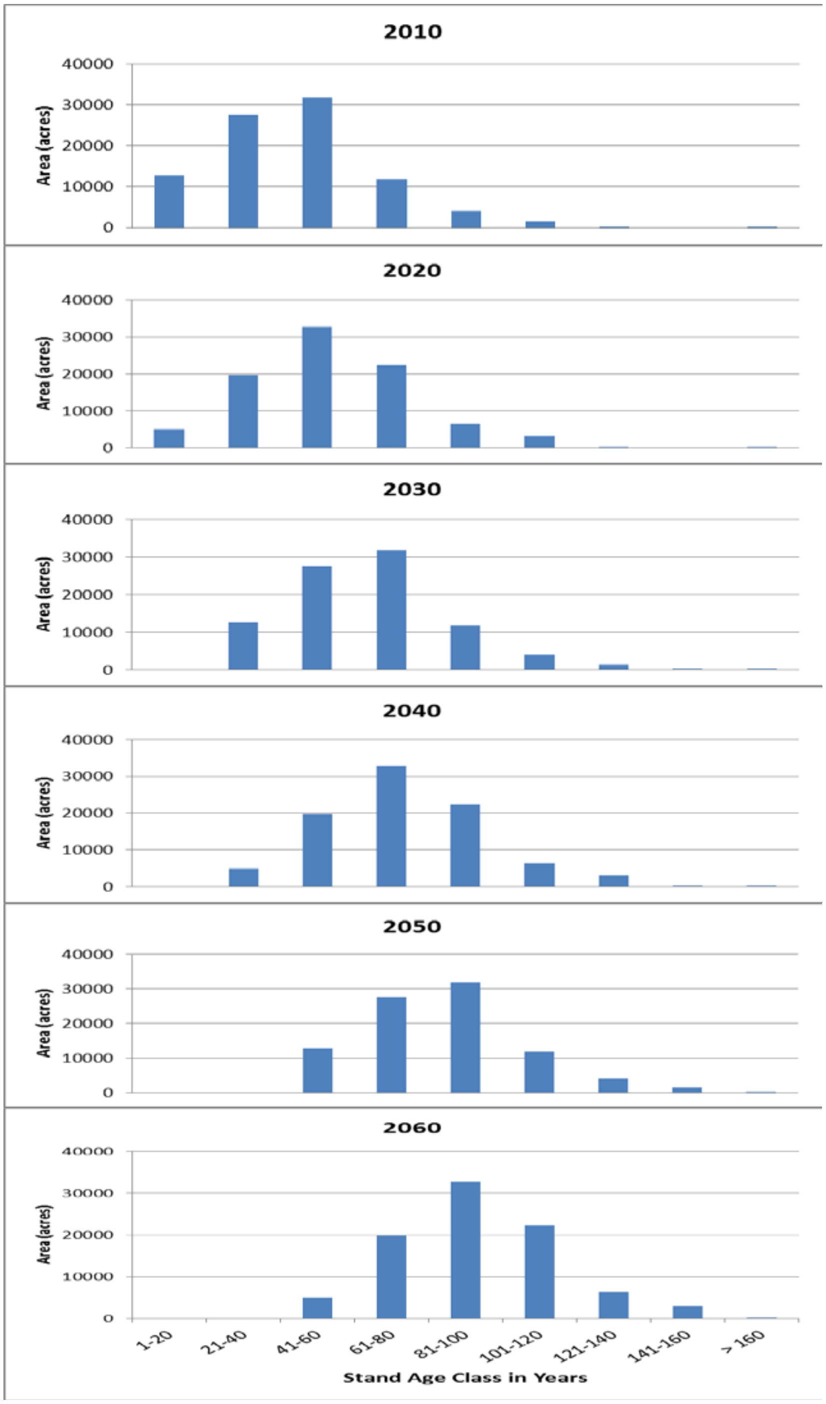

Figure 4-10. Trend in the age class distribution of timber stands within riparian zones.

Using the same projection of future landscapes as described for NSO (Section 4.3.1.5, Trend in Habitat Fitness), Green Diamond projected future probability of fisher occupancy, i.e., habitat suitable for foraging. Assuming non-habitat variables, e.g., elevation and proportion whitewood, remain at some mean value, Green Diamond extended the projection of spatially explicit estimates of fisher occupancy in the study area at 10 year intervals from 2010 to 2060. The changes in probability of fisher occupancy across Green Diamond's ownership can be seen by decade in Map 4-6. The map indicates that projections of fisher occupancy are dynamic across the ownership, but there is also a tendency for the lower elevation, more coastal regions to have lower estimates of occupancy. The overall trend indicates that the habitat associated with the highest projected occupancy (more than 0.80) declines from 135,592 acres (47% of ownership) in 2010 to 103,826 acres (36%) in 2040 and then stabilizes for the next 20 years (Figure 4-9). However, if the two highest categories of projected occupancy are combined, the proportion of Green Diamond's ownership in these two categories only declines a modest amount from 206,292 acres (71%) in 2010 to 180,248 acres (62%) in 2060. It should also be noted that the fisher occupancy model is best characterized as predicting the probability that habitat will be used as foraging by fisher and it does not include a more comprehensive assessment of habitat in a manner similar to the NSO habitat fitness.

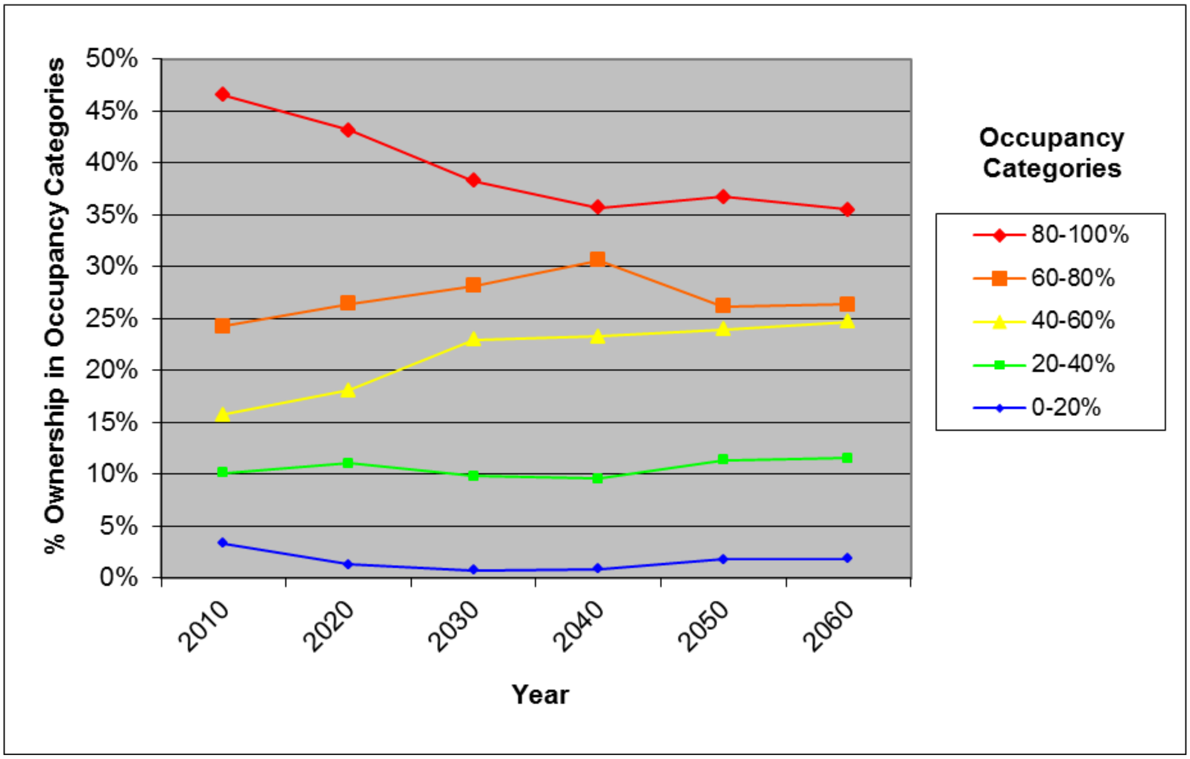

Figure 4-11. Percentage of Green Diamond Resource Company ownership in different projected decadal fisher probability of occupancy categories. Occupancy values <1.0 represent habitats projected to have below while those ≥ 1.0 are projected to have above average probability of occupancy.

4.3.3.5 Population Density

It was noted previously that track plate surveys indicated that fishers were well distributed across the majority of the ownership and detection rates suggested that fishers were relatively abundant in many areas. A Humboldt State University Masters study conducted in 2002 and 2003 (Thompson, 2008) employed a capture-resight technique to quantify the abundance and density of fisher on two separate 100-square kilometer (km^2) study sites on Green Diamond's Plan Area. Following trapping, remote cameras were used to photograph (resight) fishers. Given the problems associated with estimating density of animals that roam over large areas, radio telemetry was used to determine the proportion of time individual marked fishers spent in the study area. The proportional use of the study area by each marked individual was considered an animal equivalent, with full time occupancy equaling a full-time animal equivalent. Animal equivalents were then summed and used in a mark-recapture population estimator in place of the number of marked animals. The radio telemetry data were also used to get home range estimates.

There were sufficient radio telemetry data to estimate home range for 15 fishers. The mean home range was 602 ± 48 hectares for females, and 882 ± 400 hectares for males. Female home range size was not different across study sites. Density estimates calculated by dividing study site area by mean home range size for both study sites combined resulted in 0.17 female fisher/km^2 and 0.11 male fisher/km^2. Based on mark-resight estimates, mean population density of male and female fishers was 0.07 ± 0.01 fisher/km^2 and 0.11 ± 0.02 fisher/km^2, respectively for both years and both study sites combined. Estimates of fisher density on Green Diamond's ownership using either technique were higher than any estimates in western North America and similar to the highest reported estimates from the Northeast (Fuller et al., 2001). While this study did not estimate fisher population throughout Green Diamond's ownership, it did confirm the track plate survey conclusion that fishers were abundant in many portions of the ownership.

4.3.3.6 Population Trends

There were no surveys specifically designed to monitor trends in fisher populations on Green Diamond's ownership. However, as noted above, repeated track plate surveys in 1994, 1995, 2004 and 2006 provided an opportunity to estimate potential changes in annual occupancy rates of fishers throughout the ownership (Figure 4-10).

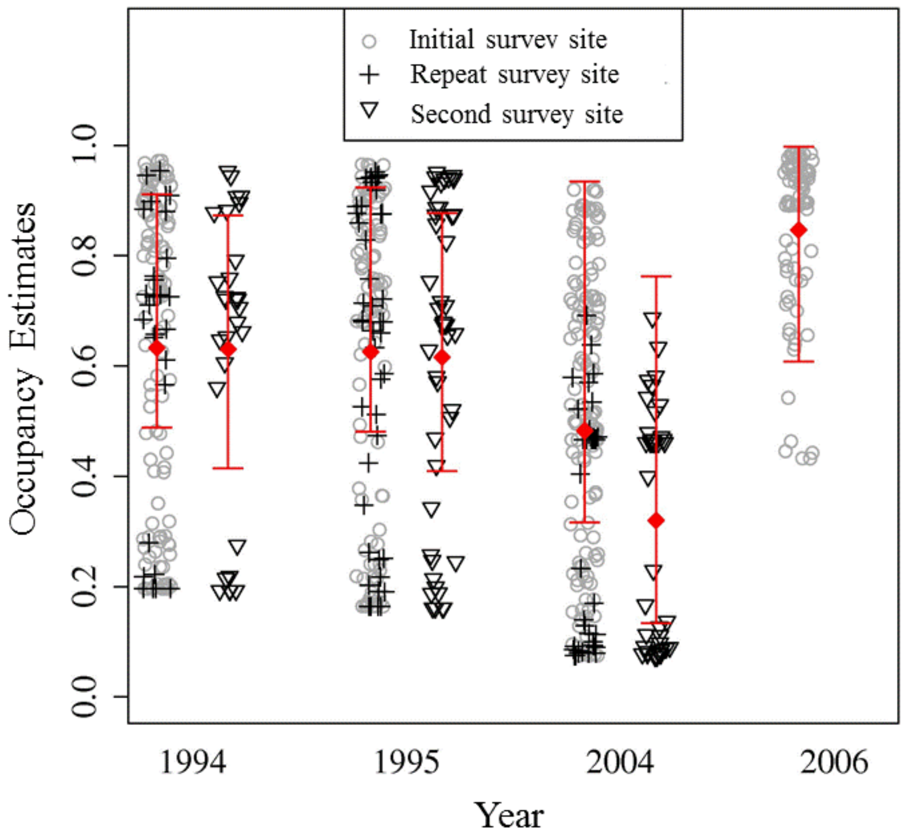

Figure 4-12. Site occupancy estimates for fisher based on track plates surveys conducted on Green Diamond ownership during 1994-95, 2004 and 2006. Red diamonds represent mean annual estimates for year-by-replicate combinations, and red lines show 90% confidence intervals. Open circles represent sites surveyed once during the initial survey period; "+" represent replicate sites surveyed during the same survey period; and diamonds represent a second complete survey during the same year.

As discussed in Section 4.3.3.3, the repeated individual track plate stations provided presence/absence data, from which Green Diamond estimated site occupancy models (MacKenzie et al., 2006) that characterized foraging habitat of fishers on Green Diamond's ownership. This analysis of fisher occupancy included a year covariate that provided the opportunity to determine if there was any statistical support for variation among years in occupancy. Results of that analysis yielded a top model that included the year covariate indicating a decrease in occupancy for year 2004 relative to the other years that were surveyed (Figure 4-10). While there are other potential explanations for a reduction in occupancy, the simplest explanation is that the fisher population was reduced in 2004 relative to other years. This corresponds to an apparent reduction in the fisher population on the Hoopa Reservation immediately to the east of the Green Diamond study area. On the Hoopa Reservation, Higley and Matthews (2009) estimated fisher population density in 2004 to 2005 was less than half the previous estimate during 1998 to 1999. They also noted a change in the sex ratio from approximately two females per male to 0.6 female per male. With no direct evidence explaining the cause of this apparent reduction in fisher numbers, they postulated it may have occurred due to changes in fisher predator numbers, disease or changes in prey populations. In addition, Higley and Matthews (2009) also reported that the fisher population was rebounding from the 2004 to 2005 decline, which is consistent with Green Diamond's observed increase in occupancy in 2006. Clearly these comparisons are circumstantial, but it does suggest that fisher populations are dynamic and may fluctuate at a regional level. However, most importantly, all these data suggest the fisher population has been resilient with no evidence of a decline during the last two decades. A more detailed review of fisher habitat and population trends with complete references is provided in Appendix C.3.

During 2010 and 2011, Green Diamond conducted a pilot study within a specific portion of the ownership to assess the function of different trail cameras and collect current information on *Martes* presence. In 2010, Green Diamond deployed remote cameras at stations centered on a 2-km^2 hexagonal grid randomly located on the ownership (Slauson et al., 2007). Green Diamond randomly selected units to sample, but also focused on areas where marten were detected during prior track plate surveys from 2004 and 2006. Cameras were deployed for a minimum of three weeks at each station and baited stations with raw chicken and a commercial trapping lure as an attractant. Cameras were baited and checked weekly with the general exception that some stations were baited and checked every other week due to complications with access due to weather or other demands on field personnel. During the pilot work in 2010, several camera models were tested to assess reliability, ease of use, function and other important factors. In 2011, Green Diamond began placing two RECONYX cameras (models HC500 and PC800) at each sample unit. Cameras were located approximately three to five meters and at right angles from the bait tree. Green Diamond sampled 75 2 square kilometer units with cameras between September 2010 and June 2011 and obtained photographic evidence of fisher at 45 stations (60%) and marten at eight stations (10.6%). Seven out of eight stations had multiple visits by marten. Fisher were detected at 75% of the stations with marten. Green Diamond cannot directly compare the results of the camera surveys to past surveys with track plates, but the results suggest that fisher occurrence remains relatively high in the northern portion of the plan area (Map 4-5).

4.3.4 Tree Voles

4.3.4.1 Distribution and Habitat

Surveys specifically designed to document distribution and/or relative abundance of tree voles across the ownership have not been conducted due to the lack of any known technique by which voles can be directly surveyed, i.e., there are no techniques by which tree voles can be easily captured or censused. However, stand-level searches for tree vole nests designed to understand nest characteristics and habitat associated with nests were conducted on Green Diamond's ownership from 1994-1996 and then again in 2001-2005. In addition, as part of NSO and other wildlife surveys, Green Diamond's wildlife crew recorded all incidental sightings of tree vole nests. Collectively, these stand-level surveys and incidental sightings created a reasonable approximation of the distribution of tree voles within the ownership (Map 4-7).

Additional evidence of the distribution of tree voles across the Plan Area can be obtained through analysis of NSO food habits. Since NSO surveys and monitoring were first initiated in 1989, Green Diamond's field biologists opportunistically collected all regurgitated owl pellets. The pattern of tree vole distribution based on NSO pellet analysis (Map 4-8) suggested that the distribution of tree voles was more extensive relative to the vole surveys and incidental sightings (Map 4-7). Presumably, NSO food habitats provided a more reliable index of tree vole distribution compared to ground surveys by field biologists. The general pattern is that tree voles are most abundant in the Korbel and Mad River region and less abundant to the north and south.

4.3.4.2 Nest Habitat

From 1994 to 1996, Green Diamond studied the abundance, nest characteristics and nest dynamics of Sonoma tree vole nests on its ownership by:

- Randomly sampling 46 stands from six stand age classes (six to nine stands per age class) to estimate abundance of tree vole nests
- Randomly selecting vole nests in each sampled stand and measuring all trees with a dbh >3.0 inches within a 0.1-acre circular plot centered on the nest tree to evaluate vole nest tree characteristics
- Intensively surveying 2.5-acre grids for tree vole nests, with six sampling periods to estimate nest occupancy over time, including: fall 1994; winter, spring and fall 1995; and winter and fall 1996
- Non-randomly selecting two stands, known to have high tree vole density, each within the five oldest stand age classes, for estimating nest occupancy

Green Diamond found 185 Sonoma tree vole nests in the five oldest stand age classes sampled, and no nests in the 10- to 19-year-old age class, but occasionally observed vole nests in 10- to 19-year-old stands elsewhere on the ownership. Density of active tree vole nests increased with stand age among the five oldest age classes, ranging from 1 nest per hectare in 20- to 29-year-old stands to 6.21 nests per hectare in 60-year-old stands. It is unknown whether the number of vole nests accurately reflects the number of voles because tree voles may have multiple nests. Nest persistence did not differ among stand age classes, and estimated median persistence time for vole nests was 28.6 months (95% CI = 25.8 to 34.8 months). Green Diamond found vole nests in eight tree species and one nest on the ground. Eighty percent of nests were in Douglas-fir trees, with tanoak the next most common tree species. Most of the nests found in tanoaks appeared to have been constructed initially by squirrels. As stand age increased, vole nests were located in larger trees, higher in trees and farther from the bole of the tree. Nest trees were similar in size to surrounding trees in younger stands but became disproportionately larger than surrounding trees as stand age increased.

From 2001 to 2005, Green Diamond sampled 68 24.7-acre square grids, and found 32 of these areas to be inhabited by tree voles. The age of forest stands sampled ranged from 23 to 129 years old. A total of 129 vole nests were located with a range of 1 to 19 per grid. Of the vole nests located, 46.5% were assessed as inhabited and 83.7% were located at the bole of the tree. Nests were located in seven species of tree and five different deformities or structures on the tree. Nests were found in a wide range of tree sizes (mean = 53 centimeters, SE = 15 centimeters) and heights (mean = 11.9 meters, SE = 0.5 meter). The mean dbh of trees on nest plots was not different from random plots, but log volume and number of stumps was greater on random plots than nest plots. There was no difference in slope or canopy closure in nest versus random plots. Green Diamond observed a positive relationship between vole abundance and forest age and distance from coast. Again, abundance was greatest toward the southern interior of the study area.

The Green Diamond studies and analyses indicate tree voles are rare or absent from the coastal portions of the study area and increase in abundance with greater distance from the coast. This phenomenon is most likely linked to the increasing presence of Douglas-fir, their primary forage, in more interior areas. Green Diamond found tree voles were present in a wide range of forest ages but abundance of nests was positively related to forest age.

4.3.4.3 Trends in Abundance and Habitat

As noted previously, there are no techniques by which tree voles can be readily captured or directly censused, so there are no tree vole population data available on Green Diamond's or adjacent ownerships. However, as described above, Green Diamond continuously collected and analyzed NSO pellets since 1989. The relative frequency of tree voles in the diets of NSO has been used to estimate their distribution and abundance in Oregon (Forsman et al., 2004b). However, prey selection by NSO is almost certainly neither random nor constant at shorter annual intervals (i.e., NSO are likely to shift prey selection based on the relative abundance or availability of a suite of prey species) so that annual variations in relative frequency may not be a reliable indicator of trends in the vole population. However, if the detection of tree voles remains had been treated using an occupancy modeling approach (MacKenzie et al., 2006), the probability of a tree vole being detected within an individual NSO territory through searching for and analyzing NSO pellets could have been calculated and occupancy of tree voles in the owl's territory estimated. Unfortunately, this rather novel approach to detecting trends in animal populations was not well developed or understood at the time that these data were collected and the analysis was not done. Therefore, although Green Diamond does not believe it is an unbiased index of trends in abundance, the proportion of tree voles in NSO pellets as depicted on Figure 4-11 were the only data available to estimate tree vole population trends in the Plan Area. The figure suggests a decline from a high in 2000 to a low period from 2001 to 2006. However, there was also a sharp decline in the effort and the total number of NSO pellets collected from 1998 to 2004, so the changes in proportion could be influenced by sampling errors associated with small sample sizes during this period or changes in prey selection by NSO. Green Diamond has continued to collect pellets at NSO sites during visits to NSO sites on an annual basis, but additional dissection and analysis of pellet data has not been conducted since 2009.

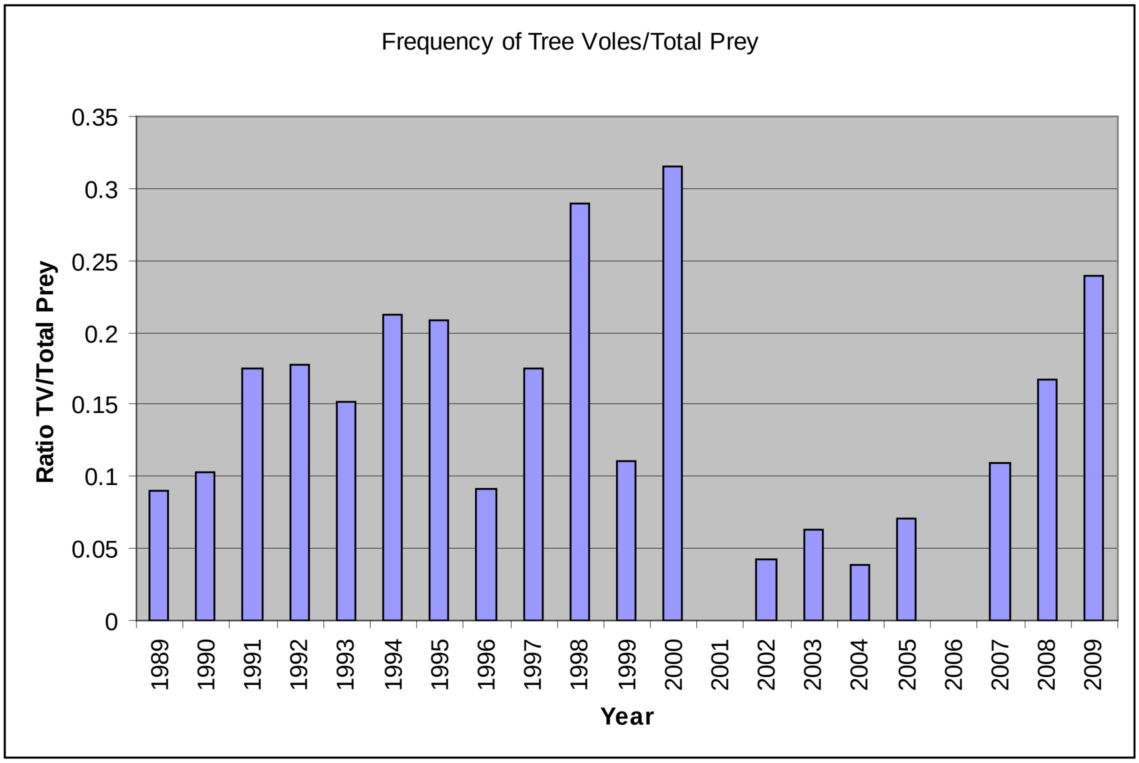

Figure 4-13. Trend in ratio of tree voles (TV) to total prey items identified in northern spotted owl pellets collected on Green Diamond ownership, 1989-2009.

The inability to capture or directly census tree voles has limited Green Diamond's ability to understand their habitat associations. As a result, the studies of tree vole habitat associations based on nest searches have only produced relatively simplistic models of vole habitat on Green Diamond's ownership. Generally, Green Diamond found voles in stands older than 20 years old and with at least 20% composition of Douglas-fir, but vole nest abundance increased with the age of stands suggesting that the best habitat was the older stands. Green Diamond also documented that the median persistence of visible vole nests was a little over two years and the nest trees tended to be larger than the surrounding trees. From these observations, Green Diamond assumed that larger more complex trees where nests could be hidden in deformities and cavities may provide for greater longevity of nests. Studies done to the east of Green Diamond's ownership on Forest Service land concluded that tree vole nests were found in stands that contained many late-seral/old-growth forest attributes such as large diameter, older and variably sized trees (Dunk et al., 2009). It seems likely that forest fragmentation may also reduce habitat fitness potential for tree voles, but the lack of any demographic studies of tree voles has precluded any direct assessment of this phenomenon. In summary, Green Diamond assumes that the best habitat occurs in older stands with more complex structure stands with a higher component of Douglas-fir that are larger or more connected to other older stands.

Green Diamond is not aware of any direct data on the dispersal distance of tree voles. However, to get an idea of what voles were capable of recolonizing, we reviewed the University of California at Berkeley Fritz-Metcalf photographic collection for historical photographs of areas that we know are currently occupied by tree voles. Based on photographic evidence and historical accounts, there were entire sub-basins of several thousand acres or more near

Korbel, CA in which all of the old growth was completely removed in the early 1900s and then most of the second growth was logged in the 1980s and 90s. These are areas in which we have documented to have a relatively high density of tree voles based on nest surveys, anecdotal observations and analysis of NSO pellets. This provides evidence that tree voles can recolonize large areas from which all habitat was removed, but we do not know how rapidly this may have occurred.

The only other data available is based on a telemetry study of home ranges and movements of tree voles in Oregon. Assuming a circular home range, the radius of median and mean home ranges were 15.5 and 23.5 meters, respectively (Swingle, 2005). Swingle (2005) also documented that the mean distance between alternate nests of individual voles was 45 meters. Based on these two lines of evidence, we made the assumption that tree voles should be able to disperse at least 50 meters through marginal habitat (Swingle, 2005), Green Diamond projected the amount of potential tree vole habitat (older than 20 years-old with 20% or more Douglas-fir) in future landscapes using the same harvest forecasting as was done for NSO and fisher (Figure 4-12). The trend in vole habitat after projected timber harvest varies between 48.5% (2030) and 50.2% (2050) of the IPA (Map 4-9).

This is a minimum estimate of suitable habitat for tree voles given Green Diamond observed vole nests in forest stands that do not meet the minimum criteria in its model. This analysis also factored in the riparian management zones and geologic protection areas mandated by Green Diamond's 2007 AHCP, which will result in a future landscape comprised of approximately 25% protected areas. This will result in an increase in the amount of older stands within the Plan Area, although many of the older stands will be relatively linear with a high proportion of edge. Green Diamond assumes these older riparian stands will provide a source population and connectivity to younger stands that will develop into a suitable age for colonization by tree voles over the term of the plan (Map 4-10). The quantity and arrangement of vole habitat within specific watersheds will vary over time as a result of harvesting and the connectivity provided by protected areas (Map 4-10). While many aspects of the habitat projections for tree voles remains untested, it seems intuitive that a landscape with a large complex network of older riparian stands connecting to developing younger stands will provide better habitat and opportunities for recolonization than the historical managed landscape in the past, most of which was harvested twice with little or no remnant forest structure.

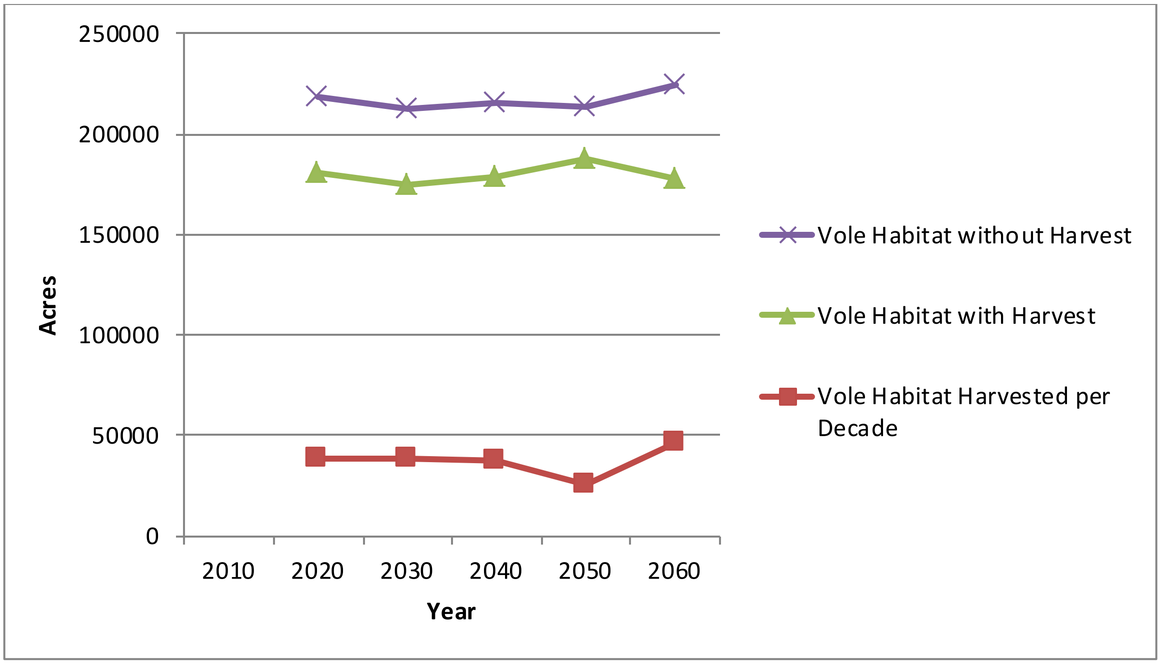

Figure 4-14. Amount of suitable tree vole habitat on Green Diamond ownership at 10-year intervals. Suitable habitat is forest stands older than 20 years of age with at least 20% basal area of Douglas fir.

4.4 OTHER SPECIES CONSIDERED IN HCP ALTERNATIVES

4.4.1 Marten

4.4.1.1 Distribution and Habitat

Until the fall of 2010, no surveys were conducted with the specific objective of determining the distribution or habitat associations of marten on Green Diamond's ownership. However, all the field techniques described above designed to survey, capture or resight (photograph) fishers were equally suitable for martens. This means the extensive track plate surveys and field techniques used to detect or capture fishers were equally likely to detect or capture martens if they were present.[1] Given the dual functionality of the track plate surveys, Green Diamond determined there were no marten detections during the 1994 or 1995 track plate surveys. The protocol Green Diamond used for fishers was initially designed and tested for marten in the Sierras (Fowler and Golightly 1994). In addition, other regional track plate surveys conducted at the same time detected no martens (Beyer and Golightly 1994). The repeat track plate survey conducted in 2004 yielded six marten detections at four track plates in Pecwan Creek (Map 4-11). To confirm the tracks recorded on track plates were marten, Green Diamond placed camera traps at select locations and obtained photographic confirmation. Repeating the track plate survey in 2006, Green Diamond obtained 13 marten detections at eight track plates in Pecwan Creek and one at a track plate in lower Bear Creek (Map 4-11). Green Diamond also confirmed marten detections in Bear Creek with a camera trap. It should be noted that although martens were detected at track plates where fishers had been previously detected in Pecwan

[1] The 1994 and 1995 track plate protocol used for Green Diamond fisher surveys included design and testing to detect martens in the Sierras. (Fowler and Golightly 1994)

Creek, no martens and fishers were detected at the same track plate during the same survey period. However, fisher and marten were detected at the Bear Creek track plate in 2006.

The lack of detections of martens during most surveys does not prove that they were absent, but the preponderance of negative data certainly indicated that martens were either very rare or absent over most of the Plan Area. As noted in Section 3.2.4, the only known population of martens within the historical range of the Humboldt subspecies occurs east of Green Diamond's ownership on Forest Service land. Presumably, the only martens detected on Green Diamond's ownership in 2004 and 2006 were dispersers or peripheral residents from this core population. Recent camera surveys conducted in 2010 and 2011 detected marten in the same vicinity (within one mile) of the 2004 and 2006 detections but the same survey effort failed to detect any marten west of the Klamath River (Hamm et al., 2012). It appears that marten continue to occupy this area of managed lands on the periphery west of the core population on public lands.

Green Diamond's research also confirms that the marten is found in serpentine areas, a unique habitat type used by martens in this area (Slauson et al., 2007). One of the few areas where Green Diamond has detected marten on its ownership in serpentine habitat is an area known as Rattlesnake Mountain in Del Norte County. This area contains a sparse overstory tree canopy with an extensive understory of dense brush and rocky substrate. Also, in Blue Creek and Pecwan Creek, collaborative research found marten in second growth forest with a mixture of hardwood and conifer tree species where redwood is not dominant. This suggests that marten habitat may not be limited by the presence or absence of extensive old growth forest. Rather, it may be that the marten is capable of occupying a variety of forest habitats.

In October 2012, Green Diamond, the U.S. Forest Service and the Yurok tribe, initiated a new study to scientifically evaluate marten dispersal ecology. The objectives of the study were to estimate the number of individuals entering second growth habitats west of the core population on Forest Service ownership and monitor fates and movements of a radio collared subset of animals. Additional objectives of the study were to determine female denning sites as well as monitor collared animals for rest site use. Between 2012 and 2014, 33 uncollared martens detections occurred along the camera transect line deployed adjacent to the core population on Forest Service land and the dispersal study area on Yurok and Green Diamond ownership. A total of 17 marten were captured and collared at camera transect locations, and an additional five marten were captured and collared at non-camera transect trap locations. Of the 22 individual marten (8 females, 14 males) radio collared in the study area, six marten exhibited dispersal behavior (movements more than 1 mile from initial capture location), but none of the collared animals appeared to attempt crossing the Klamath River west of the study area. Fifty-nine percent of the study population survived through mid-year 2014, and mortalities appear to be primarily caused by predation from bobcat (*Lynx rufus*) as evidenced by forensic necropsy. A greater proportion of males (57%) died in the study, and anecdotal information suggests that forest roads may have been a contributing factor in predation events. The preliminary evidence suggests that bobcats may pose a serious threat to the survival of marten (especially young males), but predation by fishers was not identified as a single cause of mortality. Yet, fishers were detected at 100% of camera stations deployed for the dispersal study. We cannot relate these detections in the dispersal study to numbers of fishers, but they are quite abundant in this landscape, and this observation is supported by prior track plate surveys conducted by Green Diamond. Our prior assumption that fishers also pose a serious threat to marten may be incorrect. Additional studies on the habitat use and overlap of home ranges for these two species should be conducted to better understand interactions between these two mesocarnivores and how predation by bobcats may influence marten in this area.

The data from this ongoing research have not been fully analyzed, but an increasing amount of field data from designed studies suggests that marten have expanded into managed lands since the initial track plate surveys conducted by Green Diamond in 1994, and now, resident, reproducing martens exist in this landscape. Radio tracking of the 22 collared marten resulted in the location of at least 35 rest and den sites, and a minimum of three collared females have successfully produced kits that were observed on remote cameras deployed at natal and maternal den sites. Efforts are underway to determine reproductive status of additional females suspected to have denned and vegetation sampling will take place at known rest and den sites later this summer and fall. This study will represent new information regarding habitat use by marten on managed forests in northern California.

4.4.1.2 Population Trend

With the overall dearth of marten detections, Green Diamond lacked data to assess any trends in the marten population. However, as noted in Section 3.2.4, at the same time that the core population of martens in north coastal population was apparently declining, martens were detected to the west of the core population for the first time on the ownership in 2004 and 2006. In addition, a marten was detected further to the west in Prairie Creek Redwoods State Park in 2009 and 2010. While these survey results do not allow for a definitive assessment of the trend in the coastal marten population, it appeared as if martens were dispersing further from their core population during the mid-2000s relative to the 1990s. It may be strictly coincidental, but this potential expansion of martens occurred at the same time that fishers were apparently undergoing a temporary decline in their population (Section 4.3.3.6). Negative interaction between fishers and martens has been noted in numerous locations throughout their range (Daniel 1960; Krohn et al., 1997; Hamlin et al., 2010) and the potential expansion of martens with fewer fishers may be the result of this interspecific interaction. Regardless of any potential localized expansion of martens within Green Diamond's ownership, it remains clear that the marten population was small and isolated to only a small portion of the ownership. As noted above for fisher, Green Diamond conducted pilot surveys with cameras in 2010 and 2011 to test field techniques and collect current presence/absence data within a limited portion of the ownership where marten were previously detected. Before 2010, no surveys were conducted with the specific objective of determining the distribution or habitat associations of marten on Green Diamond's ownership. However, Green Diamond's prior efforts and field techniques were equally suitable for martens. During 2010 and 2011, Green Diamond conducted a pilot study within a specific portion of the ownership to assess the function of different trail cameras and collect current information on *Martes* presence. In 2010, Green Diamond deployed remote cameras at stations centered on a 2-km^2 hexagonal grid randomly located on the ownership (Slauson et al., 2007). Green Diamond randomly selected units to sample, but also focused on areas where marten were detected during prior track plate surveys from 2004 and 2006. Cameras were deployed for a minimum of three weeks at each station and baited stations with raw chicken and a commercial trapping lure as an attractant. Cameras were baited and checked stations weekly with the general exception that some stations were baited and checked every other week due to complications with access from weather or other demands on field personnel. During the pilot work in 2010, several camera models were tested to assessing reliability, ease of use, function and other important factors. In 2011, Green Diamond began placing two RECONYX cameras (models HC500 and PC800) at each sample unit. Cameras were located approximately three to five meters and at right angles from the bait tree. Green Diamond sampled 75 2-km^2 units with cameras between September 2010 and June 2011 and obtained photographic evidence of marten at eight stations (10.6%). Seven out of eight stations had multiple visits by marten.

Section 5. Conservation Program

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Section 5 identifies the biological goals and objectives of this FHCP and describes Green Diamond's conservation program for the Plan Area. Section 5.2 establishes the conservation strategy through the identification of a series of biological goals and objectives and provides the overall framework within which the conservation strategy is built. Sections 5.3 and 5.4 provide detailed descriptions of conservation measure commitments and adaptive management measures Green Diamond will implement to achieve the biological goals and objectives within the context of covered activities. The adaptive management provisions included in section 5.3 identify options for responding to significant changes in the population or distribution of Covered Species, should such changes be detected during prescribed monitoring. Section 5.5 is a summary of management commitments Green Diamond has adopted for the Operating Conservation Program. These commitments are based on detailed information and analysis provided in sections 5.3 and 5.4.

5.2 BIOLOGICAL GOALS AND OBJECTIVES

5.2.1 Introduction

To meet the statutory criteria for FHCP approval, Green Diamond's conservation program must:

- Minimize and mitigate the impacts of authorized incidental take of Covered Species that may result from Covered Activities to the maximum extent practicable, and
- Ensure that any such take will not appreciably reduce the likelihood of the survival and recovery of such species in the wild.

In addition to these statutory criteria, the Service issued an Addendum to the HCP Handbook (also known as the Five Points Policy) stating an HCP must identify specific biological goals and objectives based on the conservation needs of the Covered Species and the potential impacts of the proposed action that warrant incidental take permit issuance (Final Addendum; 65 FR 35251).

The Handbook Addendum explains:

> *Explicit biological goals and objectives clarify the purpose and direction of an HCP's operating conservation program. They create parameters and benchmarks for developing conservation measures, provide the rationale behind the HCP's terms and conditions, promote an effective monitoring program, and, where appropriate, help determine the focus of an adaptive management strategy. . . .Biological goals provide broad, guiding principles for an HCP's operating conservation program and the biological goals are "the rationale behind the minimization and mitigation strategies" (Final Addendum; 65 FR 35251).*

Biological goals can be either habitat-based or species-based. Habitat-based goals are expressed in terms of the amount and or the quality of habitat. Species-based goals are expressed in terms specific to individuals or populations of that species. This FHCP's biological goals and objectives are primarily habitat-based but include species-based objectives for the NSO, fisher and tree voles. Biological objectives are more specific and include measurable parameters needed to achieve the biological goals. The goals and objectives guide the development of the operating conservation program.

As permit holder, Green Diamond's obligation for meeting the biological goals and objectives is proper implementation of the operating conservation program of this FHCP. To qualify for No

Surprises assurances, Green Diamond must implement the operating conservation program of this FHCP (i.e., the items denoted as Commitments in Section 5.5), the Implementation Agreement, and the terms and conditions of the Permit. Implementation may include provisions for ongoing changes in actions in order to achieve results or due to results from an adaptive management strategy (65 FR 35251).

Accordingly, to minimize and mitigate the impacts of incidental take within the Plan Area as described in this FHCP and to ensure that such take does not jeopardize the Covered Species, Green Diamond will implement measures that will, during the term of the Permit, protect and where needed allow development of the functional habitat conditions that are required for long-term survival to support well-distributed, viable populations of the Covered Species. These measures, set forth in Section 5.3, are based on the biological goals and objectives described below.

5.2.2 Biological Goals and Objectives

The Covered Species in this FHCP are the NSO, fisher, and red and Sonoma tree voles. The habitat for these species ranges from relatively young forest stands used for foraging to older forests and residual late seral structural elements used for nesting, denning and rest structures. Although the specifics differ among the Covered Species, and vary across the Plan Area, the Covered Species have adapted to using forest habitat conditions with a mosaic of forest types and age structure at a landscape scale. Within the various stands comprising the habitat mosaic, certain habitat elements are of particular value for conservation of the Covered Species. The Covered Species may benefit from management activities that promote and conserve habitat patterns at both the landscape and stand levels, and they may be mildly or acutely impacted by certain management activities or interspecies interactions that are harmful and should be minimized or avoided. Over time, Green Diamond will learn more about the Covered Species and their positive and negative responses to management activities that perpetuate, create, modify or replace habitat patterns and elements. This information will help improve the efficiency and effectiveness of this FHCP.

Based on these considerations, Green Diamond established five overarching biological goals with corresponding specific biological objectives that reflect in measureable biological terms the intended result of the proposed conservation program. As a result of the shared habitat requirements of the four Covered Species and in addition to the overall purpose of the Plan as stated in Section 1.4, the biological goals of this FHCP are to:

1. Promote Habitat Mosaic Across the Plan Area: At the landscape/Plan Area scale, provide for well-distributed, high-quality habitat for all the Covered Species with added emphasis on dynamic protection for well distributed and highly functional NSO nesting sites. The habitat will develop from and be maintained by a mosaic of older RMZs and other mature stands interspersed with patches of young growth stands regenerated by timber harvesting.
2. Retain and Recruit Targeted Habitat Elements: Provide for the retention and recruitment or development of targeted habitat elements necessary for nesting, breeding or denning of NSO, fisher and tree voles.
3. Minimize Harm to Individual NSO, Fisher and Voles: Minimize disturbance to NSOs during the nesting season, minimize disturbance to fisher in known occupied dens, prevent drowning of fisher through accidental entrapment in water tanks, and minimize direct felling of trees in RMZs bearing active or remnant vole nests. Also, cooperate in fisher capture and relocation/recovery projects provided that individual animals are

protected from harm and the animals removed are not essential for sustaining the fisher population in the Plan Area. And, implement a program to discourage, prevent, and remove unauthorized drug growing activities that are associated with the unlawful use of pesticides that harm Covered Species.

4. Barred Owl Research: Conduct a series of barred owl removal experiments to ensure the maintenance of a well distributed population of NSOs throughout the Plan Area. Ultimately, this goal will facilitate meeting NSO objectives while still allowing for the persistence of some barred owls in portions of the Plan Area.
5. Ensure Compliance and Effectiveness of the Conservation Plan through, Monitoring and Adaptation: Provide resources and structure for accountability and compliance. Gather additional data to refine and validate the NSO habitat and fisher occupancy models supporting transition to a landscape conservation plan based on habitat management. Monitor and adapt this FHCP as new information becomes available to provide habitat conditions needed to meet the general goals benefitting the Covered Species.

Each of the five biological goals for this FHCP is supported by biological objectives and corresponding conservation measures. The biological objectives of this FHCP are described here in relation to the biological goals they support.

5.2.2.1 Goal One: Promote Habitat Mosaic across the Plan Area

Objective 1A: Fundamental Premise and Primary Conservation Strategy is to Increase the Percentage of High Quality Habitat for the NSO throughout the Plan Area

For NSOs, the fundamental premise and primary conservation strategy of this FHCP is to promote increasing percentage of high quality habitat for the NSO in the Plan Area. Green Diamond quantified high quality habitat in terms of habitat that supports high rates of survival and fecundity (i.e., habitat fitness > 1.0) and low probability of abandonment (i.e., high probability that once occupied, it will remain occupied). Green Diamond used harvest forecast and growth models to project future landscapes on which the habitat fitness and abandonment models were applied. These models indicated increasing trends in high quality NSO habitat throughout the Plan Area (Section 4.3.1.5). The biological objectives are to increase over the current baseline the total amount of high quality habitat within the Plan Area (habitat with fitness values > 1.0, as defined in Section 4.3.1.4 or some future habitat metric, reviewed and approved by the Service that would replace calculations of habitat fitness) which provides the potential for a stable or increasing NSO population. However, it may be more appropriate to tie future habitat projections to the new NSO occupancy analysis (Section 5.3.5.1.2) that will be conducted following approval of this FHCP. The Plan Area habitat will be capable of supporting and should support a stable or increasing population of NSOs (Section 5.3.1.4). Other non-habitat factors (e.g., weather and barred owls) are known to influence NSO population demographics (Forsman et al., 2011; Dugger et al., 2016; Diller et al., 2016) and will cause fluctuations or trends in NSO populations that are not mediated by habitat., The spatial configuration of forest age classes and habitat types suitable for supporting high habitat fitness and site occupancy will fluctuate through time within a given watershed or sub-basin, but the total amount of the highest quality NSO habitat is projected to increase throughout the term of this FHCP (Section 4.3.1.5).

Objective 1B: Maintain Highly Functional NSO Nesting Sites Distributed Throughout the Plan Area

High quality habitat across the landscape provides an opportunity for a stable or increasing population of NSOs, which is the basis for the success of this FHCP for NSOs. However, protection of the current most highly functional (i.e., high site occupancy and fecundity) nesting sites provides added assurance that this objective will be achieved (Section 5.3.1.4). Two decades of research indicate that humans cannot predict specific locations that will support productive nest sites. Only NSOs can select sites that provide the right combination of habitat elements and abiotic factors that are conducive to long term occupancy and production of young. This FHCP affords some protection to all NSO-selected sites in the Plan Area, but identifies and immediately provides the highest level of protection to maintain the 44 most functional NSO sites currently available in the IPA. The protected NSO sites include the core nesting and roosting areas and surrounding foraging habitat. The most functional sites were ranked based on prior occupancy and fecundity, spatial distribution and future potential for high occupancy and fecundity. These sites are referred to as Dynamic Core Areas (DCAs), because the best sites are expected to be dynamic throughout the life of this FHCP. Accordingly, they can be replaced over time by new, equally or more functional, well distributed core areas established by NSOs as habitat conditions evolve across the Plan Area (Section 5.3.1.1).

Objective 1C: Maintain and Improve Fisher Denning and Resting Habitat Distributed Throughout the Plan Area

Green Diamond has not collected data to model habitat fitness for fisher, nor is there any other suitable data available for that purpose. As a result, unlike NSO, Green Diamond cannot model the habitat conditions that increase survival and fecundity for fisher. Based on fisher research within the Plan Area, a critical component of fisher habitat is the presence of available den trees and rest sites essential to provide denning and resting habitat. Fisher dens and rest sites are often in larger, older, and decadent trees associated with late seral forest stands. These structures could be lost on managed timberlands. Therefore, the primary habitat objective for fisher is to maintain or increase the number and distribution of potential denning and resting structures for fisher. At the landscape level, Green Diamond will achieve this by retaining and recruiting late seral habitat elements throughout the Plan Area. This objective will be accomplished by increasing the age of approximately 25% of the Plan Area from a current average stand age of 44 years to an average of 94 years, through limited entry management of Riparian Management Zones (RMZs) and geologically unstable zones (Section 5.3.5.2).

Objective 1D: Maintain Fisher Foraging Habitat Distributed Throughout the Plan Area

Using multi-year track plate surveys, Green Diamond estimated the probability of fisher occupancy associated with various habitat and physiographic variables in the Plan Area (Section 4.3.3). Given that track plate detections are the result of a fisher responding positively to bait, habitat associated with fisher occupancy can be best described as foraging habitat. Given that fisher feed on a wide array of food items, it is not likely that foraging habitat will be limiting on managed timberlands. The objective of maintaining well distributed foraging habitat for fisher throughout the landscape will be met by maintaining a high probability of occupancy (i.e., $p \geq 0.6$ or, after review and approval by the Service, an appropriate high occupancy estimate following future analyses) in over half of the Plan Area (Section 5.3.5.2).

Objective 1E: Maintain and Improve Vole Nesting Habitat Distributed Throughout the Plan Area

Data or models are not available to estimate habitat fitness or occupancy for tree voles. However, like NSO and fisher, tree voles evolved with and are likely to benefit from the retention and recruitment of mature and late seral forest habitat elements throughout the Plan Area.

In addition, studies on Green Diamond's ownership determined that tree voles occupy forests with at least 20% basal area of whitewood conifer species (i.e., non-redwood conifers such as Douglas-fir and grand fir) at least 20 years old. Applying this standard for suitable vole habitat across the Plan Area will ensure the existence of a desirable spatial distribution of habitat suitable for vole nesting and dispersal. The habitat objective for tree voles is a positive trend in habitat suitable for tree voles (forests with at least 20% basal area of whitewoods that are at least 20 years-old), which can be achieved by having well-distributed older stands associated with RMZs. Under this objective, the positive trend in suitable tree vole habitat will stabilize at around 50% of the Plan Area acreage.

5.2.2.2 Goal Two: Retain and Recruit Targeted Habitat Elements

Objective 2A: Retain and Recruit Habitat Elements Such as Hardwood Trees, Snags, and Decadent or Defective Trees to Provide Habitat for Nesting, Resting and Denning

All Covered Species use some similar habitat elements for nesting, denning or resting. These habitat elements are generally provided by older, larger and structurally complex or decadent trees. The objective is retention of all of these types of habitat elements when they occur in RMZs, geologically unstable areas, Habitat Retention Areas (HRAs) and any other retention areas provided for within Timber Harvesting Plans (THPs). In addition, all larger structurally complex trees providing these habitat elements as defined in Green Diamond's comprehensive plan for Terrestrial Retention of Ecosystem Elements (TREE; Appendix E) are retained inside and outside any of the retention areas described above. Green Diamond resource managers and biologists developed the TREE to ensure consistent retention application guidelines for key habitat components across the landscape. Provisions and measureable targets of the TREE are summarized in Section 5.2.2, as they apply to conservation of the Covered Species.

Future development or recruitment of habitat elements within the retained areas described above will primarily result from stochastic processes associated with natural events (e.g., wind storms, wild fire and disease) or through accidental damage due to timber harvesting activities. In addition, these retained trees will not be harvested within the life of the Permit and will be available for voluntary efforts to actively accelerate the formation of wildlife structure (e.g., inoculation of heart rot agents, fire scars, cavity formation and etc.). Where older or larger complex trees are currently absent in specific portions of the Plan Area, younger trees are retained (recruited) to serve as future potential key habitat elements as the stand matures.

5.2.2.3 Goal Three: Minimize Harm to Individual NSOs, Fisher and Voles.

Objective 3A: Minimize Disturbance and Direct Take of NSOs

For NSO, the specific objective is to ensure with a ≥95% probability of detection that all NSOs attempting to nest can do so without being harmed or harassed by timber harvest and other Covered Activities. This objective will be accomplished by conducting pre-harvest NSO surveys in all harvest units planned for timber harvest during the period when NSOs would potentially be incubating eggs, brooding nestlings or caring for recently fledged juveniles (21 February –

31 August). The specific survey requirements to achieve a ≥95% probability of detection are detailed in Appendix F. Protection measures are included in Section 5.2.

Objective 3B: Protect Fisher from Controllable Harm

Fishers are highly mobile animals not associated with a particular activity center where they remain for extended periods on a seasonal basis as observed for NSO (Section 5.3.3.2). This precludes the effective use of seasonal protective avoidance measures because the location of a fisher den cannot be identified without capture and radio collaring females, which is both impractical and involves substantial risk of harm to the fisher. However, if an active or suspected active fisher den site is identified, Green Diamond will protect the site from disturbance by harvest activities until it is no longer in active use. Confirmed den trees will be retained even after they are no longer in active use (Section 5.3.3.2).

In addition, fishers are known to be curious and will explore confined spaces. This habit can lead to their accidental entrapment within man-made fixtures such as water tanks, where they may drown or become entrapped without possibility of escape. A biological objective of this Plan is to prevent accidental entrapment or drowning of fisher in Green Diamond water systems and tanks by securing all such structures to ensure that fisher cannot enter or become entrapped. Specifics of how compliance and effectiveness of this objective will be ensured are in Section 5.3.3.2.

Lastly, fisher in the Plan Area may serve as a source population for reintroduction and species recovery projects by the Service, California Department of Fish and Wildlife (CDFW) or other entities outside the Plan Area. Such projects are not Covered Activities under this FHCP, but any cooperative actions by Green Diamond to facilitate such capture and relocation projects do constitute Covered Activities, and Green Diamond may take such cooperative actions provided that the captured animals are protected from harm.

Objective 3C: Minimize Disturbance to Tree Vole Nests in RMZs

Most tree voles live in a single nest tree and make short forays into neighboring conifers with interlocking branches. They live their entire lives within a small home range with very limited ability to disperse. Therefore, they are highly vulnerable to the direct effect of timber harvesting if they reside in a tree felled during timber harvest. Surveys specifically designed to document distribution and/or relative abundance of tree voles across the ownership have not been conducted due to the lack of any practical techniques by which voles can be directly surveyed over large areas (i.e., there are no techniques by which tree voles can be effectively captured or censured) (Section 5.3.3.3). Green Diamond conducts partial harvesting activities within RMZs and geological areas and will avoid felling trees found to support tree vole nest(s). Foresters trained by Green Diamond's biological staff to identify potential vole nests will inspect harvest trees in RMZs before marking to avoid felling of trees with potentially active vole nests. Green Diamond will conduct annual training to educate foresters and timber fallers on identification of tree vole nests and sign.

Objective 3D: Minimize Harm to Covered Species from Unauthorized and Unlawful Pesticide Use

Public and private timberlands in and around the Plan Area have experienced an epidemic of unauthorized entry and use for cultivation of marijuana crops. Excessive and unlawful use of pesticides, and in particular, rodenticide, is associated with many grow sites where woodrats and other fauna may feed on marijuana crops. Pesticides are ingested by woodrats and other fauna such that these poisons enter the food chain where they may persist and be indirectly consumed by Covered Species such as NSO and fisher. Recent research has confirmed the presence of rodenticides in the livers of deceased NSO, barred owls, and fishers (Gabriel et al., 2012, 2014, 2015, 2018). Harm to NSO and fisher may be prevented by discouraging, detecting, and removing unauthorized marijuana cultivation and associated pesticide use in the Plan Area.

5.2.2.4 Goal Four: Barred Owl Research

Phase One Pilot Barred Owl Removal Experiment – During the development of this Plan, a pilot experiment was initiated in 2009, field work completed in 2014 and the results presented in two peer-reviewed manuscripts published in 2014 and 2016. The objectives of this experiment were to determine the feasibility of doing lethal removal of barred owls; estimate the impact of barred owls on NSO occupancy, fecundity, survival and rate of population change; and assess the effectiveness of barred owl removal to allow recovery of NSOs in the Plan Area. This pilot removal experiment used a before-after-control-impact (BACI) experimental design with a paired treatment and control design in which barred owls were removed in the treated areas and allowed to persist and/or expand undisturbed in the untreated (control) areas. To begin with, this experiment provided evidence that lethal removal of barred owls was technically feasible and cost-effective (Diller et al., 2014). Some of the most important demographic results were that barred owls caused more than a four-fold increase in the estimate of NSO site extinction (i.e., probability that a NSO site will be abandoned), but following barred owl removal, the extinction rate in the treated areas returned to normal levels and NSO site occupancy was greater in treated than untreated areas. Furthermore, apparent survival and the rate of population change (lambda) were in decline prior to removal, but both of these demographic parameters showed significant increases following removal and mean lambda was 1.029 (2.9% annual increase). Mean fecundity did not show a significant increase following treatment due to high annual variation, but the greater number of occupied NSO sites on the treated areas resulted in greater productivity in the treated areas based on empirical counts of fledged young. The primary conclusion from this initial experiment was that lethal removal of barred owls allowed the recovery of the NSO population in the treated portions of the study area (Diller et al., 2016). This experiment is ongoing, but evidence to date indicates barred owls have a substantial adverse impact on NSO occupancy, and barred owl removal has a rapid, beneficial effect on NSOs. More details are provided in (Section 4.3.2 and Appendix C).

Based on the dramatic results of this experiment, other studies showing the potential for barred owl to negatively impact NSO and combined with barred owl control recommendations in the 2011 Revised Recovery Plan for the NSO (*Strix occidentalis caurina*) (USFWS, 2011a), indicate it is apparent that some form of Plan Area-wide barred owl removal should be employed to sustain NSO populations. However, the extent to which barred owls should be controlled, and the degree to which barred owls and NSOs may be able to co-exist, is unknown based on this pilot experiment. Consequently, Green Diamond proposes a series of long-term barred owl experiments in the Plan Area designed to address these data gaps and further recovery efforts for NSOs. These experiments will be implemented over the life of this FHCP in a phased approach with the completed pilot experiment designated Phase One, because it applies information learned to develop a long-term strategy for barred owl/NSO management. The primary objective of this phased research is to develop a barred owl management strategy that will provide a better understanding of the influences of barred owls on NSO and determine the density of barred owls that can be allowed to coexist on the landscape where NSO conservation is also achieved. Details of that strategy are described in Section 5.3.4.

Objective 4A: Phase Two Plan Area-Wide Barred Owl Removal Experiment

Based on the results of the Phase One experiment indicating barred owl removal is technically feasible and provides an opportunity for NSO populations to recover, Green Diamond will design, seek necessary Service and CDFW permits for, and then implement an approved barred owl removal experiment across most or all the Plan Area (Section 5.3.4.2). This experiment will have all the same study objectives as the Phase One experiment with the important difference of determining if similar results can be obtained when the treated areas include the entire Plan Area. It will use a similar BACI study design with treated and untreated (control) areas, except the treated areas (i.e., where barred owls will be removed) with minor exceptions will include the entire Plan Area, and adjacent federal lands (e.g., Willow Creek Demographic Study Area) will serve as the untreated control areas. Green Diamond estimates this experiment will be conducted for approximately 10 years or until habitat model validation is achieved for NSOs. Green Diamond has committed to continue demographic studies until model validation, which will allow analysis of treatment effects on survival and recruitment along with effects to NSO site occupancy and rate of population change. After approximately 5-10 years of implementation and analysis of the data, Green Diamond will present the results to the Service in an Annual Report or separate report that occurs concurrently with results from a future NSO demographic workshop. The specific criteria for determining when Phase Two of the experiment is complete will be a statistically significant treatment effect on one or more NSO demographic parameters. Green Diamond and the Service will meet to review the results of the report, and upon concurrence from the Service, Green Diamond will conclude Phase Two of the experiment and begin implementation of Phase Three. If the analysis shows that the results of Phase Two are not statistically significant, Green Diamond will continue implementation of Phase Two with concurrence from the Service. If Green Diamond and the Service cannot agree on the results of Phase Two and whether to initiate Phase Three, the issue will be taken to a scientific review panel. This panel will consist of independent experts on the subject at hand and include at least three members that are agreeable to both parties. The appropriate course of action relative to cessation or continued implementation of Phase Two and future analyses will be taken based on the recommendation of the majority of the panel.

Objective 4B: Phase Three Barred Owl Invasion and Co-existence Experiments and Research

Following completion and evaluation of the results of the Phase Two Plan Area-wide removal experiment, Green Diamond will design, seek necessary Service and CDFW permits for, and then implement an approved invasion and co-existence experiment (Section 5.3.4.3). The objective of this experiment will be to fine tune suppression of barred owl numbers to achieve a stable equilibrium in which FHCP NSO objectives are achieved while allowing barred owls to persist in the Plan Area. The first portion of Phase Three, in which barred owls will be allowed to re-colonize selected areas from which they had previously been removed for 10 years or more, will provide an opportunity to do an invasion experiment (Section 5.3.4.3). When the objectives of the invasion experiment have been achieved (probably 5 to 10 years) Green Diamond will shift to a co-existence experiment. The fundamental objective will be to establish a long-term maintenance level of barred owls that allows NSOs to be sustained while minimizing the lethal removal of barred owls. This long term experiment will provide an opportunity for NSO to better adapt to the negative impacts of barred owls, assess non-lethal methods of suppressing barred owl populations and evaluate the potential to manage habitat that benefits NSO over barred owls. The intent is that eventually a variety of solutions can be found that will eliminate or minimize the need for continued lethal removal of barred owls.

Goal Five: Ensure Compliance and Effectiveness of the Conservation Plan

Regulations implementing section 10(a)(1)(B) of the ESA require each HCP to implement the provisions stated therein, monitor the outcomes of the identified conservation measures, validation of the assumptions necessitated by the incomplete information upon which this Plan must rely, and identify adaptive management measures necessary to ensure that the overall conservation approach of this FHCP functions as intended. Goal Five, and the objectives identified within this section, provide a framework within which these requirements are met. Specific conservation measures, including adaptive management options, are described in detail in Sections 5.3.

A biological goal of this FHCP is to ensure the dynamic development of habitat across the Plan Area, the effectiveness of the conservation measures, the population status of Covered Species and their predicted positive response to the Conservation Program, and to detect any other factors that could benefit or harm the Covered Species in the Plan Area. The effectiveness monitoring is designed to confirm the expected benefits of the conservation program for Covered Species and to adjust conservation strategies when monitoring indicates that adaptation is appropriate. Adaptive management is also a recognized requirement of habitat conservation plans under the Service's Five Points Policy, requiring an HCP to use monitoring and adaptive management to address scientific uncertainty concerning the conservation needs of Covered Species throughout the life of the Permit (Final Addendum; 65 FR 35251).

Objective 5A: Accountability, Compliance and Training

The first step in achieving the biological goals and effectiveness of the conservation measures of this FHCP is to ensure that Green Diamond implements Covered Activities and conservation measures as planned and approved. This requires implementing the necessary staffing, funding, training, and accountability for Plan implementation. It also requires a plan for reporting to, and related oversight by the Service. When submitting any proposed THP within the Plan Area to CAL FIRE, Green Diamond will provide an informational copy of the THP filing notice and a THP area map to the Service. The THP filing notice and its cover letter will include information on potential take of FHCP Covered Species, such that it will function as the notification to the Service regarding anticipated or potential take of listed species, and implementation of FHCP conservation measures intended to reduce the level and effects of anticipated take. In addition, Green Diamond will prepare and submit an annual report to the Service by March 1 following the first full year after this FHCP effective date and every year thereafter during this FHCP term. The full details of this report are in Section 5.3.7.

Objective 5B: Habitat Model Validation

The objective is to provide independent validation of the models predicting habitat fitness and site occupancy/extinction for NSOs and occupancy by fisher using data collected from throughout the Plan Area. By continuation of the property-wide surveys and demographic mark-recapture study that have been ongoing throughout the Plan Area since 1990, validation of the models for NSO habitat will be based on:

- Continued NSO site occupancy, colonization or re-colonization consistent with model predictions (Section 5.3.5.1.2)
- Overall observed long term trend in occupied NSO sites is statistically shown to be increasing (P = 0.95) as predicted by combined habitat fitness values for the Plan Area (Section 5.3.5.1.1). In a similar manner, validation of the occupancy model for fisher will

be accomplished by data collected from future non-invasive survey techniques (Section 5.3.5.2.1)

In addition, Green Diamond expects future data collection used in the validation process will lead to model refinement providing greater confidence in the predictive abilities of the models (Section 5.3.5).

This habitat model-related objective is potentially influenced by various non-habitat parameters (e.g., weather, disease, new threats such as the barred owl, etc.) that may exceed normal limits of variation or are unlike conditions under which the habitat models were developed. Therefore, Green Diamond has proposed continuation of pre-model validation studies and conservation actions in the event that these non-habitat factors complicate the model validation process.

Objective 5C: Prescribe Adaptation and Limits of Adaptation in Response to Monitoring and Foreseeable Changes in Circumstances

While the conservation plan was designed to achieve the biological objectives, future monitoring may reveal that some are not being met. If identified threshold monitoring targets are triggered (Section 5.3.6.1), the adaptive management process will be implemented, and if warranted, corrective action taken (Section 5.3.6.4.). However, this will occur within feasible limits (Section 5.3.6.2). Furthermore, foreseeing changes in circumstances that may occur during the life of Plan, and prescribing the appropriate adaptations or limitations that would apply in response to such circumstances is also important in achieving this FHCP's biological goals and effectiveness of the conservation measures (Section 5.4).

5.3 THE OPERATING CONSERVATION PROGRAM

This Section provides a detailed description of the components, rationale and enforceable Commitments of the Operating Conservation Program for this FHCP. First, Green Diamond explains the purpose, intent and implementation of each conservation Commitment in the context of the biological goals and objectives presented in Section 5.1. Then Green Diamond separately states each conservation Commitment as an enforceable measure that it will implement to satisfy ESA Section 10(a) requirements.

Based upon its biological goals and objectives, Green Diamond developed a comprehensive Operating Conservation Program with a number of specific conservation measure Commitments. To ensure that the Covered Species are not jeopardized and to mitigate and minimize, to the maximum extent practicable, the potential effects of Covered Activities on the resident NSO, fisher and tree vole populations, Green Diamond proposes to implement a five-point conservation program. The Operating Conservation Program includes:

1. Landscape management commitments to promote a mosaic of suitable habitat across the Plan Area that benefits all of the Covered Species, with added emphasis on protection for highly productive NSO nesting sites
2. Habitat element commitments for the retention and recruitment or development of targeted habitat elements necessary for nesting, breeding, resting or denning of Covered Species
3. Covered Species protection commitments to minimize harm to individual NSOs, fisher and voles
4. Barred owl research commitments

5. Conservation program implementation, monitoring, validation and adaptation commitments

Green Diamond will integrate the Operating Conservation Program into its long-term operating plan for the next 50 years. As with all long-term plans, the conservation program will require updating and modification over time. The program provides mechanisms for adjusting measures as necessary, including validating and revising habitat models and transition from less effective to more effective conservation measures.

5.3.1 Landscape Management to Produce a Plan Area-wide Mosaic of Suitable Habitat with Added Emphasis on Protection for Highly Productive NSO Sites

5.3.1.1 Overview and Benefits to Covered Species

At the landscape scale, Green Diamond will plan and implement its business operations subject to conservation commitments providing a mosaic of suitable habitat throughout the Plan Area, long-term retention and recruitment of late seral habitat elements beneficial to NSOs, fisher and tree voles, and additional protection of highly productive NSO sites (DCAs). The landscape characteristics that Green Diamond will achieve and the habitat benefits for each of the Covered Species are described in the following subsections.

5.3.1.1.1 Northern Spotted Owl

The landscape management commitments will provide a dendritic network of intact forests that will become increasingly older throughout the life of this FHCP. Approximately 25% of the Plan Area will be in RMZs that will increase from the current average stand age of 44 years to an average of 94 years (stand age calculations were made from 2010-2060). While not considered old growth, stands of this age in the redwood region develop trees with cavities, broken tops, debris accumulations and various types of nests built by a variety of other birds and mammals, which can and do serve as NSO nest sites. Stands of this age with the typical component of hardwoods also provide ideal roosting structure for adult NSOs and their fledglings. The dendritic network of intact older forests juxtaposed with early seral stands will also create high levels of habitat heterogeneity, the key to high quality habitat for NSOs in the Plan Area.

Habitat element commitments (Section 5.3.2) augment landscape management by retaining any large residual or old growth trees with existing cavities, broken tops, lateral platforms or other structural deformities. These large residual trees provide focal areas for NSO roosting and nesting.

In summary, Green Diamond will plan and implement timber harvests to:

- Create or enhance habitat heterogeneity in a dynamic pattern across future landscapes;
- Provide retention of older forest stands within a matrix of regenerating younger forests; and
- Retain key habitat components

Applying these habitat measures to future landscapes will produce an overall upward trend in habitat fitness values for NSOs. The percentage of the ownership in the highest category (habitat lambda >1.05, meaning habitat that has the potential to support an increasing population of NSOs) is projected to increase from 35% in 2010 to 64% in 2060. Furthermore, the habitat with the lowest probability of modeled site abandonment (p <0.20) is projected to increase over time from 58% of the ownership in 2010 to 93% of the ownership in 2060 (Section 6.2.2.3). However, because timber harvesting and re-growth create variable conditions through time and there is a projected decrease for localized areas in habitat value for short periods (15 to 20 years based on the Mad River study), individual watersheds or sub-basins will have dynamic habitat values. Key habitat covariates responsible for this overall increasing trend and cyclic nature of habitat fitness values are mean open edge density and landscapes created where older stands (>40 years) are adjacent to younger stands (6-40 years). These habitat conditions with high habitat heterogeneity, which are also projected to create habitat favorable for high site occupancy, will be created by continuing to practice even-aged silviculture with small clearcut harvest units along with extensive riparian zones and scattered geologic zones. Percent hardwood and residual structure, (i.e., older trees retained from previous timber harvest) are also important habitat elements but they have a quadratic relationship with nesting habitat. This means values above an optimum level are predicted to reduce overall habitat fitness values for NSOs. NSO habitat quality is highly dynamic and active management is critical to regenerate habitat with high fitness values after re-growth of forest stands has reduced habitat heterogeneity (Section 4.3.1).

Green Diamond's plan for achieving the quantified habitat quality values described above for the NSO addresses the attainment of Objective 1A (Section 5.1.2.1 – Maintain and improve habitat fitness for the NSO throughout the Plan Area.). The specific biological objective will be to maintain a positive trend in the total amount of habitat with fitness values > 1.0, which provides the potential for a stable or increasing NSO population.

The final component of high quality habitat for NSOs on an actively managed landscape is a stable core area for roosting and nesting. Monitoring of set-asides created under the 1992 NSO HCP indicated that stable core nesting and roosting areas for NSOs need to be selected based on sites demonstrating high NSO occupancy and fecundity. Protection for core NSO areas distributed throughout the Plan Area ensures there will always be areas capable of supporting NSO pairs with high site occupancy and fecundity. Although there will also be many other occupied NSO sites with successfully reproducing pairs throughout the Plan Area, a strategy to protect highly productive NSO sites provides additional assurance that the NSO population in the Plan Area will have the potential to increase with development of high quality habitat in the Plan Area. Other non-habitat factors such as weather and barred owls have the potential to negatively influence NSO populations and may not be mediated by habitat.

Protection for highly productive NSO sites achieves Objective 1B (Section 5.1.2.2 – Protect and develop productive NSO nesting sites distributed throughout the Plan Area).

5.3.1.1.2 Fisher

As noted above, the landscape management commitments benefitting the NSO will provide a dendritic network of intact and increasingly older stands throughout the life of this FHCP. Trees in these stands particularly important to fisher are those that develop cavities. Although the lifespan of this FHCP may not be sufficiently long for cavities to develop in many conifers, cavity development usually occurs much more rapidly in hardwood species such as tanoaks, and many of these older hardwoods will develop cavities usable by fisher. The lifespan of this FHCP will, however, be long enough for conifers to develop fisher rest sites. Green Diamond's fisher studies have shown that fisher rest sites such as debris accumulations and dwarf mistletoe infestations tend to develop in relatively young conifers (Section 4.3.2).

Habitat element commitments described in Section 5.3.2 will augment Green Diamond's landscape strategy for fisher by retaining any large residual or old growth trees with existing cavities or other structural deformities. Green Diamond's past fisher telemetry studies indicated that large residual trees with cavities are particularly important, because they were the only structures that have been identified to be used for natal and maternal den sites by fisher (Section 4.3.2). The cavities typically occur in trees with heart rot where an entrance forms naturally or by primary excavators such as pileated woodpeckers. Rest structures are less specific than den sites and can occur in a variety of dead or live trees with deformities or platforms. Green Diamond's studies indicate these structures used for fisher resting and denning are often similar to NSO nesting structures.

Green Diamond has not collected data suitable for estimating habitat fitness for fisher as was done for NSOs, but we used repeated track plate surveys to estimate the probability of fisher occupancy associated with various habitat types (Section 4.3.2). Since track plate detections resulted from fisher responding positively to bait, habitat associated with fisher occupancy can be best described as foraging habitat. The future projections of foraging habitat for fisher indicate that the highest quality (>0.8 occupancy) fisher habitat is projected to decrease by about 10% over the 50-year permit, but will remain well distributed and comprise approximately 50% of the Plan Area. The amounts of medium-high (>0.6 but <0.8) occupancy habitat will be stable or decline slightly over the life of this FHCP. Overall, habitat associated with high fisher occupancy varies little through time, but like NSO habitat projections, individual watersheds may vary more dramatically through time as timber harvesting and forest succession create a mosaic of forest age classes. The primary reason high quality fisher habitat varies little through time is that elevation, the key predictor of fisher occupancy, is a physiographic covariate with no variance over time. The probability of fisher occupancy increased with increasing elevation across the ownership, but the final model for fisher occupancy also contained the habitat covariates for percent whitewood and the amount of 6- to 20-year-old forest within an 800m buffer around track plate stations. The percent whitewood had a positive influence on fisher occupancy and the amount of 6- to 20-year-old forest had a negative influence on fisher occupancy (Section 4.3.2). As elevation decreases, the percentage of whitewood in a forest stand and the amount of 6- to 20-year-old forest within an 800m buffer have a greater influence on fisher occupancy. As with elevation, the percentage of whitewoods in a stand is not likely to vary much over the 50-year permit because tree species composition does not change dramatically through time. The areas of ownership at low to intermediate elevation appear to fluctuate most based on the changing amounts of young forest resulting from timber harvest practices.

Green Diamond's current modeling suggests fisher occupancy will decline in regions with greater amounts of timber harvesting (negative influence of stands 6 to 20 years old), but there is high probability of fisher use when most of the stands are >20 years old. The pattern of timber harvesting across Green Diamond's ownership should create a dynamic mosaic of areas with variable levels of occupancy through time. However, fisher apparently are adaptable to such changes because we have verified that there is still a well distributed population across the ownership after >100 years of timber harvesting in the region.

The combination of landscape forest management creating a mosaic of young and old stands and habitat element commitments benefitting fisher address Objective 1C and Objective 1D (Section 5.2.2.1).

5.3.1.1.3 Tree Voles

As noted previously, landscape management commitments will provide a dendritic network of intact increasingly older stands throughout the life of this FHCP. In these stands, trees developing structural deformities like candelabra tops and cavities are of particular importance to voles. The habitat element commitments described in Section 5.3.2 retain large residual or old growth trees with existing structural deformities and cavities suitable for nest construction by tree voles. Although tree voles can build their nests on open branches, nests in protected structures are likely more enduring and nest inhabitants are less vulnerable to predation.

Although we lack tree vole habitat models, Green Diamond's studies indicate that voles colonize stands with at least 20% whitewood that are at least 20 years-old. Tree voles tend to select older larger trees to build their nests. Information on nest longevity in these older larger trees suggests tree voles probably have greater survival in these older trees. Green Diamond will retain and recruit late seral habitat elements through landscape management commitments under this FHCP that will develop a future landscape in which an estimated 25% or more of the Plan Area will be in some type of protected riparian zone. This will result in an increase in the amount of older stands within the Plan Area. Although many of the older stands will be relatively linear with high proportion of edge, they will provide a source population and connectivity to younger stands that will develop into a suitable age for colonization by tree voles.

The landscape management measures described above will address Objective 1E (Section 5.2.2.1 – Maintain and improve vole nesting habitat distributed throughout the Plan Area.)

5.3.1.2 Implementing Landscape Management Commitments through Timber Harvest Plans

Green Diamond will implement landscape management commitments through its THPs and associated permitting process. This FHCP will guide development of individual THPs and establishes long-term planning objectives for Plan Area management.

The Plan Area-wide mosaic of habitat will also be shaped and reinforced by the California FPRs, which regulate timber harvest. The FPRs limit clearcut size and dictate adjacency constraints between harvest units, resulting in a managed landscape with a mosaic of dispersed, small (<20 acres) even-aged harvest units. Supplements to existing FPRs intended to benefit Covered Species are described later in this document (Section 5.3.2). FPRs so supplemented would not reduce protections of any Covered Species; rather, the supplements are intended to improve protections of Covered Species or promote management options that would benefit tree voles. Where not specifically supplemented in this FHCP, FPRs will apply as established under State law. Other provisions of this Plan, such as the Riparian and Geological Management Measures, have been adapted from measures currently in effect from other plans (in this case, the AHCP/CAAA [Green Diamond, 2007]). Where such provisions are included in this FHCP, the additional benefits accruing from inclusion herein will be described.

Landscape Management Commitment One (Objective 1A): When planning and seeking approval of THPs for future timber harvests, Green Diamond will incorporate into all THPs measures that provide long-term retention and recruitment of late seral habitat elements that are beneficial to NSOs, fisher and tree voles. Those measures include:

- Riparian management zones and retention associated with geologically unstable areas (Section 5.3.1.3)

- Designation and protection for DCAs (Section 5.3.1.4)
- Group and individual tree retention in harvest units in conjunction with the plan for TREE (Section 5.3.2)

5.3.1.3 Riparian and Geological Management Measures

This FHCP includes enforceable RMZ prescriptions and protection of geologically unstable areas beneficial to the Covered Species. Although initially created through the AHCP (Green Diamond, 2007) that currently mandates their implementation, these prescriptions are also incorporated as independent and enforceable commitments of this FHCP to promote protections for terrestrial Covered Species within riparian zones where only a single light selection harvest (variable 0-30% canopy removal) is allowed during the life of this FHCP. Prescriptions for RMZs and geologically unstable areas provide a substantial conservation benefit for the Covered Species and they encumber over 25% of the Plan Area through extremely limited or no timber harvest. Accordingly, they are an important factor in the Service's consideration of whether this FHCP minimizes and mitigates take to the maximum extent practicable.

This FHCP required future habitat projections to 2060. Green Diamond's studies show that the RMZ and geologic areas will increase in average age from 45 to 95 years over the term of the permit. In addition, the proportion of older age stands (41 to 60 years) adjacent to younger stands (6 to 20 and 21 to 40 years) also contributed to the upward trend in habitat fitness values for NSO and anticipated benefits to fishers and voles given that both of these species utilize older trees with structure for nesting and denning. The location of older stands in RMZs adjacent to younger stands created through timber harvest results in more habitat heterogeneity that is projected to increase mostly due to implementation of Green Diamond's AHCP (2007), the riparian and geologic measures incorporated into this FHCP, and the FPRs. Given that NSOs commonly select lower slope positions to establish their activity centers, these areas created through implementation of protection for RMZs and geological hazard areas will have a high probability of being selected by NSOs as nesting sites. They will also provide additional late seral habitat areas beneficial to fisher and voles.

Inclusion of these RMZ and geologically unstable area provisions within this FHCP provides important benefits to terrestrial Covered Species, because even if the AHCP (Green Diamond, 2007) were withdrawn or terminated, the riparian and geologic measures in place would remain in effect for the full term of this FHCP, or for as long as this FHCP is deemed necessary for the conservation of Covered Species, up to the term limit (50 years) of this FHCP.

Listed below are the key elements of this FHCP's riparian and geological hazard management measures that as described above in Section 5.3.1.1 will play a major role in creating nesting, denning, and resting habitat for the Covered Species.

Landscape Management Commitment Two – Riparian and Geological Management Measures (Objective 1A): Green Diamond will implement all of the following measures:

- Class I RMZ Characteristics – Green Diamond will establish a RMZ of at least 150 feet (slope distance) on each bank of all Class I watercourses[1] in the Plan Area. The width

[1] Class I watercourse is defined as all current or historical fish-bearing watercourses and/or domestic water supplies that are on site and/or within 100 feet downstream of the intake. The watercourse transition line is defined as that line closest to the watercourse where perennial vegetation is permanently established. The Channel Migration Zone is defined as Current boundaries of bankfull channel along the portion of the floodplain that is likely to become part of

will be measured from the watercourse transition line or from the outer Channel Migration Zone (CMZ) edge where applicable.

Where the floodplain is wider than 150 feet on one side, the outer zone of the RMZ will extend to the outer edge of the floodplain.

An additional buffer will be added to the RMZ immediately adjacent to a floodplain, as follows:

Slide Slopes	Additional Floodplain Buffer
0-30%	30 feet
30-60%	40 feet
>60%	50 Feet

Green Diamond will establish an inner zone within each RMZ, the width of which will depend upon the streamside slope in accordance with the following:

Side Slopes	Inner Zone Width
0-30%	50 feet
30-60%	60 feet
>60%	70 Feet

Green Diamond will also establish an outer zone within each RMZ, which will extend from the outside limit of the Inner Zone edge to at least 150 feet from the bankfull channel (or CMZ edge) with the additional floodplain buffer set forth above.

- Conservation Measures within Class I RMZs:

  Single Harvest Entry – During the life of this FHCP, Green Diamond will carry out only one harvest entry within Class I RMZs, which will coincide with the even-aged harvest of the adjacent stand. The only exception will be light thinning conducted with the specific objective of enhancing wildlife structure. If cable corridors through RMZs are necessary to conduct intermediate treatments, e.g., commercial thinning, in adjacent stands before even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stands.

  - Overstory Canopy Closure:

    - Green Diamond will retain at least 85% overstory canopy closure within the Inner Zone
    - At least 70% canopy overstory closure will be retained within the Outer Zone

the active channel in the next 50 years. The area of the channel defined by a boundary that generally corresponds to the modern floodplain, but may also include terraces that are subject to significant bank erosion.

CAL FIRE protocol in effect as of the date of this FHCP will be used for sampling overstory canopy cover to determine compliance with the overstory canopy closure requirements.

- Class II RMZ Characteristics – Green Diamond will establish an RMZ of at least 75 or 100 feet on each bank of all Class II watercourses[2], as follows:

  - A 75-foot minimum width will be used on the first 1,000 feet of 1st order Class II watercourses (Class II-1 watercourses[3]). Downstream of this first 1000-foot section, the RMZ will be expanded to at least 100 feet.
  - A 100-foot minimum width will be used on all 2nd order or larger Class II watercourses (Class II-2 watercourses[4]).

    Green Diamond will establish an Inner Zone within the RMZ, the width of which will be 30 feet measured from the first line of perennial vegetation.

    Green Diamond will also establish an Outer Zone within the RMZ, which will extend the remaining 45 feet or 70 feet (depending on whether it is a Class II-1 watercourse or a Class II-2 watercourse, respectively).

  - Conservation Measures within Class II RMZs:

    - Single Harvest Entry – During the life of this FHCP, Green Diamond will carry out only one harvest entry into Class II RMZs, which will coincide with the even-aged harvest of the adjacent stand. The only exception will be light thinning conducted with the specific objective of enhancing wildlife structure. If cable corridors through RMZs are necessary to conduct intermediate treatments, e.g., commercial thinning, in adjacent stands before even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to the cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stand.

    - Overstory Canopy Closure:

      - Green Diamond will retain at least 85% overstory canopy closure within the Inner Zone
      - At least 70% overstory canopy closure will be retained within the Outer Zone

- Class III RMZ Characteristics – Additional tree retention will occur in certain Class III watercourses[5] to maintain stream bank stability, and in geologically unstable areas. However, tree retention associated with unstable areas is a relatively minor component

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[2] A Class II watercourse is defined as a watercourse that contains no fish, but supports or provides habitat for aquatic vertebrates. Seeps and springs that support or provide habitat for aquatic vertebrates are also considered Class II watercourses with respect to the conservation measures.
[3] A *Class II-1 watercourse* is defined as a subset of Class II watercourses, as illustrated in Appendix C.
[4] A Class II-2 *watercourse* is defined as a subset of Class II watercourses, as illustrated in Appendix C.
[5] A *Class III watercourse* is defined as small seasonal channels that do not support aquatic species, but has the potential to transport sediment to Class I or II watercourses.

(approximately 10%) of the total riparian retention. Appendix D includes details of the prescriptions associated with Class III watercourses and geologically unstable areas.

- Conservation Measures within Class III Equipment Exclusion Zones (EEZs) – Green Diamond will apply one of two tiers of protection measures within Class III watercourses in accordance with HPA Groups and slope gradient (the average slope as measured with a clinometer, starting from the watercourse bank and running upslope for a distance of 50 feet), as follows:

HPA Group	Slope Gradient
Smith River	<65%=Tier A
	>65%=Tier B
Coastal Klamath	<70%=Tier A
	>70%=Tier B
Korbel	<65%=Tier A
	>65%=Tier B
Humboldt Bay	<60%=Tier A
	>60%=Tier B

- Class III Tier A Protection Measures:

  - EEZ:

    - Green Diamond will establish a 30-foot EEZ, except for a) existing roads; b) road watercourse crossings; and c) skid trail watercourse crossings.
    - The exception for skid trail watercourse crossings is only applicable when the following conditions are met – Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to using existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.
    - Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.

  - Large Woody Debris (LWD) Retention – Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ
  - Site Preparation – Green Diamond will not ignite fire during site preparation within the EEZ

- Class III Tier B Protection Measures:

  - EEZ – Green Diamond will establish a 50-foot EEZ, except for existing roads, road watercourse crossings, and skid trail watercourse crossings.
  - The exception for skid trail watercourse crossings is only applicable when the following conditions are met – Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to

using existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.

- Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
- Hardwood Retention – Green Diamond will retain all hardwoods and nonmerchantable trees within the EEZ except where necessary to create cable corridors or for the safe falling of merchantable trees.
- Site Preparation – Green Diamond will not ignite fire during site preparation within the EEZ.
- Conifer Retention – Green Diamond will retain conifers where they contribute to maintaining bank stability or if they are acting as a control point in the channel.
- A minimum average of one conifer 15 inches DBH or greater per 50 feet of stream length within the EEZ will be retained.
- LWD Retention – Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ.

- Geological Management Measures – Green Diamond will establish a variety of measures to address geologically unstable areas. These measures include retention of trees to minimize and mitigate sediment input from steep streamside slopes, headwall swales, deep-seated landslides and shallow rapid landslides. The criteria for tree retention are relatively complex and often region-specific within the Plan Area so the full details are included in Appendix D under "Slope Stability Measures" (pp D-11 to D-15.)

5.3.1.4 Protection of Highly Functional NSO Sites (DCAs)

The fundamental premise of this FHCP is that a mosaic of high quality habitat will be maintained for the Covered Species within the term of the permit through retention of some habitat elements and regrowth of other habitat components temporarily lost due to timber harvest. This central conservation strategy is augmented by specific landscape commitments and through measures that mitigate potential impacts to Covered Species. The primary mitigation strategy for NSO under this FHCP is the establishment of DCAs as the highest priority and level of protection for the most productive NSO sites distributed throughout the Plan Area. DCAs are intended to be dynamic and adaptive within this FHCP's managed landscape. This is in contrast to the static reserve concept of set-asides established under the NSO HCP. The new approach is based on knowledge gained from monitoring and research conducted during 23 years of implementation of the NSO HCP (Green Diamond, 1992). In this section, we describe how what we learned supports our new approach to NSO management, by comparing population metrics from set-asides with the DCA strategy.

As noted in Section 4.3.1.3, the value of set-asides under the NSO HCP (Green Diamond, 1992) varied such that some contributed to both NSO survival and fecundity and others were never occupied by NSOs. To assess the demographic contribution of set-asides, Green Diamond developed a methodology quantifying the apparent biological value of different set-asides. Estimating the contribution to NSO survival of individual set-asides was problematic, because individual birds moved around through time and it was not feasible to quantify individual survival rates for the set-asides. However, Green Diamond was able to quantify set-asides based on their contribution to NSO fecundity (female owlets produced per female NSO). Therefore, Green Diamond calculated the biological value of set-asides by summing the number of fledglings produced per year over the duration of the study and then expressed the fledgling success per year per NSO territories in each set-aside. Twenty-five of the 39 set-asides had low biological value (mean annual fecundity per NSO territory 0 to <0.13) either because there were no NSOs that occupied the set-aside or the set-aside was occupied by NSOs that rarely fledged any young. Fourteen set-asides had moderate to high biological value (fecundity >0.15 but <0.45). Under the NSO HCP, these sites with high biological value may be displaced and taken through harvesting adjacent to set-asides, subject to the limits of authorized incidental take. In fact, four NSO sites within set asides were lawfully displaced under the NSO HCP and more of the most functional NSO sites associated with set-asides could potentially be displaced in this manner (Green Diamond, 1992).

The biological value of the 1992 set-asides was most likely a function of creating a stable core area for roosting and nesting. It is also apparent that these stable core areas need to be selected based on sites that have demonstrated high NSO occupancy and fecundity. This FHCP dramatically improves upon the concept of set-asides by creating a new and more productive and efficient conservation strategy through DCAs. The DCAs will serve as stable and protected core roosting and nesting areas for the NSOs, similar to set-asides, but they will be no-take such that a sufficient amount of foraging habitat will be maintained around the core area to ensure its continued high occupancy and fecundity. Furthermore, given the dynamic nature of high quality habitat throughout the life of this FHCP, they will be adaptive in that some or all may ultimately be moved to riparian and geologic areas once these areas have been selected for occupancy by NSOs, and they have demonstrated over time that they will function as productive NSO sites within the managed landscape.

5.3.1.4.1 Selection and Designation of DCAs

Green Diamond concludes the best strategy for maintaining NSO sites is letting NSOs choose the core areas and demonstrate the potential of the site through established targets for occupancy and fecundity. This allows NSO pairs, not biologists as was done with set-asides, to choose the sites. These sites are dynamic through time because they will move in response to changes in the landscape and the NSOs' selection of suitable core areas. Green Diamond projects that by the end of the Permit term an estimated 25% or more of the Plan Area will consist of older forest stands (average age = 94 years) with late seral habitat elements in riparian and geological areas, which are likely to result in stable roosting and nesting core areas that will contribute to high habitat fitness as defined by Green Diamond's habitat model for the NSO (Section 5.3.1.1).

Upon issuance of the ITP, Green Diamond will immediately designate and protect 44 DCAs in the Plan Area. Green Diamond selected the initial DCAs by first evaluating all sites within the Plan Area during the course of study (1990-2015) (Appendix G contains a list of NSO sites not proposed as DCAs). The criteria included selecting the most functional sites in terms of high occupancy and fecundity while considering extenuating factors related to maintaining a good spatial distribution and considering barred owl influences on NSO site occupancy (Diller et al., 2016). As a consequence, some sites not occupied in recent years, but demonstrated high occupancy and fecundity during the early years of the NSO HCP warranted inclusion, because these sites have clearly been negatively affected by barred owls in recent years. Green Diamond expects that these sites will return to high productivity as soon as this negative effect of interspecies competition with the barred owl has been eliminated. Some other sites with more moderate productivity were selected over more productive sites, because they fulfilled spatial objectives where no other potential DCAs were available. To determine the minimum core roosting and nesting area for DCAs, in conjunction with the 10-Year Review (Appendix C) of the NSO HCP, we calculated the area used for nest site locations from 1990 through 2007 (see Section 4.3.1 for explanation for cutoff date for study). Using NSO sites with at least three nest-years, we calculated the area occupied by all nests using a 95% adaptive kernel estimator (Kie et al., 1996). Green Diamond used the 80th percentile as the cutoff to describe core area size around nest sites, because this captured all the sites where birds exhibited typical site fidelity and eliminated the "outliers" where birds made dramatic uncharacteristic shifts in nests sites. The 80th percentile nest core area for 94 NSO territories was estimated as 76 acres. We compared this to any recommendations from the scientific literature on the appropriate core area for NSOs. The Interagency Scientific Committee (ISC) (Thomas et al., 1990), which was tasked to develop a conservation strategy for the NSO concluded that at least 80 acres of suitable nesting owl habitat should be retained around the activity centers of all known pairs of owls in the managed forests. The 80 acres was not based on any modeling projections, but direct empirical observations of numerous examples of this phenomenon throughout the range of the NSO. Thomas et al., (1990) noted that NSO occupied old-growth patches in younger stands that resulted from fires, severe windstorms, and even inefficient logging practices in past years, which provided evidence that an 80 acre core was sufficient to provide for the nesting and roosting needs of NSOs. Furthermore, we considered that take of owl sites in DCAs will not be permitted (see paragraph below) and at least 89 acres of nesting habitat must be retained to avoid triggering a take assessment. Therefore, Green Diamond selected the larger more conservative area of 89 acres as the minimum core area size of DCAs unless it was not possible because the site lacked suitable nesting habitat to create a core area of this size. In addition to the core area that can be readily delineated and mapped, sufficient foraging habitat will also be maintained around each DCA to support a highly productive site. This foraging habitat will not be mapped as part of this FHCP, because it is highly dynamic and will fluctuate through time. However, the criteria to maintain sufficient foraging habitat will be considered and mapped as part of any THP that occurs within 0.5 miles of the DCA site.

Rationale for the DCA Strategy

The most definitive attempt to develop a conservation strategy for the NSO based on biology, conservation theory and extensive modeling was done by the Interagency Scientific Committee (ISC) (Thomas et al., 1990). After careful analysis, the ISC abandoned an existing, flawed system of one- to three-pair Spotted Owl Habitat Areas, in favor of protecting larger blocks of habitat, which they termed Habitat Conservation Areas). Their modeling simulations indicated that large blocks of habitat capable of supporting multiple pairs, and spaced closely enough to facilitate dispersal between blocks, was the most likely strategy to ensure a long-term viable population while allowing some flexibility for timber harvesting in what they termed the "matrix."

The ISC delineated and mapped a network of HCAs and, wherever possible, each HCA contained a minimum of 20 NSO pairs. The 20-pair criterion was based on models of population persistence and empirical studies of bird populations, which estimated that 60% of the NSO sites would be currently suitable and occupied by NSO (i.e., ≥12 suitable occupied sites per HCA). In general, mean occupancy increased with cluster size, percentage of suitable sites, and percentage of the landscape in HCAs. Beyond clusters of about size 20, however, changes in landscape percentage had little effect on mean occupancy. Juvenile NSOs typically disperse away from the natal area in relatively random fashion for distances up to approximately 90 miles. If the natal area is within a relatively large HCA, a successful dispersal event usually occurred within the natal cluster. With fewer suitable sites, or smaller clusters, dispersing juveniles may leave their natal cluster and enter the surrounding forest matrix, resulting in a lower likelihood of successful dispersal. As a consequence, marginal gains in mean occupancy were not constant with incremental increases in cluster size. Rather large improvements to occupancy resulted from increases in cluster size from 5 to 10; much smaller gains were realized in increases from 10 to 20 territories per cluster.

Both empirical and theoretical studies support the inference from the ISC that increasing NSO cluster size positively affects NSO population viability. Small populations quickly escape from the dangers of demographic stochasticity with even slight increases in population size (Goodman, 1987). Populations also gain security from environmental uncertainty with increasing numbers, but at a much slower rate than from demographic effects (Shaffer, 1987). A similar analysis to develop a reserve design for NSOs was done by Lamberson et al., (1994), with the same general conclusion as the ISC report.

The ISC strategy established 12 miles as the maximum edge-to-edge nearest neighbor distance between HCAs. This value was within the known dispersal distance of about two-thirds of all radio-marked juvenile NSOs studied. Where insufficient habitat was available to support 20-pair HCAs, the ISC delineated a network of smaller HCAs, but shortened the maximum distance between them to 7 miles to facilitate dispersal. Known dispersal distances of juvenile NSO within the Green Diamond study area averaged 6.8 miles (n=239, SE=0.43) and 87% of these dispersal events were within 12 miles.

The 2008 Final NSO Recovery Plan (USFWS, 2008a), revised in 2011, adopted in principle the ISC conservation strategy of strategically placed NSO clusters, referred to in that recovery plan as Managed Owl Conservation Areas (MOCAs). In response to peer review and public comment that the NSO conservation strategy should take a more ecosystem-based approach, the Service redesigned the MOCAs in the Revised 2011 Recovery Plan, and the physiographic provinces were adopted as the primary recovery units.

Although the initial ISC management strategy was not specifically adopted, and has been modified from its initial form in subsequent land management plans, the NSO cluster conservation strategy still exists, and is embedded in the Critical Habitat Rule for NSOs (USFWS, 2012a). The system of reserve areas under the Northwest Forest Plan was created in large part to achieve the ISC strategy and these reserves remain a substantial component of the critical habitat designation for NSOs.

Habitat differences between ISC and FHCP

In the ISC strategy and subsequently adopted versions of that strategy, clusters of NSOs were designated within landscapes that would be managed for late-successional forest conditions. These reserved landscapes were generally intended to gradually recover to conditions considered to be optimal for NSOs to persist, as they would gradually become an interconnected landscape of late-seral forest. Northern flying squirrels, the primary prey species for the NSO over much of its range, does best in well-connected forest stands dominated by late seral conditions. However, under the proposed FHCP, the DCAs are not included within a late-successional reserve network. Woodrats, the primary prey base in the Plan Area, do best within a landscape with a variety of seral stages, since their habitat needs are best met under conditions promoted by early and mid-seral forests. Hence, establishing a network of DCAs in the redwood region within a reserve system would not function optimally for NSOs, as a result of their primary prey gradually being eliminated under closed canopy forest. The DCA network established under this FCHP would protect highly functional nesting and roosting core areas within a landscape of early and mid-seral forest conditions with abundant woodrats.

Incorporation of a Cluster Strategy into Green Diamond's FHCP

The DCA strategy of this FHCP does not specifically mimic the reserve strategy of the ISC strategy or the NSO recovery plan. However, the biology behind the DCA strategy is consistent with the same fundamental conservation strategy for the NSO. The goal is to provide for occupied and highly functional NSO sites (i.e., high occupancy and fecundity) embedded in a matrix of base (non-DCA) NSO sites that will provide additional demographic and spatial support. The mean nearest neighbor distance measured from the centroid of the proposed DCAs is 1.8 miles; the maximum distance between the outer perimeters of two DCAs in the Klamath region is 6.7 miles (Map 5-1). This density of DCAs is consistent with distances anticipated to occur between occupied NSO sites within reserves under the ISC strategy. The spatial arrangement of the DCAs with the associated base NSO sites in the Korbel/Mad River area represent the equivalent of one large NSO cluster of 26 DCAs and over twice that many base NSO sites. (As of 2015, 166 active NSO sites were known to occur within the Plan Area and surrounding 0.5 mile buffer.) Based on the ISC strategy, an NSO cluster of this size will be strongly buffered from both demographic and environmental stochasticity.

To the north, a more linear arrangement of 16 DCAs and approximately twice that many base sites are distributed along the Redwood Creek and Lower Klamath River watersheds. Based on their prior history of occupancy, we expect all of these DCAs, plus many more base sites, to be occupied after implementation of the conservation strategy throughout the Plan Area. Hence, this area will also meet the numerical target for a fully functional NSO cluster. The linear distribution of these NSO sites could somewhat detract from its functionality, but NSO are known to be associated with the lower portions of watersheds, which will facilitate dispersal among NSO sites. Additional support for this relatively linear arrangement of DCAs is provided by multiple NSO sites that occur within the forests of the Hoopa Valley Indian Reservation.

The final two DCAs are in the Salmon Creek Tract, which in 2015 had nine additional occupied base NSO sites within the Plan Area, and five additional occupied sites within 0.5 mile of the Plan Area. Although this area has historically had a high proportion of functional NSO sites, it is not considered equivalent to an ISC-like NSO cluster. Its primary purpose is to provide demographic support, and contribute to successful dispersal, to adjacent lands administered by the Bureau of Land Management (Headwaters Forest) and Humboldt Redwood Company lands that are managed under an HCP that includes the NSO.

Adaptive Management Considerations to Augment DCAs if Needed

The adaptive management strategy in this FHCP provides for up to 1,068 acres of habitat to meet potential future needs for the NSO. If future monitoring should document that more DCAs or larger DCAs are needed to conserve the NSO, up to 1,068 additional acres of timberland could be allocated to new DCAs or to maintain additional nesting/roosting habitat around existing DCAs (Section 5.3.5).

These 1,068 acres potentially allocated under adaptive management to DCA augmentation represents a maximum of 12 DCAs. This value was set as the upper limit because, based on the ISC strategy, that is the number necessary for persistence of a single NSO cluster. The net effect of adding 12 DCAs would be to bolster the demographic support of the existing NSO conservation strategy. Designation of additional DCAs would occur only after the NSO population in the Plan Area showed evidence of a declining trend. This would mean that the number of occupied base sites would be declining, but the number of functional DCAs was constant. Adding additional DCAs in an area with a declining NSO population would provide demographic support along with maintaining the continuity among NSO sites so that the area would continue to function as an NSO cluster. For example, three to four additional DCAs might be added to an area of declining NSO population in the Redwood Creek or Klamath River basin where the loss in base sites resulted in reduced continuity in the total network of NSO sites.

No Take of DCAs

Because the goal of the DCA strategy is to maintain highly productive NSO sites, and take has been shown to negatively impact fecundity (Section 6.2.4), take will not be permitted at owl sites in DCAs. To avoid take of DCAs, sufficient habitat will be maintained in a 0.5-mile radius buffer around the owl site associated with the DCA (i.e. site within or immediately adjacent to the DCA boundary). Currently, this threshold includes a 89-acre core of nesting habitat (age >46) and a minimum of 144 acres of age class >31 (primarily foraging and roosting habitat) for a total of 233 acres. Some highly functional owl sites in DCAs currently lack 233 acres, which means no additional removal of suitable habitat is allowed in the 0.5 mile buffer until regrowth has resulted in >233 acres of foraging habitat. Furthermore, these thresholds may be improved or refined as part of the model validation process (Section 5.2.2.5). Alternatively, non-DCA NSO sites can be taken through timber harvest within 0.5 miles of the NSO site. If harvest does not reduce habitat below the thresholds described above, no take will be assessed. See Section 6.2.4.1 for further discussion.

Green Diamond calculated the biological value (mean annual fecundity) of DCAs in the same manner as was done for the set-asides in 1992 (Table 5-1). Relative to biological value, seven set-asides were considered to have high (≥0.3) mean fecundity with an overall average of 0.26, while 26 of the DCAs have high (≥0.3) mean fecundity and the 44 DCAs have slightly greater average fecundity than the set asides with an overall mean annual fecundity of 0.30. Another comparison of past biological value of set-asides versus the proposed DCAs is to note that the set-asides, collectively, were large enough to provide core areas for 61 pairs of NSOs (based on our estimates of density), but they produced an average of only 11.0 fledgling NSOs per year. In contrast, the 44 DCAs are designed to provide a core area for a single pair of NSOs, but these sites produced an average of 16.7 fledgling NSOs per year. This provides compelling evidence DCAs will likely provide much greater biological value than the set asides. In addition, relative to the riparian zones protected under the NSO HCP, the NSO habitat provided in this FHCP will include approximately 90,000 acres of riparian and geological zones much of which already is or will become high quality roosting and nesting habitat (Green Diamond, 1992).

As noted earlier, DCA selection criterion included well-distributed sites arrayed across the core of the ownership. The mean nearest neighbor distance measured from the centroid of DCAs was 1.8 miles with a maximum distance of 6.7 miles between the outer perimeters of two DCAs in the Klamath region (Map 5-1). NSO sites within a matrix of other selected sites that were < 2 miles apart were not selected to be DCAs. There are also substantial areas without DCAs (e.g., Maple Creek and Little River drainages), but these gaps could not be addressed at this time because there are no known NSO sites in these areas with demonstrated high occupancy and fecundity. DCAs could be designated in these areas in the future if qualified, productive NSO sites are established there and new DCAs are substituted for current DCAs in accordance with this FHCP. Green Diamond also did not designate DCAs in small isolated tracts, because it will be more difficult to minimize influences from barred owls in these areas isolated from the larger blocks of the Plan Area and greater amounts of edge to core area.

Although the most productive sites as defined above will be protected, Green Diamond will not protect all existing NSO sites from take. Some sites will be available for future harvest to provide Green Diamond with continued operational flexibility gained through harvest of mature timber stands. Some of these productive NSO sites in former set asides are already located in riparian and geological areas that will be retained when the adjacent stands are harvested. Green Diamond hypothesizes that many of these NSO sites in former set asides and other sites within and adjacent to RMZs and geologic zones will not be taken by future timber harvest (as described in Sections 6.2.4 and 6.2.5) and that NSO will continue to occupy and reproduce in these areas.

Although it is a goal of the NSO conservation strategy for DCAs to be dynamic to ensure a well distributed array of highly productive DCAs across the Plan Area, other factors such as extended periods of unfavorable weather for nesting may temporarily depress the NSO population and prevent the delineation of new DCAs. Regardless of unexpected declines in the NSO population, Green Diamond will maintain a minimum of 44 DCAs. As described previously, the initial mapped DCAs have a minimum no-harvest core area of 89 acres (mean area 85.9 acres) except in rare cases where the site lacked suitable nesting habitat to create a core area of this size and a total of 233 acres of habitat in a 0.5-mile radius centered on the owl site. In addition, to ensure well distributed foraging habitat, clearcut timber harvest immediately adjacent to a DCA (i.e., harvest unit boundary is in contact with the DCA boundary) will have the California FPR adjacency requirements doubled (i.e., six years or 10 feet, but not < 6 years) with other harvest units that are immediately adjacent to the DCA. These initial default DCA criteria are subject to revision if during the model validation and refinement process, site occupancy and/or fecundity can increase with modified conservation criteria.

Green Diamond will maintain a minimum of 44 DCAs within the Plan Area over the term of the Permit. The number of DCAs will not decrease below 44 within the Plan Area even if Green Diamond ownership adjustments cause a net reduction in the IPA of up to 15%, which is authorized without amendment under this FHCP (Section 1.4.7.2). Green Diamond may not sell land with a DCA and remove such land from the Plan Area unless it designates a replacement site that qualifies as a DCA located in the same or a neighboring OMU.

When Green Diamond adds lands to the Plan Area as described in 1.4.7, it will designate one additional DCA from within those added lands for every net increase of 8,000 acres added to the IPA. Because the IPA is 357,415 acres and the FHCP allows for a net acreage increase of up to 15 % of the IPA, the addition of Covered Lands to the Plan Area could result in the addition of up to a maximum of 6 DCAs within the adjustment limit of 15% (357,415*15% = 53,612 acres; 53,612/8,000 = 6). This rate is consistent with the existing ratio of DCAs within the IPA (357,415 acres/44 DCAs). For example, if Green Diamond acquires land and adds it to the Plan Area resulting in a net increase of 21,000 acres added to the IPA, Green Diamond would select from existing NSO sites within the expansion area that meet the DCA criteria and add two DCAs to the Plan Area. If information on occupancy and fecundity for NSO sites is deficient for the lands added to the Plan Area, following the enrollment of additional Covered Lands, Green Diamond will survey and monitor NSO sites on the Covered Lands for a minimum period of 4 years before designating new DCAs. This time period is required to gain information on NSO site occupancy and fecundity as described in 5.3.1.4.4. During this 4 year period, Green Diamond will not take (Section 6.2.4.1) any NSO sites on the added Covered Lands prior to designation of the DCAs. If there is not a sufficient number of NSO sites on the added Covered Lands that qualify for required designation as DCAs, Green Diamond will designate contingent DCAs on the added Covered Lands with concurrence from the Service. After designation of DCAs on the added Covered Lands, Green Diamond will apply procedures described in 6.2 for take of other NSO sites on the added Covered Lands. Contingent on the size and location of the added Covered Lands, Green Diamond may also designate a new NSO OMU for added Covered Lands or combine added Covered Lands into an existing OMU. These designations will also be made with concurrence by the Service. Although Green Diamond is not required to increase the number of DCAs when land acquisitions do not result in a net incremental increase in Covered Lands of at least 8,000 acres added to the IPA, Green

Diamond may choose to designate one or more DCAs on such added Covered Lands subject to criteria described in Section 5.3.1.4.4.

Table 5-1. Characteristics of 44 proposed Dynamic Core Areas (DCA) within Green Diamond's FHCP from 1992-2015.

DCA #	DCA Site Name	Acres	Starting Year of Occupancy	Year Last Occupied	First Ten Years (1992-2001)			All Years (1992-2015)			Last 10 Years (2006-2015)			Last 5 Years (2011-2015)		
					Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied
1	Hunter 500	78.2	2006	2015	ENA[a]	--	--	0.22	4	10	0.22	4	10	0.25	2	5
2	W302	87.4	1992	2015	0.39	7	9	0.30	12	22	0.07	1	10	0.00	0	5
3	W100	76.9	1992	2007	0.35	7	10	0.30	9	16	0.00	0	2	0.00	0	0
4	East Fork Hunter	56.0	2004	2015	ENA	--	--	0.39	7	12	0.29	4	10	0.20	2	5
5	T-Line	98.1	1992	2015	0.29	4	9	0.18	7	23	0.06	1	10	0.10	1	5
6	Ambrose	80.8	1993	2010	0.33	2	8	0.33	6	16	0.33	2	5	0.00	0	0
7	Notchkoo	72.3	1992	2009	0.3	3	7	0.23	5	15	0.00	0	4	0.00	0	0
8	Lower Roach	98.6	1992	2014	0.4	4	7	0.33	4	10	0.00	0	1	0.00	0	1
9	Morek Creek	107.7	1992	2015	0.38	3	10	0.33	4	18	0.50	1	6	0.00	0	4
10	Hancorne Ranch	90.4	2001	2012	0.5	1	1	0.30	3	9	0.00	0	5	0.00	0	2
11	WM400	105.5	1992	2013	0.17	2	10	0.25	7	22	0.40	4	8	0.00	0	3
12	WM200	79.6	1992	2005	0.43	6	8	0.32	7	12	0.00	0	0	0.00	0	0
13	Panther Bridge	81.1	1992	2015	0.29	4	10	0.14	4	22	0.00	0	8	0.00	0	5
14	Garrett Creek	76.5	1992	2012	0.25	2	10	0.17	4	22	0.00	0	8	0.00	0	2
15	Dolly Varden	118.2	1992	2006	0.39	7	10	0.29	7	15	0.00	0	1	0.00	0	0
16	Lower Dolf Creek	67.9	1999	2013	0.33	2	3	0.15	4	14	0.00	0	7	0.00	0	3
17	Jurin	91.2	1993	2015	0.31	5	9	0.18	7	22	0.11	2	10	0.20	2	5
18	Old 299 #1	81.3	1992	2015	0.35	7	10	0.19	9	24	0.10	2	10	0.00	0	5
19	Lupton Creek #1	92.7	1992	2015	0.5	9	10	0.31	10	23	0.08	1	9	0.00	0	5
20	Cal Barrel WO	81.7	1992	2015	0.44	7	10	0.30	12	24	0.06	1	10	0.00	0	5
21	SF Bald Mt.Creek	69.4	1992	2015	0.22	4	10	0.19	8	24	0.13	2	10	0.00	0	5
22	Camp Bauer	103.8	1992	2015	0.45	9	10	0.33	12	20	0.08	1	7	0.10	1	5
23	Fernwood	93.4	1992	2015	0.28	5	9	0.24	8	22	0.30	3	10	0.00	0	5

DCA #	DCA Site Name	Acres	Starting Year of Occupancy	Year Last Occupied	First Ten Years (1992-2001)			All Years (1992-2015)			Last 10 Years (2006-2015)			Last 5 Years (2011-2015)		
					Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied
24	Noisy Creek	129.7	1992	2011	0.50	4	7	0.54	13	17	0.75	6	6	0.00	0	1
25	4230 #1	76.0	1992	2015	0.06	1	9	0.32	14	23	0.56	10	10	0.30	3	5
26	Canyon Creek #1	73.5	1992	2015	0.44	8	10	0.50	20	24	0.50	7	10	0.30	3	5
27	4076	84.7	1992	2015	0.31	5	10	0.33	16	24	0.55	11	10	0.60	6	5
28	6007	78.5	1997	2015	ENA	--	1	0.50	9	14	0.44	7	10	0.38	3	5
29	Devil's Creek	97.0	1999	2015	0.67	4	3	0.47	15	17	0.33	6	10	0.20	2	5
30	Dry Creek	68.0	1992	2015	0.10	2	10	0.29	14	24	0.30	6	10	0.40	4	5
31	4851	65.9	1992	2013	0.25	5	10	0.18	7	23	0.00	0	9	0.00	0	4
32	6600	70.7	1992	2014	0.38	3	4	0.36	5	11	0.00	0	6	0.00	0	4
33	Noname Creek	77.6	1992	2012	0.38	5	10	0.36	5	21	0.00	0	7	0.00	0	3
34	Pardee South	71.5	2004	2015	ENA	--	0	0.31	5	11	0.31	5	9	0.25	2	5
35	Boulder Creek #3	104.1	1992	2010	0.00	0	10	0.13	4	16	0.67	4	3	0.00	0	0
36	Boulder Creek #2	78.9	1992	2015	0.33	6	10	0.31	11	22	0.17	2	8	0.10	1	5
37	Camp Gate North	76.6	1992	2014	0.83	15	10	0.54	15	21	0.00	0	7	0.00	0	4
38	Boulder Creek #5	96.9	1997	2015	0.50	2	4	0.43	6	12	0.00	0	6	0.00	0	4
39	Camp Gate South	72.4	1992	2015	0.25	5	10	0.29	11	24	0.20	2	10	0.50	2	5
40	Mt. Andy	95.7	1994	2015	0.00	0	5	0.25	5	15	0.38	3	6	0.50	1	2
41	North Goodman Prairie	130.3	1992	2015	0.29	4	10	0.27	6	22	0.50	2	8	1.00	2	5
42	Graham Creek	89.3	1992	2014	0.40	8	10	0.29	12	23	0.14	2	9	0.00	0	4
43	EBF	74.3	1992	2015	0.69	11	9	0.50	22	23	0.40	8	10	0.50	5	5
44	Salmon Creek #3	77.1	1992	2015	0.80	8	9	0.36	10	21	0.13	2	8	0.00	0	5

[a]ENA – Estimate Not Available because reproductive status was unknown or site was not occupied.

Landscape Management Commitment Three (Objective 1B): Green Diamond will establish an initial set of 44 DCAs in the IPA immediately upon issuance of the ITP (Table 5-1). Green Diamond designates 44 DCAs in the IPA and will maintain a minimum of 44 DCAs in the Plan Area throughout the term of this FHCP. Green Diamond selected the initial DCAs because of their demonstrated ability to provide high site occupancy and fecundity for NSOs and because they provide a good spatial distribution across the IPA.

5.3.1.4.2 The criteria applicable to all DCAs are as follows:

- DCAs are designed to provide a core nesting area for a single pair of NSOs with a minimum no-harvest core area of 89 acres of nesting/roosting habitat where **available.**
- NSO sites within DCAs will be managed to include within a 0.5-mile circular buffer (502 acres):
  - 89 acres of forest stands 46 years old and older, and
  - 233 acres of stands 31 years old and older
- Clearcut timber harvest immediately adjacent to a DCA (i.e., harvest unit boundary is in contact with the DCA boundary) must comply with adjacency requirements providing a biologically more conservative strategy. These requirements include adjacent stands being at least 6 years old or 10 feet tall, but not < 6 years with other harvest units that are also immediately adjacent to the DCA. This provision essentially doubles requirements of the current (2013) California Forest Practice Rules regarding age and tree regrowth in adjacent stands and by providing time for recolonization of woodrats, is designed to improve foraging habitat conditions in forest stands adjacent to DCAs. This provision does not change FPR for separation of units, or distances of separation, or size of individual harvest units. Should FPRs change during the term of this FHCP, adjacency requirements will be implemented as stated in this section (i.e., based on adaptation of FPRs in place upon signing), or future requirements of revised FPRs, whichever provides more biological conservation value to the covered species. The size of even-age management units, which can be no more than 20 acres for non-shovel yarded ground-based systems, 30 acres for aerial, cable or shovel yarding systems, and 40 acres when justified according to specified criteria (14 CCR 913.1[a][2]).
- The distance between even-age management units, which must be "separated by a logical logging unit that is at least as large as the area being harvested or 20 acres, whichever is less, and must be separated by at least 300 feet in all directions" (14 CCR 913.1[a][3]).
- The timing of the harvest of contiguous even-age management units, which cannot occur unless regenerating stand in a previously harvested, adjacent clearcut unit is at least 5 years of age or 5 feet tall, and three years of age from the time of establishment on the site (14 CCR 913[a][4][A]).

5.3.1.4.3 Transition from 1992 Set-Asides to DCAs

Upon FHCP approval, all set-aside areas defined in the NSO HCP (Green Diamond, 1992) that are not included in a newly designated DCA will be available for timber harvest (Table 5-2). However, Green Diamond will plan and implement harvesting of these former set-asides within the Plan Area to maximize the persistence of any existing NSO sites. Green Diamond will do this using a pattern of harvest unit layouts that will avoid the core nesting area until the final harvest unit(s) within that set-aside. Depending on the size of the former set-aside area, the actual displacement of an NSO site will not occur for 5 to 15 years following FHCP approval.

The importance of this lag in harvesting in or near NSO sites within former set-asides is that it will allow the NSO sites to be replaced with new DCAs that are projected to develop in the Plan Area, according to criteria described in Section 5.3.1.4.4, below).

Landscape Management Commitment Four (Objective 1B): Upon approval of this FHCP, timber harvesting within formerly designated set-asides in the Plan Area that are not designated as DCAs will be planned and implemented to delay take of any existing NSO sites within the former set-aside. Owl sites within formerly designated set-asides with a history of high rates of occupancy and/or reproduction (i.e., highly functional) have been included in the initial DCA network, and will be protected consistent with provisions for DCAs. Other owl sites within formerly designated set-asides not included in the initial DCA network may be subject to take, depending on their history of occupancy, and actual scheduling and location of future timber harvest. However, harvest units within these areas will be scheduled in a manner to delay take of NSO sites as long as possible within the constraints of the FPRs adjacency requirements. The harvest unit containing the current NSO site will be the last unit scheduled in the harvesting sequence. Any such taking will be accounted for, according to take accounting procedures described in Section 6.

5.3.1.4.4 DCA Monitoring, Spatial Distribution and Replacement

An important component of the NSO conservation strategy is a well-distributed array of protected nesting core areas, (DCAs) with high occupancy and good fecundity. However, it is also critical that the location of DCAs be dynamic, because they occur on a changing managed landscape. The purpose is to allow the location of DCAs to move through time to maintain their biological functionality while also providing flexibility in timber harvesting. As noted in Section 4.3.1, Plan Area-wide habitat fitness potential is projected to generally increase throughout the life of this FHCP, but at any given location, the quality of the habitat to support survival and fecundity of NSOs will fluctuate through time. The Lower Mad River Case Study provides direct support for the dynamic nature of habitat as projected by the habitat fitness model (Section 4.3.1). This means location of DCAs will move over time either because they are no longer functional (i.e., they no longer support high occupancy and fecundity) and there are other highly functional DCAs which can replace them, or because there are redundant functional DCAs within the same sub-basin.

Assuming the NSO population responds as the habitat models project, and as already demonstrated in portions of the Plan Area, over time Green Diamond will be able to delineate new DCAs to replace pre-existing DCAs. In order to maintain the biological value of the DCAs, Green Diamond will only replace DCAs when all the selection criteria are met.

Any DCA replacements must meet certain spacing criteria. Green Diamond's ownership has multiple Owl Management Units (OMUs) of 20,000 to 60,000 acres based on physiographic and/or biological factors. OMUs are large enough to potentially support 10 to 15 NSO sites (Table 5-3). Map 5-2 describes the location and boundaries of these OMUs.[6] To ensure a well-distributed array of DCAs without excessive clumping, a new DCA must replace a DCA in the same OMU or in the immediately adjacent OMU. Where possible, preference will be afforded to new DCAs that occur in the OMU that most closely borders the replaced DCA. . The location of

[6] OMU boundaries may be subject to modification in the future, with the concurrence of the Service, to account for future potential refinements in the habitat fitness model or modifications in how Green Diamond validates the habitat fitness model.

a new DCA should also mitigate the risk of concentrating multiple DCAs vulnerable to the same localized adverse impact, such as a wildfire.

A DCA may be replaced when it has declined below or otherwise does not meet the biological thresholds for a DCA (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25 averaged over the last four years). The biological thresholds for a DCA could be revised in the future as new methods will likely incorporate estimates of fecundity and occupancy into a single parameter estimate. Green Diamond will use accepted methods for occupancy analysis to develop a new and equivalent biological threshold for designation and replacement of DCAs. As previously stated, the strategy for DCAs is to maintain the most productive NSO sites as DCAs across the Plan Area. In order for a site to be productive, it must first be occupied by a pair of NSO and that pair of NSO must successfully nest and fledge young. Therefore, upon review and approval of the Service, a single parameter estimate that incorporates both occupancy and reproductive success could be the future measure of DCA function. The determination whether to replace the DCA will be based on an assessment of the potential causes of the decline in biological function of the NSO site. If the decline is likely the result of a stochastic or transitory factor (i.e., turnover at the site where a previously resident NSO is replaced by a new NSO), but the habitat fitness and occupancy models indicate the site should be biologically valuable, the site will not automatically be a candidate for replacement. Regardless of the replacement justification, a replacement DCA must be located within the same or adjacent OMU, and must either meet the DCA biological thresholds described above or at least have a substantially higher (approximately 25%) mean annual occupancy and mean fecundity than the DCA to be replaced.

Green Diamond may also replace a DCA for economic reasons or to meet other Green Diamond objectives, so long as the replacement DCA is located within the same or adjacent OMU, and the replacement DCA either meets the biological threshold criteria (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25 averaged over the last four years) or has a substantially higher (approximately 25%) mean annual occupancy and mean fecundity.

Green Diamond will not replace any DCAs for at least 5 years after the Conservation Program has been in effect. This is because barred owls play a role in both the occupancy and reproductive productivity of NSOs (Diller et al., 2016) and it may take five years to allow NSO to select sites strictly on habitat quality. Knowing the annual status of existing and potentially new DCAs will be important. Green Diamond will survey DCAs annually using a protocol that achieves an overall 95% probability of detecting NSOs if they are present (Appendix H).

Green Diamond will monitor all NSO sites in current DCAs throughout the life of this FHCP. However, following model validation, survey requirements will be relaxed and all potential new DCA sites will not be known. Although not required under the conservation strategy of this FHCP, it will be in Green Diamond's best interest to survey for potential new DCAs that will provide for flexibility in exchanging DCAs. However, in the unlikely event that no potential replacement DCAs are known and the demographic performance (occupancy and fecundity) of a DCA declines below the threshold for establishing new DCAs (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25 averaged over the last four years), surveys to locate a replacement DCA will be required. The habitat fitness or multi-state occupancy model (Section 5.3.5.1.2) could be used to locate at least three owl sites in the same or adjacent OMU with the highest habitat potential. These sites will receive annual site visits to determine occupancy and reproductive success to determine which would provide a suitable replacement DCA for the underperforming DCA.

Table 5-2. Schedule of Set Asides and NSO sites that have occupied these areas (1992-2015).

Set Aside Name	Acres	Site Name	Mean Fecundity	Total Fledglings	Years Occupied	Year Last Occupied	FHCP Site Status
4076	297.1	4076	0.36	16	22	2015	DCA
		4128	0.10	1	7	2015	Base_1[b]
		4300	0.00	0	6	2015	Base_1
4230	77.0	4230#1	0.32	14	23	2015	DCA
4850	875.9	4850	0.41	9	11	2002	Base_2[c]
		4851	0.18	7	23	2014	DCA
		6600	0.42	5	10	2014	DCA
		Bear Creek	0.17	1	3	2002	Base_1
		Maple Creek #1	0.31	5	19	2015	Base_1
		Maple Creek #2	0.00	0	2	1994	Base_1
5700	76.2	5700	0.13	6	23	2015	Base_1
6007	193.8	6007	0.50	9	14	2015	DCA
Bald Mt. Creek	61.2	Bald Mt. Creek	0.20	4	10	2002	Base_2
Black Dog Creek	167.7	Lower Dry Creek	0.27	6	13	2015	Base_1
Blue Creek Cabin	498.8	Blue Creek Cabin	0.14	3	14	2006	DCA
Boulder Creek	1987.8	Boulder Creek #1	0.21	3	8	2015	Base_1

Table 5-2. Schedule of Set Asides and NSO sites that have occupied these areas (1992-2015).

Set Aside Name	Acres	Site Name	Mean Fecundity	Total Fledglings	Years Occupied	Year Last Occupied	FHCP Site Status
		Boulder Creek #2	0.31	11	22	2015	DCA
		Boulder Creek #3	0.13	4	16	2010	DCA
		Boulder Creek #4	0.00	0	3	2013	Base_2
		Boulder Creek #5	0.60	6	11	2015	DCA
		Camp Gate	0.00	0	5	2015	Base_1
		Camp Gate North	0.55	11	12	2012	DCA
		Camp Gate South	0.25	8	18	2011	DCA
Bug Creek	371.5	None	ENA[a]	---	0	---	---
Cal Barrel	192.5	Cal Barrel	0.10	2	11	2009	Base_1
Camp Bauer	241.1	Camp Bauer	0.33	12	20	2015	DCA
		Jiggs Creek	0.21	5	13	2006	Base_2
Canyon Creek	188.3	Canyon Creek #1	0.29	7	14	2015	DCA
Devil's Creek	113.3	Devil's Creek	0.00	0	1	1999	DCA
Dolly Varden	374.2	Dolly Varden	0.25	2	5	2006	DCA
EBF	111.6	EBF	0.50	22	23	2015	DCA
Fawn Prairie	242.3	None	ENA	---	0	---	---

Table 5-2. Schedule of Set Asides and NSO sites that have occupied these areas (1992-2015).

Set Aside Name	Acres	Site Name	Mean Fecundity	Total Fledglings	Years Occupied	Year Last Occupied	FHCP Site Status
H131	166.9	H131	0.00	0	1	1993	Base_1
Humbug Creek	162.6	Humbug Creek	0.33	8	19	2014	Peripheral
Johnson Creek	125.2	None	ENA	---	0	---	---
Little Deer Creek	680.8	Deer Creek	0.50	3	6	1997	Peripheral
		Little Deer Creek	0.29	4	12	2013	Peripheral
Lower Tully Creek	376.1	None	ENA	---	0	---	---
Lupton Creek	249.0	Lupton Creek #1	0.31	10	21	2015	DCA
		Lupton Creek #2	0.25	1	7	2009	Base_1
		Lupton Creek #3	0.00	0	11	2014	Base_2
McCloud Creek	174.9	None	ENA	---	0	---	---
Mettah Creek	176.3	None	ENA	---	0	---	---
Morek Creek	1002.7	None	ENA	---	0	---	---
Mule Creek	853.1	Denman Creek	ENA	---	1	2002	Base_2
		Mule Creek	0.07	1	13	2015	Base_1
No Name Creek	735.2	7000	0.24	8	21	2015	Base_1
		Noname Creek	0.50	4	10	2012	DCA

Table 5-2. Schedule of Set Asides and NSO sites that have occupied these areas (1992-2015).

Set Aside Name	Acres	Site Name	Mean Fecundity	Total Fledglings	Years Occupied	Year Last Occupied	FHCP Site Status
		Upper Noname Creek	0.00	0	6	2003	Base_1
Old 299	172.1	Old 299 #1	0.19	9	24	2015	DCA
Poverty Creek	363.9	Poverty Creek	0.22	7	18	2015	Base_1
Puter Creek	127.8	Quarry Creek	0.21	6	17	2015	Base_2
Redwood Creek	181.1	Dick Bird	0.25	1	3	2007	Base_1
Roddiscraft/Powerline	312.3	Powerline North	1.00	2	1	2009	Base_1
		Roddiscraft Powerline	0.00	0	1	2011	Base_1
		Snow Camp Creek	0.50	2	2	1995	Base_2
Salmon Creek	218.0	Salmon Creek #3	0.20	4	14	2015	DCA
		Salmon Creek #5	0.00	0	2	2012	Base_1
SF Bald Mt.	130.0	SF Bald Mt. Creek	0.18	7	22	2015	DCA
T300	71.8	T300	0.00	0	9	2012	Base_1
Upper Tully Creek	239.5	Upper Tulley Creek	0.50	2	4	1996	Base_2
Walsh	148.2	Middle Salmon Creek	0.30	3	5	2015	Base_1
		Walsh	0.18	4	11	2015	Base_1
Williams Ridge	261.8	Williams Ridge	ENA	---	1	1995	Base_2

Table 5-2. Schedule of Set Asides and NSO sites that have occupied these areas (1992-2015).

Set Aside Name	Acres	Site Name	Mean Fecundity	Total Fledglings	Years Occupied	Year Last Occupied	FHCP Site Status
Wiregrass	229.0	None	ENA	---	0	---	---

[a]ENA – Estimate Not Available because reproductive status was unknown or no site occurs within set aside.

[b]Base_1 indicates active NSO sites that will occur outside DCAs after implementation of this FHCP.

[c]Base_2 indicates vacant (unoccupied for 3 consecutive years) NSO sites occurring outside DCAs after implementation of this FHCP.

Note: Estimates of mean fecundity are derived from site-years when reproductive data was determined based on protocol surveys and NSO were located within the boundaries of set asides. FHCP site status code refers to the resultant management of the site after implementation of the plan.

Table 5-3. OMUs used to evaluate active NSO sites within geographical areas of somewhat similar habitat composition and management history.

OMU #	OMU Name	OMU Acres	# Active NSO sites	#DCAs
1	Smith River	27,543	3	0
2	Wilson, Hunter, Terwer Creeks	44,171	11	5
3	McGarvey, Ah Pah, Surpur Creeks	30,281	0	0
4	Tectah, Mettah, Roach, Tully Creeks	55,668	9	7
5	Maple Creek	40,004	4	0
6	Redwood Creek	27,835	9	8
7	Little River	34,534	2	0
8	North Fork Mad River	26,467	11	6
9	Lower Mad River, Jacoby Creek	24,915	31	8
10	Upper Mad River, - Upper Redwood Creek	22,848	17	8
11	Humboldt Bay, Eel River	24,085	23	2

Note: The OMUs serve as the basis for maintaining an appropriate spatial distribution of DCAs and grouped into three regions, a basis for model validation. For purposes of habitat model validation within the Plan Area, OMUs were combined within three regions. The north region combines OMUs 1 through 4, a central region combines OMUs 5-8 and a southern region combines OMUs 9 through 11.

Landscape Management Commitment Five (Objective 1B): Monitoring, spatial distribution, replacement, and addition of DCAs will be governed by the following set of rules:

- Green Diamond can delineate new DCAs to replace existing DCAs, but a replacement DCA must be in the same NSO OMU, or if the DCA is near the border of an OMU, the OMU immediately adjacent.
- Green Diamond will evaluate DCAs for potential replacement if there is reduced biological functionality. A replacement may be warranted, if the new DCA meets or exceeds the DCA functional criteria (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25, averaged over the last four years) or has a substantially higher (approximately 25%) occupancy and fecundity relative to the DCA to be replaced.
- Green Diamond may replace a DCA for economic reasons or to meet other company business objectives if the new DCA meets the DCA functional criteria or has substantially higher (approximately 25%) occupancy and fecundity relative to the replaced DCA with no extenuating circumstances.

- Green Diamond will not replace DCAs for at least five years after the Plan Area-wide barred owl experiment has gone into effect.
- Green Diamond will survey DCAs annually using a protocol designed to achieve an overall 95% probability of detecting NSOs if they are present.
- Green Diamond will designate one additional DCA for each incremental net increase in the Plan Area of 8,000 acres added to the IPA. Each additional DCA will be located within the scope of the added Covered Lands and will either meet the criteria for a DCA or be designated as a contingent DCA with the concurrence of the Service.

In the past, commercial thinning and unevenaged silviculture under California FPRs was a minor component of Green Diamond's silvicultural treatments. Accordingly, these practices were not evaluated for effects on habitat for Covered Species in the Plan Area. Accordingly, 'silviculture' will be included as a covariate in analyses of site occupancy for NSO and fisher, or an analysis of fecundity, or lambda for NSO. If the 'silviculture' covariate enters any of the top competitive models for any of these analyses, Green Diamond will initiate studies to assess the habitat value of stands generated from other silvicultural prescriptions (Section 5.3.6).

Landscape Management Commitment Six (Objective 1A, 1D): Green Diamond will include 'silviculture' as a covariate in analyses of site occupancy for NSOs and fisher, or an analysis of fecundity, or lambda for NSOs.

- If the 'silviculture' covariate enters any of the top competitive models for any of these analyses, Green Diamond will initiate studies to assess the habitat value of stands generated from silvicultural prescriptions other than regeneration harvest.
- If research indicates that silvicultural prescriptions resulting in retention of important habitat conditions, such as moderate to high canopy closure, multi-layered stands, or understory conditions more favorable to Covered Species, Green Diamond will consider adaptive management options (Section 5.3.6) to implement these silvicultural practices to improve conservation of those species.

5.3.2 Retain and Recruit Targeted Habitat Elements

When planning timber harvests, Green Diamond will include measures providing long-term retention and recruitment of late seral habitat elements beneficial to NSOs, fisher and tree voles. In addition to retention associated with riparian areas (Section 5.3.1.3), the primary mechanism for retaining and recruiting late seral structure includes group and individual tree retention in harvest units in conjunction with the TREE plan described below.

The basis for TREE guidelines are standards initially developed under Green Diamond's NSO HCP (Green Diamond, 1992). Although Green Diamond initially created these retention guidelines specifically to accelerate future NSO habitat development, these same wildlife trees will likely provide most of the future late seral wildlife structure. In 2005, Green Diamond provided additional guidance on tree retention within its ownership in the Terrestrial Dead Wood Management Plan (Green Diamond, 2005). The goal of the document was to provide additional clarification and guidance on types, amounts and placement of green and dead tree retention at various spatial scales. With modifications and augmentations to address the needs of all the Covered Species, this original document served as the foundation for the new TREE document, which is the guide for tree retention under this FHCP (Appendix E).

The amount of tree retention within harvest units will be guided by retention required for riparian and geological areas (Section 5.3.1.3). When a unit lacks riparian or geological retention, Green Diamond's terrestrial retention will include a minimum of a one-half acre or larger HRA or smaller groups of trees (clumps) or scattered trees equivalent to the per acre retention requirement specified in the TREE. Green Diamond will retain trees with larger diameters and the highest quality existing structure first, followed by lower biological quality trees. Special consideration for retention is also given to specific conifer and hardwood trees that possess existing structure such as den or nest cavities. In harvest units, where they exist, evergreen hardwoods will be marked for retention at a level of two trees per acre of even-age harvest.

In areas dominated by evergreen hardwood species, Green Diamond will orient retention toward these species with emphasis placed on larger trees within the stand. Regardless of the amount of riparian or geological retention, at least two evergreen hardwoods will be retained per acre throughout the unit as scattered trees. If the harvest area is lacking in riparian or geological retention, an HRA of at least one-half acre will be designated in addition to the scattered retention of hardwood trees and other conifer trees with high value to wildlife. If suitable areas for HRA designation do not exist, the equivalent area in tree clumps is permissible. Green Diamond will emphasize retaining the larger trees with existing structure, but in the absence of this habitat element, the largest hardwoods should be retained for future habitat. The scattered retention focuses on providing dispersed den and rest tree opportunities for non-volant species like fisher. The scattered retention could provide future nesting opportunities for NSOs, but this species is more capable of accessing clumped retention within the managed landscape. The combination of clumped and scattered retention is likely to benefit a variety of species.

Green Diamond's goal is to make a concerted effort to retain all snags (defined as a standing dead or mostly dead tree) unless they constitute a clear safety or fire hazard. Certain wildlife species have a strong connection with downed Coarse Woody Debris (CWD), but studies to date on Green Diamond's ownership have shown little direct association between any wildlife species and CWD. The only exception is that fisher show a weak association with areas having a higher density of fir logs (Klug, 1997). There are no amphibian species in this area closely tied to CWD and unlike studies in other parts of its range; NSOs within Green Diamond's ownership do not show an association with CWD. In spite of this, Green Diamond believes CWD plays an important role in nutrient cycling and overall structural diversity of stands, and may have important indirect benefits to a variety of species.

Green Diamond's general policy is retaining all non-merchantable CWD within stands. Future CWD recruitment will result directly from natural tree mortality (stem exclusion, disease, animal damage, etc.) within developing stands as well as the retention of existing snags and green wildlife trees. Since they do not likely provide critical wildlife habitat, Green Diamond may remove merchantable redwood logs without internal rot outside watercourses. Broadcast burning occasionally results in the loss of CWD, but Green Diamond strives for low intensity burns only consuming smaller (<2 inches diameter) material. For the same reasons, Green Diamond considers trees and snags with large hollows critical conservation elements on the managed landscape, large woody debris with hollows or large cavities generally have relatively greater value to wildlife compared to pieces without cavities or with small cavities.

Green Diamond will monitor and report the amount of pre- and post-harvest tree and snag retention in annual reports to the Service. During harvest unit layout, foresters will document the number of green trees planned for retention and estimate the number of snags per acre. After harvest and any slash burning activities, the units will be visited to estimate the quantity of post-harvest green trees and snags. Green Diamond will store this information in a database for future analyses and reporting of compliance under this FHCP.

Habitat Element Retention Commitment One: Green Diamond shall implement the TREE Guidelines for Green (Live) Tree and Snag Retention (Objective 2A)

A. Candidate Tree Selection:

- Retain large defective trees using the TREE's tree retention scorecard
- Retain defective or poorly formed trees, e.g., animal damaged, forked top, broken top, mistletoe broom, etc.
- Retain a mix of conifers and hardwoods (approximately 50/50 mix where possible
- Retain conifer species preference: Douglas-fir, hemlock, white fir, cedar, spruce, redwood
- Retain hardwood species preference: tanoak, Pacific madrone, California laurel, chinquapin
- Consider protection from wind throw and site preparation burning when designating HRA and tree clump locations
- Retain trees with the average diameter equal to or greater than the average diameter of trees in the THP area

B. Retention Guidelines – Evaluate the method and level of tree retention needed within each THP unit as follows:

- Conifer Dominated Harvest Areas[7] with RMZ Retention:

  - Retain all scorecard trees ≥7
  - Retain other evergreen hardwoods at a rate of two trees per clearcut acre where they exist

- Conifer Dominated Harvest Areas without RMZ Retention:

  - Retain all scorecard trees ≥7
  - Retain other conifer at a minimum rate of one tree per clearcut acre.
  - Retain other qualifying evergreen hardwoods at a rate of two trees per clearcut acre where they exist. If the unit lacks hardwoods to meet minimum retention standards, retain an additional conifer up to two trees per acre if harvest unit is in a one or two tree per clearcut acre retention area.
  - Retention should be a combination of approaches (HRA, tree clumps or scattered trees). HRAs are typically prescribed in cable yarding areas since this type of clumped retention is more practical in these areas. Trees retained in Streamside Management Zones (SMZs) and Class III Tier B areas count toward overall tree retention.

- Hardwood Dominated Harvest Areas[8] with RMZ Retention:

[7] Forest stands with >15,000 board feet of conifer per acre.
[8] Forest stands with <15,000 board feet conifer per acre and dominated by hardwood stems.

- Retention in all hardwood dominated areas is at least two trees per clearcut acre regardless of the watershed
- Retain all scorecard trees ≥7
- Retain scattered or clumped evergreen hardwood trees at a rate of two trees per clearcut acre and also retain conifer trees scoring ≥7

- Hardwood Dominated Harvest Areas without RMZ Retention:

  - Retain all scorecard trees ≥7
  - Retain ½ acre HRA or clumps totaling 0.5 acres and scattered evergreen hardwood trees at a rate of two trees per clearcut acre

C. Relationship with Snag and RMZ Retention – Live tree retention is in addition to snag and RMZ retention. Green trees retained as described in these retention guidelines will augment structure provided by snag retention and within AHCP areas, i.e., Green Diamond will not include retained snags and trees left within RMZs as part of the count for Wildlife Tree Retention.

D. Live Tree Retention Scoring Criteria Used for Identification of Existing Wildlife Habitat Elements (Appendix E, TREE for definitions):

- Dbh – Conifers ≥30 inches and Hardwoods ≥18 inches (3 points)
- Bole features:

  - Trees with an internal hollow or large cavity (4 points)
  - Trees with a small cavity, internal rot or mistletoe broom (2 points)
  - Trees with crevice cover, i.e., loose or deeply furrowed bark (1 point)

- Crown features – Trees with complex crown, lateral large limbs, epicormic branching (1 point)
- Vole nest factor – Tree containing an active or remnant tree vole nest having canopy connectivity with existing RMZ/Geological retention (2 points) and all others (1 point)
- Unit scarcity factor, i.e., post-harvest density of late seral habitat elements, <1 acre (2 points), >1/acre but <2/acre (1 point), >2/acre (0 points)
- Watershed scarcity factor, i.e., planning watershed factor is determined programmatically and is added to the total score, impaired or special wildlife value (1 point), all others (0 points)

5.3.3 Protection of Individuals of the Covered Species

Consistent with the criteria for approval of a habitat conservation plan under ESA Section 10, the Operating Conservation Program of this FHCP incorporates measures to avoid and minimize the risk of taking Covered Species as well as measures to mitigate incidental take. This describes measures that Green Diamond will implement to avoid and minimize the risk of take.

5.3.3.1 Northern Spotted Owl

Because NSOs are a federally-listed species, the specific objective is to ensure all NSOs attempting to nest can do so without being harmed or harassed by timber harvest. Green

Diamond will accomplish this objective by conducting pre-harvest NSO surveys in all harvest units planned for timber harvest during the period when NSOs may be incubating eggs, brooding nestlings or caring for recently fledged juveniles (21 February through 31 August) or at some time after this date as determined by a qualified biologist. Green Diamond will survey timber harvest plans according to its NSO protocol (see Appendix F for survey protocol).

Covered Species Protection Commitment One (Objective 3A): According to the NSO survey protocol (Appendix F), Green Diamond will conduct pre-harvest NSO surveys in all harvest units planned for timber harvest during the period when NSOs may be incubating eggs, brooding nestlings or caring for recently fledged juveniles (21 February through 31 August) and will avoid timber harvest in that unit during that period if breeding NSOs are detected, and activities have the potential to harm, kill or injure NSOs.

5.3.3.2 Fisher

Given that surveys to locate fisher den sites are impractical (i.e., den sites can only be reliably found using radio telemetry), Green Diamond will not use seasonal surveys or timber falling restrictions for fisher. Green Diamond's telemetry studies indicate fisher are sensitive to human activity and typically flee areas when humans approach on foot. Therefore, it is very unlikely Green Diamond will fell occupied natal or maternal den trees even if harvest occurs during fisher denning season (first of March through end of May). Fisher data collected by Green Diamond and from nearby Hoopa Reservation indicate fisher only den in cavities in relatively large conifers or hardwoods. Green Diamond will target these trees for retention based on its habitat element retention plan (TREE) described in Section 5.3.2. In addition, if fisher monitoring reveals an occupied den, Green Diamond will protect the site with a 0.25-mile radius no-harvest buffer until it determines the fisher abandoned the den or the kits have been moved to a different den tree more than 0.25 miles from the harvest area. The confirmed den tree will be retained even after the den is no longer in active use.

Green Diamond also documented fisher deaths at abandoned or unmaintained water tanks. Apparently, fishers are highly inquisitive and will jump into water tanks with an unrestricted opening, resulting in drowning or entrapment. This FHCP mandates, that Green Diamond maintain and fisher proof water tanks with permanent structures sealing tanks from inadvertent fisher entry. Included in the first annual report will be a catalog and map of all current and abandoned water tanks within the Plan Area and documentation that each structure has been checked at least once a year to ensure that it is secured against potential entry by fishers.

Although the fisher is relatively scarce throughout its range, the Plan Area population is relatively abundant and may serve as a source population for reintroducing and recovering fisher in other areas where suitable habitat is available. In 2010, Green Diamond cooperated with and assisted the California Department of Fish and Game (now California Department of Fish and Wildlife, CDFW), the Service, and Sierra Pacific Industries (SPI) in capturing fisher on Green Diamond property. Captured fisher were relocated to available habitat in the Stirling Management Area, a 160,000-acre tract of timberland in northern California that is owned by SPI. Under a Candidate Conservation Agreement with Assurances (CCAA) between SPI and the Service (Enhancement of Survival Permit [TE 166855-0], SPI received regulatory assurances for reintroducing fisher into key habitat areas without unacceptable SPI risk for unlawful timber harvest should the fisher be listed under the ESA. The capture and handling of fisher was also authorized by the CDFW.

Although professional biologists perform the capture, handling and relocation of fisher in accordance with safeguards designed to minimize stress or injury to the animal, the potential remains that take will result due to stress, injury or even death. Because a healthy fisher population will likely persist, the Plan Area could again serve as a source population for fisher capture and reintroduction/relocation in other portions of its range during this FHCP term. Fisher capture and relocation is not an essential management activity that could result in incidental take and for which Green Diamond is in need of regulatory assurances. However, for purposes of fisher conservation and recovery, Green Diamond is willing to cooperate with and provide technical assistance to the Service, CDFW, and the owners or managers of habitat proposed for fisher reintroduction, provided that the capture and relocation of fisher from the Plan Area will not compromise the fisher occupancy and population objectives of this FHCP.

Covered Species Protection Commitment Two (Objective 3B): If fisher monitoring (Section 5.3.5.2) or other activities reveal an active den, the site will be protected with a 0.25-mile radius no-harvest buffer until it has been determined that the den has been abandoned or the fisher kits have been moved to another den tree more than 0.25 miles from the harvest area. Any confirmed den trees will be retained.

Covered Species Protection Commitment Three (Objective 3B): Green Diamond will ensure all water tanks and pipes used for timberland management in the Plan Area are fisher-proofed to prevent entrapment and/or drowning. Green Diamond will ensure that any such facility or structure found to not be secured in the future will be repaired, retrofitted, or replaced in a timely manner to ensure its inaccessibility to fishers. Included in the first annual report will be a catalog and map of all current and abandoned water tanks within the Plan Area and documentation that each structure has been checked at least once a year to ensure that it is secured against potential entry by fishers.

Covered Species Protection Commitment Four (Objective 3B): Green Diamond will cooperate in any Service- and CDFW-approved fisher capture and relocation/ reintroduction recovery project, following guidelines for fisher protection during the capture and relocation process and provided that removal of individual fisher does not compromise the fisher occupancy and population objectives of this FHCP.

5.3.3.3 Tree Voles

Tree voles are inherently difficult to survey for, and the most effective approach to determine if a potential tree vole nest is occupied is to climb the tree and search the structure. The act of searching may cause some damage to the nest and prompt the inhabitant to flush from the nest. This is not a feasible survey approach to apply to management of Covered Activities over hundreds of thousands of acres. Further, given the stochastic nature of tree vole nests and the susceptibility of tree voles to predation by at least seven avian and mammalian predators, Green Diamond does not propose to actively identify and protect potential or occupied tree vole nests during harvesting activities. The one exception is the RMZs and geological areas where individual inspection and marking of harvest trees is required, but even in these limited areas, it is not feasible to identify all vole nests to completely avoid take of voles. However, the best potential nest trees are the largest trees with structural deformities and cavities. Green Diamond will protect these trees as part of the targeted protection under TREE (Section 5.3.2) in all portions of harvest units. In addition, Green Diamond will protect a large percentage of tree vole nests through requisite riparian, geologic or other terrestrial retention during the timber harvest planning process (Section 5.3.1). These areas will serve as population sources for recolonization of harvest areas as adjacent stands develop sufficient age and structure suitable for vole habitat.

Covered Species Protection Commitment Five (Objective 3C): When, in limited circumstances, Green Diamond conducts partial harvesting activities within RMZs and geological areas, it will avoid felling trees containing tree vole nest(s). Foresters will inspect potential harvest trees before marking to avoid felling trees with active or remnant vole nests.

5.3.3.4 All Covered Species

Public and private timberlands in and around the Plan Area have experienced an epidemic of unauthorized entry and use for cultivation of marijuana crops. Excessive and unlawful use of pesticides and, in particular, rodenticide, is associated with many grow sites where woodrats and other fauna may feed on marijuana crops. Pesticides are ingested by woodrats and other fauna such that these poisons enter the food chain where they may persist and be indirectly consumed by Covered Species such as NSO and fisher. Recent research has confirmed the presence of rodenticides in the livers of deceased NSO, barred owls, and fishers (Gabriel et al., 2012). Harm to NSO and fisher may be prevented by discouraging, detecting, and removing unauthorized marijuana cultivation and associated pesticide use in the Plan Area.

Covered Species Protection Commitment Six (Objective 3D): To discourage and prevent unauthorized marijuana cultivation and associated abuse of pesticides in the Plan Area, Green Diamond will maintain a system of controlled access for the Plan Area using locked gates on roads, security patrols, and written permits for authorized use of the Plan Area. To detect and remove unauthorized activities, Green Diamond will maintain security patrols for the Plan Area, conduct at least one annual aerial surveillance for marijuana cultivation hot spots where Covered Species are likely to be exposed to pesticide use in the Plan Area, and provide annual safety training for field employees on detection and reporting of suspicious and unauthorized use of the Plan Area. When unauthorized marijuana cultivation and/or pesticide abuse is detected by Green Diamond, it will be reported to local law enforcement. If Green Diamond finds evidence of pesticide abuse that may take Covered Species, it will report the circumstances to the Service for investigation and possible prosecution.

5.3.4 Barred Owl Research

During the early development of this FHCP, there was growing evidence throughout the species range that NSO populations were potentially suffering negative impacts from the invasion and dramatic expansion of the congeneric barred owl into the Pacific Northwest. The expansion occurred southward from British Columbia and Washington, and barred owls have only recently, since around 2000, increased on Green Diamond’s ownership to population densities associated with negative impacts on NSOs. Recognizing that barred owl could reach densities in the region, as reported for regions to the north, which would have the potential to substantially displace NSOs in the Plan Area and thwart some of this FHCP habitat conservation measures designed to benefit NSOs. In particular, maintaining a well distributed array of DCAs with high occupancy and fecundity, and validation of habitat models (i.e., NSO population increasing in response to increases in the amount and quality of habitat) could be seriously jeopardized if barred owl numbers were allowed to continue to increase. Because there had been no research to determine, using a scientifically rigorous experimental approach, the demographic impact of barred owls on NSO and how this threat might be addressed, Green Diamond launched the first pilot barred owl removal experiment. This important first step to support this FHCP was termed Phase One of a long-term barred owl research program.

5.3.4.1 Phase One Pilot Barred Owl Removal Experiment

A 2008 meta-analysis of NSO populations, including study areas from across the subspecies' range, concluded that the population on the Green Diamond study area was apparently stable or increasing until 2001, when it began to decline (Forsman et al., 2011). The 2008 meta-analysis could not determine cause and effect relationships. However, the presence of barred owls was negatively associated with fecundity and apparent survival of NSO and the apparent decline in NSO coincided with an increase in barred owl numbers.

Although the increase in barred owl was the most probable hypothesis for the decline of NSO on our study area, experimental studies had not been conducted to isolate the effect of barred owls from other potential sources that may contribute to NSO population declines. A panel of scientists reviewed potential experimental designs and concluded that a demographic approach with a paired BACI experiment design where removal of barred owls was the treatment provided the greatest inference and statistical power (Johnson et al., 2008). The first draft recovery plan for the NSO (USFWS, 2008a) and the subsequent revised plan (USFWS, 2011a) expressed the need for such barred owl experimental removal experiments to be conducted and ultimately the Service completed an EIS to conduct four barred owl removal experiments throughout the Pacific Northwest (USFWS, 2013). Green Diamond's pilot removal proposal was evaluated by the Barred Owl Work Group, a group formed under auspices of the 2008 Northern Spotted Owl Recovery Plan (USFWS, 2008a). The group provided support for the experiment, because it was consistent with the recovery plan and was complementary to the USFWS EIS to conduct barred owl removal experiments on mostly public lands in Oregon, Washington and California.

The Phase One Pilot Barred Owl Removal Experiment was initiated in 2009 when the Green Diamond NSO demographic study area was partitioned into areas of approximately equal total acreage where barred owls were to be lethally removed (treated) and areas where barred owls would be undisturbed (untreated). The objectives of this experiment were to determine the feasibility of doing lethal removal of barred owls; estimate the impact of barred owls on NSO occupancy, fecundity, survival, and rate of population change; and assess the effectiveness of barred owl removal to allow recovery of NSO in the Plan Area. The field work for this pilot experiment was completed in 2014 and the results were presented in two peer-reviewed manuscripts that were published in 2014 and 2016 (Diller et al., 2014, 2016). The following section describes the key findings of the Phase One Experiment, with a more complete description in Section 4.3.2 and Appendix C.

Cost and Feasibility - The Phase One Experiment was designed to achieve several objectives with the first related to the cost and feasibility of doing lethal removal of barred owls. Lethal removal of vertebrates is often quite controversial for social and ethical reasons, but it is also often criticized for reasons related to cost and feasibility. Lethal removal of barred owls had never been done so the first objective of this experiment was to document whether removals could be conducted efficiently and effectively using practical, humane techniques and at reasonable cost and staffing levels. Equipment costs were minimal so the primary cost was time spent locating and removing the barred owls. The treatment effect of the BACI study was to remove all territorial barred owls from the treated areas, so feasibility was a function of the proportion of known territorial owls that could be removed.

We collected 73 of 81 territorial barred owls detected from 2009 to 2012 during 122 field visits. The eight owls not collected were not detected after two or three visits to the site indicating they had abandoned the site or were no longer exhibiting territorial behavior. It took an average of 2 hours and 23 minutes to collect each barred owl from the time of arrival at a site to the time a collected bird was completely processed for field data, which typically involved drawing a blood sample and doing buccal and cloacal swabs. The results were not published, but in subsequent years when we were no longer doing intensive field data collection, the time was reduced. Most barred owls were collected within one-half hour of arrival at a site with the average inflated by a few individuals that were particularly difficult to collect. We concluded that lethal removal of barred owls was rapid, technically feasible, and cost-effective (Diller et al., 2014).

Demographic Response of NSO to Barred Owl Removal – Green Diamond's long-term NSO demographic study provided almost two decades of pretreatment data from which to estimate the demographic response of NSO to barred owl removal. The fundamental premise of our classic BACI experiment was to determine if trends in any of the NSO demographic parameters changed between treated and untreated areas following treatment (barred owl removal). Specifically, we estimated occupancy parameters (rates of site occupancy, extinction and colonization), fecundity, survival and rate of population change pre- and post-treatment to determine if the relationship among any of these demographic parameters changed post treatment relative to pretreatment. Based on the theoretical underpinnings of a BACI experiment, any statistically significant post treatment changes in the parameters of interest can be attributed to the treatment effect (barred owl removal).

Some of the most important demographic results were that barred owls caused more than a four-fold increase in the estimate of NSO site extinction (i.e., probability that a NSO site will be abandoned), but following barred owl removal, the extinction rate in the treated areas returned to normal levels and NSO site occupancy was greater in treated than untreated areas. Furthermore, apparent survival and the rate of population change (lambda) were both in decline prior to removal, but these demographic parameters showed significant increases following removal. Mean apparent survival was 0.859 and 0.822 for treated and untreated areas, respectively. Probably the most dramatic result was that prior to treatment, mean lambda was declining 3.6% for all areas, but post treatment, mean lambda was 1.029 (2.9% annual increase) and 0.87 for treated and untreated areas, respectively. Mean fecundity did not show a significant increase following treatment due to high annual variation, but the greater number of occupied spotted owl sites on the treated areas resulted in greater productivity in the treated areas based on empirical counts of fledged young. The primary conclusion from this initial experiment was that lethal removal of barred owls allowed the recovery of the NSO population in the treated portions of the study area (Diller et al., 2016). For more detailed results, see Section 4.3.2 and Appendix C.

5.3.4.2 Phase Two Plan Area-Wide Barred Owl Removal Experiment

The dramatic results from the Phase One pilot removal experiment strongly suggest that a Plan Area-wide barred owl removal experiment is feasible and cost-effective, and in addition to habitat management could provide a significant contribution to NSO conservation and recovery. Accordingly, a Plan-Area wide Barred Owl removal experiment is proposed as a component of this FHCP to promote NSO recovery and to achieve NSO objectives including validation of habitat models and maintaining a well-distributed array of occupied NSO sites. The objectives of this experiment will be essentially the same as the Phase One experiment with the important difference of determining if similar results can be obtained when the treated areas are approximately doubled in size and where NSO populations that have been suppressed by barred owls for a decade or more.

This removal experiment will use the same BACI experimental design with paired treated and untreated (control) areas except the entire Plan Area will be a treated (i.e., barred owls removed) except for isolated areas where it may be impractical. The control area will be the Willow Creek Demographic Study Area, which has been in existence since 1985 and has overlapping datasets on NSO occupancy, survival, fecundity and rate of population change with Green Diamond's study area since 1990. Although it is approximately 20 to 30 miles to the east of and is in a different physiographic province to Green Diamond's ownership (California Klamath versus California Coast), juvenile NSOs regularly disperse between the two study areas, and most importantly, demographic parameters for the two study areas have mirrored each other closely over the last two decades until Green Diamond initiated the removal experiment (Dugger et al., 2016). Other potential areas that can be used as untreated control areas are adjacent state and national parks or Forest Service lands, but it is uncertain if the appropriate NSO monitoring will be occurring in these areas to allow for statistical comparisons.

This experiment is important because it will allow Green Diamond to assess the feasibility of doing barred owl removal on a much larger scale and after barred owls have been established for decades and potentially occurring at higher densities. Of particular interest will be barred owl immigration rates given that the Plan Area will potentially be surrounded by lands supporting high densities of barred owls. The level of immigration will potentially delay, or even suppress, a positive NSO demographic response in the future, which will provide valuable information concerning the recovery of NSOs in other portions of its range. Green Diamond will conduct the experiment until a statistically significant trend is detected in the parameters of interest (e.g., survival, fecundity, lambda) between Green Diamond and the Willow Creek Study Area. We anticipate Phase Two of the experiment to take between 5 and 10 years based on Diller et al., 2016.

Barred Owl Research Commitment Two (Objective 4A): Implement the phase two Plan Area-wide barred owl removal experiment (Section 5.3.4.2). All phases of barred owl experiments and research will require approval from appropriate agencies regarding permits and authorizations.

5.3.4.3 Phase Three Barred Owl Invasion and Co-existence Experiments

The objective of these experiments will be to fine tune suppression of barred owl numbers to achieve a stable equilibrium in which FHCP NSO objectives are achieved while allowing barred owls to persist in the Plan Area. Many of the details of these experiments are yet to be determined subject to the final outcome of Green Diamond's removal experiment and other ongoing barred owl studies throughout the range of the NSO.

The first part of the invasion experiment in which barred owls will be allowed to re-colonize selected areas from which they had been previously removed will provide an opportunity to do an invasion experiment (Johnson et al., 2008). An invasion experiment is suited to areas with few barred owls (a low baseline or starting condition) because of insufficient time to expand or recolonize, which would be the case for the Plan Area after completing the Phase Two experiment. An invasion experiment is similar to a removal experiment in that the study area is divided into treatment and control areas. However, the treatment and control areas are reversed in the invasion study. Specifically, for the Green Diamond study, this will involve designating portions of the Plan Area as treatment areas where barred owl numbers will be allowed to increase naturally or are only partially suppressed and other areas as controls (barred owl-suppressed zones) in which barred owls will continue to be removed. The hypothesis is that initially NSO vital rates in treatment and control areas do not differ due to low numbers of barred owls. As barred owl numbers increase in treatment areas, a threshold will be reached where there are measurable decreases in NSO vital rates relative to control areas (Johnson et al., 2008).

A potential limitation of an invasion study is that barred owls would be required to increase naturally, and therefore it could take a long time to obtain results from the experiment. The invasion experiment may be one of the only ways to determine the threshold level for barred owl populations, and removal costs may be reduced since not all barred owls will be removed (Johnson et al., 2008).

Initial selection of the areas that will be maintained as control areas free of negative barred owl impacts will be based on identifying spatially appropriate areas that Green Diamond's historical data and occupancy model projects as being the most important to NSOs. While important, this invasion study cannot occur at the expense of achieving NSO objectives. It is likely that control areas will include the DCA sites and potential replacement DCA sites (Section 5.3.1.4) such that barred owl abundance does not negatively influence occupancy and recruitment at the most productive NSO sites. Therefore, the invasion study design will likely be more site-based than area-based (as in Phase One) where either individual NSO sites or clusters of NSO sites are pooled in treatment and controls. It will be important to thoughtfully consider potential confounding effects in the selection of treatments and controls during the design of the invasion study. It is also possible that the invasion study is conducted under the general design of occupancy and site level studies (Johnson et al. 2008). While Green Diamond cannot predict the location of DCA sites at commencement of Phase Three, the distribution of DCA sites will be determined by the OMUs and spacing criteria. This experiment will also address where it is most practical to lethally remove barred owls (i.e., good access and away from areas with mixed ownerships).

After achieving the invasion study's objectives (a statistically different trend in NSO vital rates or occupancy between treatment and control areas), the barred/NSO studies will shift to a co-existence experiment. The fundamental objective will be to establish a long-term maintenance level of barred owls that allows NSOs to be sustained while minimizing the lethal removal of barred owls. This experiment will be adaptive in nature and based on what has been learned from all the experiments that have preceded it. Presumably, there will continue to be areas with different levels of barred owl removal, but the size and location of what may become barred owl management zones will be modified depending on the population response of both NSO and barred owls. For example, if NSOs are exceeding population projections, Green Diamond will reduce the level of barred owl lethal removal. However, if the reverse occurs, Green Diamond may have to lethally remove barred owls in areas previously designated as barred owl safe zones.

This long-term co-existence experiment will also have the goal of reducing or eliminating the need to use lethal removal as the primary tool for controlling barred owl populations. Part of the solution may come from the owls. If NSO are allowed to coexist, including successful reproduction, with barred owls for multiple generations, natural selection should favor NSO that can minimize negative interactions with barred owls. During this time it will also allow Green Diamond and other researchers to look at habitat use of the two species and design some forestry experiments in the hope that eventually habitat can be managed to favor NSO over barred owls. Finally, it will allow time to experiment with some non-lethal methods (e.g., suppressing fecundity rates) that will eliminate or minimize the need for continued lethal removal of barred owls.

Barred Owl Research Commitment Three (Objective 4C): Following completion of the phase two experiment and concurrence by the Service, implement the phase three barred owl invasion and co-existence experiments (Section 5.3.4.3).

5.3.5 Effectiveness Monitoring Program, Model Validation and Adaptive Management

5.3.5.1 Northern Spotted Owl

5.3.5.1.1 Model Validation – Habitat Fitness

The initial NSO HCP (Green Diamond, 1992) was based on approximately two years of site specific data collection. Its successor, this FHCP, is based on approximately two decades of research and monitoring creating one of the largest existing NSO datasets. The data collected were incorporated into extensive sophisticated analyses as part of a mandated Ten-Year review (Appendix C.2). This led to the development of a model of habitat fitness that could be projected into future landscapes for NSOs. The future projections of habitat fitness indicate an overall increasing trend in the best habitat (i.e. greatest fitness values), which suggests that if the non-habitat covariates (e.g., weather and barred owls) are within the median values under which the habitat fitness model projections were made, the NSO population is capable of increasing in the Plan Area. However, this habitat fitness model is limited like all mathematical models of ecological processes, i.e., it cannot ever completely capture any ecological system's entire complexity and inherent nuance. Further, it is a deterministic model when both future habitat and non-habitat variables are in fact highly stochastic; particularly as those projections are made further into the future. While this habitat fitness model was based on extensive site-specific data and state-of-the-art statistical models, all statistical models require verification or validation and initially should be viewed as testable hypotheses. The term 'model validation' can have a variety of meanings, but as Green Diamond is using the term, the habitat fitness model will be considered validated when we can verify that the conclusions and predictions from the models are both reliable (i.e., predictions of increasing habitat quality manifests in stable or increasing NSO population) and useful (i.e., help understand and design conservation measures that promote future stable or increasing populations of NSO).

One of the primary objectives of the effectiveness monitoring program for NSOs is to validate the habitat fitness model through independent verification of the model predictions in terms of overall NSO population response. Measuring habitat fitness directly is problematic (i.e., fecundity can be estimated for an area, but survival cannot since the NSOs contributing to survival often move during their lifetime) so the closest approximation will be to correlate resident NSO abundance within some designated area. Green Diamond assumes NSOs occupying an area with predicted high habitat fitness (λ_H >1.0) should have sufficiently high survival and fecundity so the area's resident NSO population could potentially increase assuming non-habitat variables are within median past values (Appendix C, Chapter 4, pp. C-168 to C-172).

Using future survey results gathered throughout the Plan Area, the estimated number of occupied NSO sites in the three NSO regions (spatially grouped OMUs which represent different physiographic regions in the Plan Area) will be compared to the estimated number of NSO sites at the initiation of the Phase II (Plan Area-wide) barred owl removal experiment. Green Diamond will validate the overall predictions of the habitat fitness model by a comparison of trends in estimated NSO abundance as indicated by the region-wide estimated number of paired and single occupied NSO sites and the predicted trend in region-wide habitat quality. In general, since the highest category of habitat fitness (λ_H >1.05) is projected to increase dramatically averaged across the three NSO regions (Appendix C, pp. C-210 to C-215), validation will be achieved when NSO abundance has a similar upward trend through time. However, given the many factors in addition to habitat quality (i.e. weather, competition from barred owls, fluctuations in prey base abundance and stochastic demographic factors) that can influence NSO populations, it is not expected that the trajectories between observed and predicted NSO numbers will be in precise concordance within some predetermined statistical limits for all OMUs. Following the necessary time interval described below (approximately 7 years), model validation with all the FHCP ramifications for monitoring and take will be achieved as long as the overall observed long term trends in estimated occupied NSO sites for each of the three NSO regions are statistically shown to be stable or increasing (P = 0.95) as predicted by the region-wide upward trend in habitat quality. The full details of habitat fitness model validation are described in Appendix I.

5.3.5.1.2 Model Validation – Site Occupancy

The habitat fitness model was developed to analyze all of the habitat (including timber harvest, set-asides and take) and non-habitat variables influencing NSO population trends, and as such, was partly a heuristic model to help understand and design conservation measures that promote future stable or increasing populations of NSO. The validation of this model was based on the ability to affirmatively answer the question: “Do future trends in NSO abundance match habitat fitness model predictions of increasing overall habitat quality?” A second modeling approach, popularized in the wildlife field by MacKenzie and his colleagues (MacKenzie et al., 2002, 2003, 2006), will be used to address the question: “Are NSOs found in areas where the model predicts occupancy should be high?” This second type of model will be a site occupancy model, which will be used to estimate the number of occupied NSO sites in the three NSO regions as a threshold or trigger for achieving FHCP habitat fitness model validation.

As part of the Ten-Year Review of the initial Green Diamond NSO HCP, an abandonment model was developed (see Appendix C, pp. C-25 to C-33), but we lacked the necessary data to construct a site occupancy model for NSO. Green Diamond has begun to assimilate data that can be used for development of an occupancy model, and within three years of the signing of this FHCP, a first draft of a site occupancy model (MacKenzie et al., 2002, 2003, 2006 will be developed. Occupancy models are based on the premise that detectability of an individual is imperfect and that repeat surveys can be used to determine what proportion of non-detections are false negatives (i.e., individual present but not detected). The repeat surveys generate detection histories for each site (i.e., series of 1’s and 0’s representing species detected/not detected) from which detection probabilities can be estimated. In addition, the detection histories can be used to estimate other model parameters including site occupancy, colonization and extinction rates.

Further developments of occupancy models have led to the development of multi-state occupancy models (Nichols et al., 2007, 2008). As implied by the name, instead of a single state (species detected/not detected), multiple states can be modeled. In the case of the NSO surveys for the Plan Area, the multiple states will likely include detection/non-detection of NSO and detection/non-detection of fledglings. A full suite of covariates both biologically meaningful and readily implemented by management will be included in this occupancy model. Along with providing estimates of site occupancy and reproduction, the habitat covariates associated with this multi-state occupancy model will potentially provide a new more management useful definition of NSO habitat and thresholds of take. For example, the habitat fitness model integrated model inputs from separate nesting, nighttime activity, survival and fecundity models

(Appendix C, Chapter 4, pp. C-168 to C-172). Included in these models were a variety of spatially explicit covariates (e.g., edge density and mean patch density) produced by complex computer intensive GIS analyses using FRAGSTATS. While very useful to understand how the various habitat elements function to meet the needs of NSO, and how overall forest management strategies influence Plan area-wide habitat quality, the complex habitat fitness model does not lend itself to predicting how site specific management actions (i.e., harvest units) may influence habitat quality for a specific NSO site. The goal of the multi-state occupancy model will be to include management covariates that are more easily calculated and interpreted, which potentially can then be used to provide a simpler definition of NSO habitat and the thresholds likely to result in take.

Following its development, the site occupancy model will be tested and refined so that future spatially explicit projections of NSO occupancy and reproduction can be made. Testing of the model will be done through comparisons of expected versus observed occupied NSO sites with successful nesting and the results will be used to continue to improve the predictability of the model. Maximizing predictability of the model will be important, because it will be used as one component for estimating take of NSO sites following model validation (Appendix I).

To support validation and development of both of these models, Green Diamond must do surveys for NSOs throughout the Plan Area and annually attempt to locate all individual territorial NSOs. However, unlike the surveys with an overall detection probability of 95% designed to avoid harm to individual NSOs due to timber harvesting, these surveys only require sufficiently high detection probability to validate the models within prescribed statistical limits (Appendix I). Once Green Diamond achieves model validation, the intensive Plan Area demographic NSO surveys and data collection used in model validation can be suspended. However, Green Diamond must continue NSO surveys to protect individual nesting NSOs, monitor DCAs, and monitor NSO fecundity in the Plan Area as described below.

The results from Diller et al., 2016 suggest that model validation should be possible within 10 years following approval of this FHCP and the Phase Two barred owl removal experiment. However, it is impossible to predict exactly how much time or data Green Diamond needs for model validation. Instead of simply needing more data, if the overall NSO population is declining relative to the baseline 6 years after FHCP approval and initiation of barred owl removal, it may indicate that the projections of improving habitat quality may not be met and model validation may not be achieved. This will initiate a preliminary analysis in conjunction with the Service to attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management. As described under Population Trend, 10 years following signing of this FHCP adaptive management assessment will be triggered if the NSO population has shown evidence of decline despite barred owl removal and predictions of increases in the quantity and quality of NSO habitat.

NSO Monitoring Commitment One (Objective 5B): Using future survey results gathered throughout the Plan Area, Green Diamond will compare the estimated number of occupied NSO sites in the three NSO regions to overall habitat fitness values, in accordance with the procedures and assumptions described in Section 5.3.5.1. Validation of the habitat fitness model will be achieved when the overall observed long term trend in occupied owl sites is statistically shown to be stable or increasing (P = 0.95) as predicted by the average of all OMUs within the NSO regions, as agreed upon by Green Diamond and the Service, and consistent with the intent of this section.

NSO Monitoring Commitment Two (Objective 5B): Within three years of signing this FHCP, Green Diamond will construct an initial multi-state site occupancy model. The model will be used to develop projections of NSO occupancy and fecundity. The comparison of expected versus observed occupied NSO sites with successful nesting will not be used as a threshold or trigger for achieving FHCP model validation. However, it will be a requirement to have successfully completed an NSO multi-state site occupancy model before the new FHCP conservation measures contingent on model validation will be implemented, because it will be used to predict where an NSO site is likely to occur for estimating take following model validation (Section 5.3.5.1). It may also lead to a more useful habitat model for management purposes and thresholds for estimating when take may occur. It should be noted that some details of the model-based displacement assessment may change if Green Diamond gains new insight into the response of NSO to timber harvesting during the process of model validation. The Service will have input on model revisions including model selection

5.3.5.1.3 Population Trend

While there is no specific NSO population objective, Green Diamond expects a positive trend in the NSO population for at least the first 10-15 years of this FHCP. This population increase is predicted because the Plan Area-wide barred owl removal experiment will release extensive areas of habitat for NSO occupancy. Equally important, the projections of future habitat fitness shows substantial increases from 2010 to 2020 with lesser increases from 2020 to 2030 (Section 4.3.1.5, Figure 4-1). In fact, an NSO population increase is the essence of model validation described above. Therefore, assuming non-habitat variables (e.g., weather) remain within the range of normal variation that was observed during model development (1990-2005) and all components of the conservation strategy are implemented, Green Diamond predicts the NSO population will increase within the Plan Area from the initiation of barred owl removal. If the NSO population does increase in the Plan Area as predicted, and the habitat fitness model has been validated, then Green Diamond will no longer directly monitor the entire NSO population across the Plan Area. Instead, Green Diamond will monitor all NSO sites associated with DCAs and at least 12 additional spatially stratified randomly selected sites associated with obtaining a fecundity estimate for the Plan Area NSO population (Section 5.3.5.1.4). Furthermore, at least 20% of the potential take sites will be monitored annually (Section 6.2.3.1) and site occupancy surveys will continue throughout the Plan Area (Section 6.2.3.1). In addition, habitat conditions as projected by the multi-state site occupancy model or some other improved future model will be monitored and reported.

If the projections of the habitat fitness model have not been met because of inconclusive population trends or depression of the NSO population due to a non-habitat covariate (e.g., weather, disease or off-property illegal rodenticide use), Green Diamond will continue to gather the extensive NSO survey and mark-recapture data until validation has been achieved or during periods when there is a lapse in permitting to conduct barred owl removal experiments.

However, instead of inconclusive trends, if the overall NSO population is declining relative to the baseline 6 years after FHCP approval and initiation of barred owl removal, it would indicate that the projections of habitat fitness model may not be met. This will initiate a preliminary analysis in conjunction with the Service to attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management. However, if the overall NSO population is continuing to decline relative to the baseline 10 years after FHCP approval and barred owl removal, it would indicate that the projections of the habitat fitness model are not going to be met without corrective action. To determine if the Plan Area-wide NSO population is in decline, Green Diamond will evaluate estimates of realized population change and estimates of occupied NSO sites from the initiation of barred owl removal for any specific area. The starting point for assessing trends in the NSO population will be the first NSO breeding season after this FHCP is approved and the Phase Two removal experiment is initiated (Section 5.3.4). If there is evidence of a statistically significant (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al., 2016) decline relative to the NSO population at the initiation of this FHCP and barred owl removal, Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken (see Section 5.3.6). During this time, the full monitoring protocol for NSOs will continue throughout the Plan Area.

NSO Monitoring Commitment Three (Objective 5B): If the NSO population increases in the Plan Area, as predicted, and Green Diamond validates the projections of the habitat fitness model, then direct monitoring of the entire NSO population across the Plan Area will be replaced by monitoring habitat conditions projected by the multi-state site occupancy or some other improved future model along with monitoring all the DCAs and at least 12 additional spatially stratified randomly selected sites. Furthermore, at least 20% of the potential take sites will be monitored annually and site occupancy surveys will continue throughout the Plan Area (Section 6.2.3).

NSO Monitoring Commitment Four (Objective 5B): Unless and until Green Diamond validates a habitat fitness model, Green Diamond will continue the extensive NSO surveys and mark-recapture data collection.

NSO Monitoring Commitment Five (Objective 5C): If the overall NSO population is declining relative to the baseline 6 years after FHCP approval and initiation of barred owl removal, a preliminary analysis in conjunction with the Service will be conducted to attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management. If after 10 years there is evidence of a statistically significant (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al. 2016) decline in the Plan Area NSO population relative to the NSO population at the initiation of barred owl removal, Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken. Adaptive Management measures to be considered are described in Section 5.3.6. The Adaptive Management measures described in that section are intended to anticipate potential future responses. Additional Adaptive Management measures may be considered by Green Diamond, as they may more appropriately address causes of future NSO decline, should declines be documented according to these commitment standards.

5.3.5.1.4 Fecundity

In addition to an initial increasing NSO population, the projections of future habitat fitness indicated that following implementation of barred owl removal, there should be good fecundity in the Plan Area assuming that future non-habitat factors remain within normal limits observed in the past. Model validation will provide high confidence in the predictions of suitable habitat, but it is possible some non-habitat factor will shift beyond normal limits seen in the past and cause declines in the NSO population. As a barometer to ensure the NSO population remains healthy, all the DCAs and a minimum of 12 other sites meeting the criteria for determining occupancy and reproduction, and selected by a stratified random sample designed to achieve spatial balance, will be assessed annually to estimate mean fecundity in the Plan Area. Green Diamond will compare mean fecundity at the monitored sites with the trend since the initiation of barred owl removal for a specific region as described above for the population trend. The trend in fecundity over the last six years within the Plan Area will be compared to the trend in comparable regional fecundity estimates (i.e., Forest Service Willow Creek Study Area, Hoopa Study Areas, or other pertinent regional studies that utilize the same field protocols and fecundity estimation techniques) over the same time interval. A trend in estimated mean fecundity from the Plan Area statistically lower ($p \leq 0.05$) than the regional mean will trigger adaptive management to assess the problem and provide corrective actions if warranted (Section 5.3.6).

NSO Monitoring Commitment Six (Objective 1B, 5C): Green Diamond will annually assess the mean reproductive success of the NSO population in the Plan Area at all DCAs plus a minimum of 12 other NSO sites selected by a spatially stratified random sample will be assessed to determine the mean reproductive success of the NSO population in the Plan Area. The 12 additional sites will be randomly selected at a rate of one per OMU unless additional sites are not available. Sites in adjacent OMUs may be substituted where deficiencies exist in other OMUs. The trend in fecundity over the prior six years within the Plan Area will be compared to the trend in comparable regional averages of fecundity over the same time interval. If the trend in mean fecundity estimate from the Plan Area is statistically lower ($p \leq 0.05$) than the regional mean, adaptive management will be triggered to assess the problem and provide corrective actions if warranted.

5.3.5.2 Fisher

5.3.5.2.1 Model validation

The fundamental premise for fisher conservation is ample foraging habitat and potential resting and denning habitat will increase through time. Green Diamond does not have the capability to produce a habitat fitness model for fisher that would integrate all aspects of their habitat. However, we developed an occupancy model that can be used to estimate the probability that a fisher will occupy (i.e., foraging or moving through) a specific point in the Plan Area. Validation of this fisher occupancy model relies on data collected using future non-invasive survey techniques estimating fisher occupancy rates. Fisher track plate surveys occurred throughout the Plan Area during 1994, 1995, 2004 and 2006. Green Diamond plans similar future surveys, and within 5 years of FHCP approval, these survey results will provide the first attempts to validate or refine the fisher occupancy model. Following this initial validation attempt, further refinement will rely on surveys in which at least half of the Plan Area will be surveyed at 5-year intervals. This will permit either a validation or refinement of the fisher occupancy model at 10-year intervals.

Validation of the occupancy model will be based on demonstrating high fisher occupancy in areas that are predicted to have high probability of occupancy. In other words, validation is based on the question: Are fisher found at specific areas where the model predicts occupancy should be high? To test for this form of site-specific model validation, Green Diamond will conduct a Chi-square analysis after accumulating five years of initial occupancy surveys or when enough data are available. In this procedure, we will compute probability of occupancy at specific locations using the current model, and bin these values into categories. Using the new locations, Green Diamond then will compute the number of expected and observed locations in each category of probability of occupancy. From these numbers, we will compute a Chi-square statistic to assess significance and regress observed numbers onto expected numbers. If the occupancy model is useful for site-specific predictions of fisher occupancy, the Chi-square statistic will be significant and the regression of numbers observed onto number expected will show positive correlation. If the test is not significant, we cannot conclude zero correlation, but a re-analysis will be conducted to refine the occupancy model to improve the cross-validation test.

Unlike NSOs, Green Diamond knows little about the factors that may limit fisher populations and does not propose substantially reduced monitoring efforts following model validation. However, if additional data and monitoring do allow for a reduction in monitoring needs, Green Diamond will propose this under this FHCP's general adaptive management provisions.

Fisher Monitoring Commitment One (Objective 1D): Within 5 years of FHCP approval, Green Diamond will use non-invasive survey results to attempt validation of the fisher occupancy model. Following this initial validation attempt, further refinement will rely on surveys in which at least half of the Plan Area will be surveyed at five-year intervals. During each 5-year period, one half of the current (as of the date of the survey) Green Diamond ownership will be surveyed. In alternate 5-year periods, the remaining half of the ownership will be surveyed, so that each decade 100% of the Green Diamond ownership will have been surveyed, and data contributed toward this modeling effort. This will permit either a validation or refinement of the fisher occupancy model at 10-year intervals. Occupancy model validation requires demonstrating high fisher occupancy ($\Psi>0.6$) in areas predicted to have high probability of occupancy.

5.3.5.2.2 Population Trend

Although Green Diamond maintains that habitat will exist to support a stable or increasing fisher population, the population may be highly sensitive to non-habitat factors such as disease. Therefore, we hypothesize that the fisher population will oscillate through time around some stable or increasing trend. Green Diamond will test this hypothesis using fisher occupancy rates as a surrogate for fisher abundance. Following initial occupancy model validation or refinement, Green Diamond will estimate occupancy rates for at least half the Plan Area at five-year intervals so that the entire Plan Area is surveyed every 10 years. If there is statistically significant evidence ($p \leq 0.05$) that fisher occupancy rates have declined for five years or more in all or a major portion of the Plan Area (e.g., ~50,000 acre watershed area), Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken (Section 5.3.6). If warranted, this may require the use of hair snares, scat dogs or mark-recapture to collect demographic and disease data on fisher in these same areas. A major or substantial portion of the plan area was considered to be 15%, or approximately 50,000 acres.

Fisher Monitoring Commitment Two (Objective 5C): Green Diamond will estimate occupancy rates for at least half the Plan Area at 5-year intervals so that the entire Plan Area is surveyed every 10 years, as described in Fisher Monitoring Commitment One. If statistically significant evidence ($p \leq 0.05$) suggests declining fisher occupancy rates for 5 years or more in all or a major portion of the Plan Area, Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken. An initial list of possible adaptive management measures is included in Section 5.3.6. Green Diamond may consider and propose other adaptive management options, should other responses to fisher declines be more appropriate and effective.

5.3.5.3 Tree voles

Because no data are available to compute a tree vole habitat model, monitoring tree voles will not include a model validation component. Green Diamond studied the abundance, nest characteristics, and nest dynamics of Sonoma tree voles in the Korbel region of the ownership that had relatively high densities of tree voles (Thompson and Diller, 2002). Following this successful study with tree voles, Green Diamond initiated a pilot study to investigate the distribution and abundance of Sonoma tree vole (tree voles south of the Klamath River) nests throughout Douglas-fir forests on Green Diamond's ownership. A systematic random sample of 10-hectare quadrats was selected, and within each quadrat, 12 to 16 transects were walked by two to four observers. A total of 68 quadrats were sampled from 2001 to 2004. Sampling involved observers visually searching all trees along transects for the presence of vole nests. After all transects were completed, observers randomly selected one transect completed by other observers and then re-sampled these transects for vole nests. The purpose of re-sampling transects was to approximate the line transect detection function. To determine vegetative characteristics of nest sites, a 0.042-hectare plot (23.4-meter radius) centered on the nest tree was sampled along with at least four random plots within the 10-hectare quadrat (Appendix C, pp. C-105 to C-107).

This attempt to estimate the distribution and abundance of trees through direct searches of stands looking for their nests was informative and indicated that tree voles were very patchily distributed and quite rare in many areas. However, it was ruled out as an effective monitoring tool because of the high cost associated with stand searches by field crews and the need to climb trees to confirm vole nests and estimate detection probabilities.

Given the lack of any direct survey method for tree voles, the primary approach to monitoring property-wide trends in tree vole populations will be through evaluating presence of tree voles in NSO pellets collected during demographic monitoring. NSO food habits as revealed by pellets do not allow us to investigate stand-level habitat associations of tree voles since there is no way to know where the NSO may have been foraging when it successfully captured a tree vole. However, the relative frequency of tree voles in the diets of NSO has been used to estimate their distribution and abundance in Oregon (Forsman et al., 2004b). Because prey selection by NSO is almost certainly neither random nor constant at shorter annual intervals (i.e., NSO are likely to shift prey selection based on the relative abundance or availability of a suite of prey species), annual variations in relative frequency may not be a reliable indicator of the vole population. Evidence of a potential cyclic trend in tree vole frequency can be seen from NSO pellets collected across Green Diamond's ownership from 1989 through 2009 (Figure 5-1), However, potential shifts in prey selection cannot be directly estimated and there is no known statistical approach to estimate the contribution that these potential shifts may have in the apparent trends observed in tree vole frequency in owl pellets. However, if the detection of tree vole remains is treated using an occupancy modeling approach (MacKenzie et al., 2006), the probability of a tree vole being detected within an individual NSO territory through searching for and analyzing NSO pellets can be calculated and occupancy of tree voles in the owl's territory estimated.

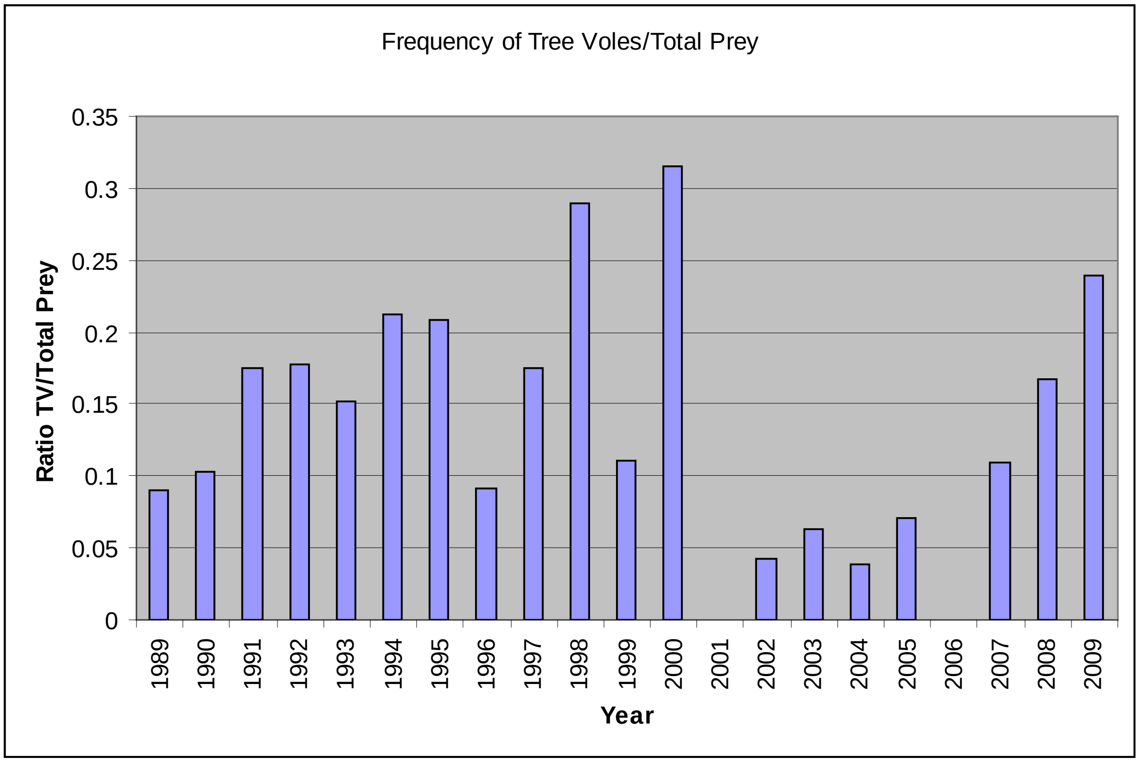

Figure 5-1. Trend in the ratio of tree voles to all prey items identified in all northern spotted owl pellets collected on Green Diamond's ownership, 1989-2009.

The detection probability (i.e., our ability to detect tree vole remains given that they are present in the area hunted by the owls) is the product of multiple components. Among others, these components include an owl locating and capturing a tree vole, a biologist finding an owl pellet, the pellet containing vole remains etc. In some years specific territories may not even be occupied by owls, which can be readily handled as missing observations using occupancy modeling. Ultimately, the distribution and tree vole occupancy can be estimated across the Plan Area annually, which will provide a useful and cost-effective metric to monitor the tree vole population.

To estimate tree vole occupancy, Green Diamond will continue to collect pellets from all NSO sites being monitored with an expected minimum sample size of 200 total prey items (average annual number of prey items in the NSO pellets collected from 1989 to 2009).[9] In addition, an analysis of past tree vole occupancy at NSO sites will be done on pellets collected from 1989 to 2012. This analysis will be completed within a year of Plan approval and it will be used to establish adaptive management thresholds.

Tree vole occupancy and distribution using NSO pellets will remain the default commitment unless a more effective and cost-efficient protocol is developed that is mutually acceptable to the Service and Green Diamond. Such a potential protocol has emerged due to recent

[9] NSO pellets which are formed compressed regurgitations of indigestible prey remains such as hair, teeth and bones from an NSO stomach, often disintegrate when falling to the ground. Therefore, intact pellets and portions of pellets are collected during researcher visits to NSO activity centers. Collections of unspecified numbers of pellets are organized by NSO site name and date for dissection and quantification at a future date.

advances in genetic technology that have created opportunities to monitor populations that may be more sensitive to detecting changes in the population with relatively less effort and cost. Green Diamond will investigate the feasibility and cost of using a landscape genetic approach to monitoring vole populations. Measures of genetic diversity and genetic structure within and among vole populations may provide insight into trends in population size and identify the level of migration among sites. Based on studies with other species (Luikart et al., 1998; Garza and Williamson, 2001; Storfer et al., 2009) genetic data can be used to assess either increases or reductions in population size that are not immediately obvious demographically. In these instances, losses of genetic diversity can be detected as changes in *genetically effective* population size (N_e), which estimates the number of breeding individuals (Luikart et al., 1998).

In addition to benefits of using genetic analyses to estimate population sizes, maintaining genetic diversity within and among vole populations may be important to ensure long term survival in an actively managed landscape. Genetic diversity is maintained in relatively large population sizes, as well as via connectivity (i.e., gene flow) among populations. Immigrants can bring new genetic diversity into populations, thereby increasing overall diversity (Wright, 1931; Slatkin, 1985). For these reasons, genetic diversity and connectivity assessments have become an increasingly common tool for guiding management of amphibian populations (Storfer et al., 2009).

Typically, landscape genetic studies involve capturing and removing small tissue samples to obtain high quality genetic material. Since there is no effective technique to trap tree voles, obtaining tissue samples would involve climbing a potential nest tree, flushing the occupant from the nest and then capturing by hand on the ground. Although Green Diamond has done this previously to support several phylogenetic studies (Murray, 1995; Bellinger et al., 2005; Blois and Arbogast, 2006), it does involve substantial effort and has the potential to injure the tree vole. As a result, we will also investigate the feasibility of using tree vole bones from NSO pellets to obtain genetic material. If this is feasible, it will also allow Green Diamond to take a retrospective look at the genetics of tree vole populations from NSO pellets that were collected beginning in 1989.

Following NSO model validation, Green Diamond will no longer be monitoring all NSO sites throughout the Plan Area (Section 5.3.3), which will reduce the number of pellets that will be collected to assess relative frequency of tree voles. However, Green Diamond will continue to monitor a minimum of 44 DCAs along with 12 supplemental sites to estimate annual fecundity rates (Section 5.3.3) and 20% of the take sites. Therefore, pellets will continue to be collected at a minimum of 56 sites scattered across the Plan Area, which will provide an adequate sample for assessment of tree vole population dynamics. Ultimately, a landscape genetic approach may supplement, replace or be rejected as a tool for monitoring tree vole populations.

Tree Vole Monitoring Commitment (Objective 1E, 5C): Within 3 years following FHCP approval, Green Diamond will develop an occupancy model to detect changes in tree voles in NSO pellets. Green Diamond will also investigate the feasibility and cost effectiveness of using tree vole bones from pellets to obtain genetic material that potentially can be used in a landscape genetic approach to monitoring tree voles. If the landscape genetic approach is found to be effective and efficient, it may with the concurrence of the Service and Green Diamond, supplement or replace the approach based on collection of NSO pellets. An initial list of possible adaptive management measures is included in Section 5.3.6. Green Diamond may consider and propose other adaptive management options, should other responses to vole declines be more appropriate and effective.

5.3.6 Adaptive Management Measures

In response to monitoring outcomes and within the range of changes identified within this section, Green Diamond will initiate reviews and implement adaptive management measures.

5.3.6.1 Adaptive Management Triggers

The adaptive management process addresses scientific uncertainties through monitoring of Covered Species to determine whether FHCP conservation measures have intended effects. Different monitoring outcomes for the Covered Species (Section 5.3.5) could trigger corrective action under adaptive management. If this occurs, Green Diamond will initiate an adaptive management process identifying appropriate change in the conservation measures if they are warranted**.** The adaptive management process will include an assessment identifying the potential cause behind any negative monitoring result, its potential management activity relationship and any appropriate management changes. Green Diamond will notify the Service within 30 days after an analysis indicates a problem exists, requesting technical assistance from the Service in determining the cause of the negative result(s). All available information will be used to make this determination, including results from other monitoring or research projects throughout the region where applicable.

If Green Diamond and the Service cannot agree on the cause or appropriate corrective action necessary to address the problem, the issue will be taken to a scientific review panel. This panel will consist of independent experts on the subject at hand and consist of at least three members. The Service and Green Diamond can recommend panel members, and the initial panel members can suggest others, but ultimately, all of the science panel members must be acceptable to both the Service and Green Diamond. The panel's role is to provide technical analysis of the data related to the issue in question and any other available information to the extent it is relevant to the Covered Species in the Plan Area. The panel will attempt to reach conclusions on whether the negative result(s) was (were) management-related and whether or not changes are warranted in the conservation program to address the problem(s), and based on this, make their recommendations to the Service. Although the Service and Green Diamond will continue to reach a mutually agreeable decision, ultimately the final decision relative to adaptive management will be made by the Service with respect to whether adverse effects on a species may be caused by Green Diamond management practices and therefore redressable through changes in management within the Plan Area. However, the adaptive management changes must be made within the limits of the range of adaptive management changes as described below (Section 5.3.6.2).

A basic premise of adaptive management is that early warning of unanticipated and undesirable outcomes of FHCP implementation, such as declines in the number and/or distribution of Covered Species, should be assessed as early as possible. Early assessment of issues provides better opportunity to address them, and consider ways to resolve these issues, that are more biologically sound and cost effective. Thus, our adaptive management process considers, in many cases, an early warning "yellow light" trigger, as well as a second, more urgent "red light" trigger for more persistent or urgent issues. Objective yellow light triggers cause Green Diamond to continue and intensify monitoring efforts. The adaptive management process is initiated for each species if monitoring shows that red light conditions have been triggered. When a red light is triggered, Green Diamond has the burden of investigating the cause of the red light condition and whether it is redressable through changes in Green Diamond management practices. Green Diamond's findings are reported to the Service together with proposed actions if the conditions are found to be caused by and redressable through Green

Diamond's management of the Plan Area. If the Service agrees or finds that a red light condition may be redressed in whole or in part by adaptive management, then the recommended adaptive management measures are implemented by Green Diamond and debited from the applicable adaptive management account for the species (Section 5.3.6.2). The actions that will be taken for these two types of triggers are described below.

Yellow Light Threshold Trigger

When a yellow light threshold is exceeded, the following will occur:

1. Exceedance of a yellow light threshold will trigger an internal assessment to determine the cause of the exceedance. Green Diamond will continue and intensify monitoring efforts (Section 5.3.6.2).

2. Green Diamond will design the internal assessment to identify the cause the yellow light condition, its relationship to management activities, and what, if any, changes to management are appropriate. Green Diamond will use all available information to make this determination, including results from other monitoring sites throughout the Plan Area, and results from other monitoring projects where applicable.

3. Green Diamond will notify the Service within 30 days after the analysis indicates that any yellow light threshold has been exceeded. Green Diamond will request the technical assistance of the Service in determining the cause of the exceedance. All available information will be used to make this determination.

The procedures followed, conclusions reached, and any changes in monitoring undertaken to address a yellow light condition will be documented in a report to the Service.

Red Light Threshold Trigger

When a red light threshold is exceeded, the following will occur:

1. In the event that a red light threshold is exceeded, Green Diamond will notify the Service within 30 days of that finding.

2. Green Diamond will endeavor to obtain input from the Service regarding identification of any feasible interim changes in the Operating Conservation Program in the area in which the red light threshold is exceeded that could be made by Green Diamond to avoid management-caused exacerbation of the red light condition pending a full assessment of the causes of the exceedance.

3. An in-depth assessment with the full participation of the Service will be conducted to determine the likely cause(s) of the red light threshold condition, and appropriate management changes to address the issue.

4. A scientific review panel which consists of independent experts on the subject at hand will be assembled at the request of either party if Green Diamond and the Service cannot agree on the course of action to address the red light condition.

a. The role of the panel will be to provide technical analysis of the data and any other available information to the extent it is relevant to the conservation of the Covered Species in the Plan Area.

b. The panel will attempt to reach conclusions on whether the exceedance of the red light threshold was management induced.

c. The panel will have three members, with the goal that all are agreed upon by the Service and Green Diamond. If Green Diamond and the Service cannot agree on the members, the Service and Green Diamond will each select one member and agree upon the third.

d. Adaptive management changes will not be made unless the analysis is conclusive in the opinion of a majority of the scientific review panel; if the results are not conclusive, the monitoring will be extended for another five years and the monitoring protocol will be evaluated to ensure that appropriate methodologies are being applied.

5. Just as the biological goals and objectives set forth in Section 5.1 guided the development of the prescriptions set forth in this FHCP, Green Diamond will look to the applicable goals and objectives to guide the development of any changes to the prescriptions pursuant to a red light trigger, using the information gained from the monitoring and adaptive management processes.

Adaptive Management Commitment One (Objective 5C): Green Diamond will notify the Service within 30 days after an analysis indicates any monitoring threshold (yellow light or red light) has been exceeded, and request technical assistance from the Service to determine the cause of the negative result(s). If Green Diamond and the Service cannot agree on the cause or appropriate corrective action necessary to address a red light trigger, the issue will be taken to a scientific review panel. This panel will consist of independent experts on the subject at hand and include at least three members that are agreeable to both parties**.**

Adaptive Management Commitment Two (Objective 5C): The following triggers will initiate adaptive management measures:

- NSO:
  - As an early indicator of trends, if the NSO population declines in the 6 years following approval of this FHCP relative to the baseline NSO population (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al., 2016), Green Diamond will initiate a preliminary review in collaboration with the Service. The starting point for assessing trends in the NSO population will be the first NSO breeding season after this FHCP is approved (Section 5.3.4). This preliminary review will attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management (yellow light).
  - If the NSO population continues to decline in the 10 years following approval of this FHCP relative to the NSO population at the initiation of barred owl removal (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al., 2016), the adaptive management process will be implemented (red light).

  - If the trend in mean fecundity estimate from the Plan Area is statistically lower ($p \leq 0.05$) than a comparable regional mean, the full adaptive management measures will be implemented (red light).

- Fisher

  - A statistically significant ($p = 0.05$) decrease in occupancy estimates for a major portion (e.g., ~50,000 acres) of the plan area at 5 years after occupancy model development (yellow light). Any yellow light areas must be re-surveyed during the next 5-year interval for occupancy surveys that would otherwise be limited to that half of the plan area that was not surveyed when the yellow light condition occurred.
  - A statistically significant decrease in occupancy estimates in the same yellow light area at 10 years (red light).

- Tree voles

  - Although analyses may reveal patterns in tree vole occupancy that merit different metrics, the anticipated default thresholds will be: There is a statistically significant ($p=0.05$) decrease in occupancy estimates for a major portion (e.g., ~50,000 acres) of the plan area for three consecutive years. This trigger may be replaced with a genetic metric such as a significant reduction in the effective population size if a new genetic approach to monitoring can be developed for tree voles (yellow light).
  - A statistically significant ($p=0.05$) decrease in occupancy estimates in the same yellow light area for ≥ 5 consecutive years (red light).

5.3.6.2 Range of Adaptive Management Changes

Long-term conservation of Covered Species involves substantial uncertainty regarding these species' responses to forest management, as currently practiced and as anticipated to evolve under this FHCP. This uncertainty applies throughout these species' ranges, and is not strictly an outcome of this FHCP. Voles have not been the focus of intensive research in the past, resulting in substantial reliance upon assumptions in the projection of future outcomes during the 50-year term of FHCP implementation. To ensure long-term conservation of these species, this FHCP includes a degree of flexibility in its response to new information, and an adaptive management approach to addressing unanticipated declines in either population numbers or distribution within the Plan Area, should they be documented through the proposed monitoring.

Responses to species' declines needs to be specifically tailored to the causes of such declines to ensure that they are reversed, and that resources allocated to addressing those issues are appropriately and optimally allocated. Continued monitoring of the Covered Species documented as in decline, without developing an appropriate means to respond, would not effectively serve the mandate of this FHCP to conserve the Covered Species. Green Diamond anticipates that economic and staffing resources dedicated to monitoring as initially described in this FHCP would be reallocated, at least in part. The purpose of this reallocation would be to gather information to understand the reasons for the decline, and develop and implement adaptive management measures to reverse those trends. This may result in less emphasis in monitoring, but would increase the emphasis on addressing biological issues that preclude conservation of the Covered Species.

To establish a framework within which adaptive management responses can be considered, Green Diamond provides the following options that will be considered in response to apparent, unacceptable species' declines. These options do not represent up-front commitments by Green Diamond, as they represent only an up-front identification of issues that are not fully understood at this time. More appropriately, they represent options that Green Diamond may consider when and if unacceptable declines are documented, as potential means to address specific causes of those declines. Conversely, they also do not represent a complete array of options that may be considered in the future; the actual adaptive management response, and the options available to implement that response, can only be determined in the future when issue-specific information is available regarding the species' decline, should it occur.

Green Diamond may defray costs associated with implementing the following species-specific adaptive management measures by redirecting its committed financial and staffing resources from monitoring toward research. The research will be directed at understanding and reversing declines in populations of Covered Species within the plan area. Any such research must be triggered by information gathered during required monitoring, and specific measures must result from the research that address identified, on-the-ground problems. The intent of this redirection of resources is to focus ongoing FHCP implementation on understanding the reasons for Covered Species declines, should they occur, and to work with the Service toward finding effective solutions to these declines, in lieu of redundant monitoring that may not further document or illuminate the issue. Such re-allocation of resources will be agreed to and coordinated with the Service as part of ongoing cooperation in FHCP implementation.

In response to the Adaptive Management Triggers (Section 5.3.6.1), and if warranted by the adaptive management assessment process, Green Diamond will implement changes in the following components of the Conservation Program:

Green Diamond will establish the Adaptive Management Reserve Account (AMRA) to fund the management adjustments that may be made during the life of this FHCP.

For NSO, the adaptive management account provides for additional habitat protection based on objective performance triggers and empirical understanding of NSO habitat use.

- The AMRA will be credited with an opening balance of 1068 acres for any combination of expansion of existing DCAs or creation of additional DCAs.
- Any modification of the current NSO measures described in Section 5.3, will debited from the AMRA. Debits will be reflected in the account on an on-going basis, and the account will be summarized biennially.

Delineation of NSO DCAs (Section 5.2.1.4.1) mandates a minimum of 89 acres of contiguous nesting/roosting habitat where available. Green Diamond relied upon substantial local data collected under the NSO HCP to estimate the appropriate acreage allocated to DCAs (Green Diamond, 1992). The standard of 89 acres as the basis for DCA core size represents the most conservative estimate based on take threshold, scientific literature and an internal analysis of data collected since 1990. Future DCA occupancy (or occupancy of any site, for that matter) may suggest that this initial standard may be inadequate to support occupancy at a sufficient rate, or may be larger than necessary.

- Size and/or silvicultural prescriptions of DCAs – Green Diamond may modify the size and/or silvicultural prescriptions of the core or surrounding foraging habitat associated with DCAs if there is evidence that either or both of these factors are limiting the biological effectiveness of DCAs. The upper limit of such changes will be equivalent to not more than 1,068 acres

- Take avoidance measures associated with DCAs – Green Diamond may modify the circular buffer size or acreage threshold of nesting/roosting habitat for assessing take avoidance of NSO in DCAs. For example, additional data collected may show that a circular buffer larger or smaller than 0.5 mile, or a watershed oriented polygon are improved thresholds for take; or that different amounts or spatial configurations of nesting/roosting habitat within the buffer improve predictions for take of NSO. If these take avoidance measures are shown to be effective, they would also become the new thresholds for assessing take of base (non-DCA) NSO sites throughout the Plan Area upon concurrence by the Service.

Green Diamond proposes to test for silvicultural covariates that may influence habitat selection in stands managed under partial removal silvicultural applications. The company has not historically implemented such applications extensively within the Plan Area. In the absence of empirical data, the Service must rely on a conservative (i.e., more protective to NSO) approach to take accounting from this lack of empirical information.

- Green Diamond may test for specific covariates that test for the influence of partial thinning silvicultural methods, specifically to determine the influence that those methods may have on post-harvest occupancy and reproduction by NSO, with the intent of determining how those methods may modify take accounting.

For fisher, the adaptive management account is funding-based to allow for a more flexible approach to new management prescriptions based on research rather than additional pre-determined habitat measures that are not presently known to benefit fisher. Based on past monitoring and future model predictions, there will be an abundance of fisher habitat throughout the term of the permit. Unlike NSO, habitat fitness models do not exist for fisher, so we are not currently able to use quantitative methods to identify or predict habitat that would be capable of supporting an increasing population of fisher. As such, there is no a priori biological rationale for adding even more habitat or habitat of a particular nature in the event of a fisher population decline.

The fisher adaptive management account will consist of a total budget for the Plan Term with an opening balance of $500,000 (expendable at a rate of no more than $100,000 per year), of which, up to $250,000 may be applied to research in response to adaptive management triggers to investigate causation and the balance (no less than $250,000) may be applied to the expense of additional conservation measures or changes to Green Diamond management practices for the benefit of fishers. The AMRA budget balance will be reported and inflation adjusted by Green Diamond with the filing of every fourth Annual Report based on the Gross Domestic Product (GDP) deflator calculated by the United States Bureau of Economic Analysis. With the filing of every fourth Annual Report, Green Diamond will first deduct any eligible expenditures during the reporting period from the AMRA budget balance at the beginning of the reporting period (i.e., $500,000 at initiation of Forest HCP). The remaining AMRA balance will then be inflation adjusted by reference to the year of the most recent inflation-adjusted AMRA budget balance as the baseline, and reported to the Service as the AMRA budget balance for the next four-year reporting period. For example, if this FHCP is approved in 2017 and there are no AMRA budget expenditures before the first AMRA budget balance inflation adjustment is reported in the 2021 Annual Report and the GDP price index in 2021 reflected a 2.0% annual inflation rate from 2017 to 2021, the AMRA would increase to $541,216.08. If the AMRA expenditures for research were $200,000 between 2021 and 2025, then the 2025 Annual Report would show that the 2025- adjusted AMRA budget balance of $585,829.69 was reduced by $200,000 and an AMRA balance of $352,040.40 would then be inflation adjusted and reported, using 2025 as the baseline. That new inflation adjusted AMRA balance ($366,262.83 if 2% annual inflation continued in the 2021-2025 period) would then apply to the next reporting period of 2025 through 2029.

In developing the management strategy for fishers in this FHCP, Green Diamond has relied substantially on the extensive network of RMZs and geologically unstable areas, subject to limited entry, to provide habitat elements for fishers. Those habitat elements include large, hollow downed logs, snags and decadent green trees. Data from Hoopa Valley Indian Reservation indicate that tanoak is the most frequently used tree species for denning sites, a hardwood that is substantially more limited in the redwood portion of the Plan Area. Should monitoring or other evidence indicate that hollow trees and other natural structures used for den sites become limited, potentially reducing the survival and/or fecundity of fisher populations in the Plan Area, Green Diamond will consider the following adaptive management measures to improve future den availability.

- Green Diamond may modify the TREE to include provisions to retain additional low economic value trees with hollows and other structural features favorable to fishers, especially through the life of the future stands. Such modifications may include changes to the scoring method to increase the number of trees ranking as a "7", or committing to retaining one or more of the highest scoring trees per acre, even if no tree scores as high as "7" using the current scorecard method. For harvest units that contain no or few trees likely to develop hollows or other structures favorable to fishers, Green Diamond will consider taking proactive measures to promote long-term development of those features. Methods may include topping to promote "candelabra" tops, inducing heart rot, or physical creation of hollows.
- Projects within RMZs or geologically unstable areas, that are otherwise consistent with provisions for silvicultural activities within these land allocations, will promote the development of a minimum of one hollow tree per 100 meters (328 feet) of stream for all Class I and Class II watercourses. When working within geologically unstable areas, promote the development of a minimum of one hollow tree for each hectare of area.

The adaptive management account for voles also is funding-based to allow for a more flexible approach to new management prescriptions based on research rather than additional pre-determined habitat measures that are not presently known to benefit voles. As with fishers, suitable vole habitat is expected to be abundant throughout the term of the plan and there is no a priori biological rationale for adding even more habitat in the event of a vole population decline. Instead, adaptive management for vole is based on funding research and potential corrective action to address the cause of some future vole decline.

- The vole adaptive management account will consist of a total budget for this FHCP Term with an opening balance of $500,000 (expendable at a rate of no more than $100,000 per year), of which, up to $250,000 may be applied to research in response to adaptive management triggers to investigate causation and the balance (no less than $250,000) may be applied to the expense of additional conservation measures or changes to Green Diamond management practices for the benefit of voles. The AMRA budget balance will be reported and inflation adjusted by Green Diamond with the filing of every fourth Annual Report based on the GDP deflator calculated by the United States Bureau of Economic Analysis. With the filing of every fourth Annual Report, Green Diamond will first deduct any eligible expenditures during the reporting period from the AMRA budget balance at the beginning of the reporting period (i.e., $500,000 at initiation of FHCP). The remaining AMRA balance will then be inflation adjusted by reference to the year of the most recent inflation-adjusted AMRA budget balance as the baseline, and reported to the Service as the AMRA budget balance for the next four-year reporting period. For example, if this FHCP is approved in 2017 and there are no AMRA budget expenditures before the first AMRA budget balance inflation adjustment is reported in the 2021 Annual Report and the GDP price index in 2021 reflected a 2.0% annual inflation rate from 2017 to 2021, the AMRA would increase to $541,216.08. If the AMRA expenditures for research were $200,000 between 2021 and 2025, then the 2025 Annual Report would show that the 2025- adjusted AMRA budget balance of $585,829.69 was reduced by $200,000 and an AMRA balance of $352,040.40 would then be inflation adjusted and reported, using 2025 as the baseline. That new inflation adjusted AMRA balance ($366,262.83 if 2% annual inflation continued in the 2021-2025 period) would then apply to the next reporting period of 2025 through 2029.

Initial FHCP management of voles in the Plan Area relied heavily on an analysis that tested the connectivity of future landscapes for voles. That analysis assumed that voles would be able to recolonize and survive in forest stands with a substantial Douglas-fir component, at least 20 years of age, and with canopy connection to other trees and occupied stands. Limited information is available regarding vole dispersal distances and canopy conditions used during dispersal. Should vole re-occupancy of regenerating stands not occur as predicted, as documented through the proposed vole monitoring strategy (5.3.6.1), Green Diamond will promote improved recolonization through consideration of options, including the following:

- Conduct research to better estimate dispersal conditions and distances through which voles typically move when expanding their distribution into forest stands regenerating after harvest
- Conduct research to better evaluate the effects of stand thinning on dispersal and habitat use by voles

Trees used by voles for nesting/breeding purposes typically are more structurally diverse than are trees not used for those purposes. The TREE currently requires trees scoring 7 or higher during pre-harvest evaluation be retained and not harvested, provided safety and operational concerns can be addressed. Thus the retention of residual trees is subject to the availability of such trees in the preharvest landscape. If unavailable (i.e., if no trees score a minimum of 7), the TREE does not require retention of residual trees, potentially resulting in fewer opportunities for structural complexity in future stands. Should monitoring of tree voles demonstrate a reduction in vole numbers or distribution attributable to a future lack of stand structural complexity, Green Diamond will evaluate and implement as appropriate one or more of the following adaptive management options to address habitat limiting factors determined to directly or indirectly result from implementation of this FHCP.

- To promote retention and development of structurally complex Douglas-fir trees in the future landscape, adaptive management will consider modifications to provisions of the TREE to include one or more trees per acre, of the highest score, intended to provide source trees that develop, or can be manipulated to develop, complex structure during their lifespan in the regenerating stand.
- If entering RMZs or other limited harvest stands projects will include provisions to develop complex trees through direct or indirect manipulation of individual trees or groups of trees.
- When conducting thinning or applying similar partial harvest silvicultural practices, Green Diamond will consider options to avoid or reduce the harvest of Douglas-fir with obvious “candelabra” structure, to conserve these habitat features important to tree voles.

Adaptive Management Commitment Three (Objective 5C): Green Diamond will implement one or more of the following adjustments to the Conservation Program and Effectiveness Monitoring Program for Covered Species in response to monitoring outcomes that warrant corrective action, either through mutual agreement between Green Diamond and the Service, or through the assessment of the Scientific Review Panel.

- Number of DCAs – Green Diamond will designate up to a maximum of 12 additional DCAs across the Plan Area that meet the criteria set forth in Section 5.3.1.4.4 (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25 averaged over the last 4 years) if there is evidence that more DCAs are required to achieve NSO objectives. The location and spacing of additional DCAs will be dependent on availability (NSO need to demonstrate the suitability of a site) and where new DCAs would provide the greatest demographic support and add continuity among existing NSO sites.
- Size and/or silvicultural prescriptions of DCAs – Green Diamond may modify the size and/or silvicultural prescriptions of the core or surrounding foraging habitat associated with DCAs if there is evidence that either or both of these factors are limiting the biological effectiveness of DCAs. The upper limit of such changes will be equivalent to not more than 1068 acres (Section 5.3.1.4.1).
- Adjustments of take authorization – Green Diamond will evaluate the authorized rate of NSO take and adjust, in collaboration with the Service, if warranted in response to a population decline detected through monitoring.
- Management related fisher decline – If adaptive management is triggered by a statistically significant decline ($p \leq 0.05$) (Section 5.3.5.2) in the occupancy rate for fisher, and it has been concluded that it is directly or indirectly related to one of the covered activities, Green Diamond will adjust the measures of the TREE or protect other fisher habitat or habitat structural elements up to the $250,000 budget allowance in the AMRA.
- Management related tree vole decline – If adaptive management is triggered by significant reductions in occupancy rates of tree voles in prey remains of NSOs, and it has been concluded that it is directly or indirectly related to one of the covered activities, Green Diamond will adjust the conservation measures of the TREE to promote the retention of additional forest structure anticipated to improve tree vole occupancy and dispersal in regenerating stands up to the $250,000 budget allowance in the AMRA:

5.3.6.3 FHCP Changes Resulting from Minor Modifications or Monitoring and Adaptive Management under the AHCP

As provided for in Section 12.1 of the Final Implementation Agreement for the AHCP (Green Diamond, 2007), the Service, NMFS, or Green Diamond may propose minor modifications to the AHCP through adaptive management or to make corrections, refinements, or clarifications.

Upon approval by the Service, any correction, refinement, or clarification of an AHCP prescription that is equivalent or substantially similar to a conservation measure in the FHCP (e.g. prescriptions for management of RMZs or unstable slopes), shall be incorporated into the FHCP as a correction, clarification or refinement of the corresponding conservation measure prescribed in the FHCP.

For minor modifications resulting from Adaptive Management as described in Section 6.2.6.1 of the AHCP, Green Diamond will institute the adaptive management process under the AHCP in the event of a yellow light threshold trigger, a red light threshold trigger, Steep Streamside Slope trigger, or results from the experimental watersheds monitoring program that identify an appropriate change in the conservation measures. Should Green Diamond propose any adaptive management change in the unstable slope or RMZ width and prescriptions under the AHCP, such a proposal will also be deemed to be a proposed adaptive management measure under this FHCP and it shall require approval by the Service under both the AHCP and this FHCP before it will be implemented by Green Diamond. The intent of this provision is that no adaptive management measures will be taken under this FHCP unless they are judged by mutual agreement between Green Diamond and the Service, or the assessment of the Scientific Review Panel to be either neutral or beneficial to the conservation program for the Covered Species under this FHCP.

5.3.6.4 Other Adaptive Management Conditions.

5.3.6.4.1 Service-Initiated Adaptive Management.

The Service shall notify Green Diamond if the Service believes that one or more of the adaptive management provisions in this FHCP have been triggered and that Green Diamond has not changed its management practices accordingly as prescribed herein. Within 30 days of such notification, Green Diamond shall initiate the adaptive management procedures or changes set forth in the adaptive management program and shall report to the Service on what actions have been taken. Changes in management strategies or mitigation measures that are implemented pursuant to the adaptive management program provided for in this FHCP do not constitute Unforeseen Circumstances and do not require amendment of the ITP or this FHCP.

5.3.6.4.2 No Increase in Take.

Adaptive management measures shall not be implemented or approved if they will result in an increase in the amount and nature of take, or increase the impacts of take of Covered Species beyond that associated with the range of changes analyzed under the FCHP, the biological opinion issued in connection with the ITP, and the analysis of the FCHP in the EIS prepared in connection with the ITP approval, including any amendments thereto. Any adaptive management changes outside the scope of this FHCP and amendments thereto must be processed as Major Amendments pursuant to Section 5.3.7.

5.3.6.4.3 Reductions in Mitigation.

Green Diamond will not implement adaptive management changes outside the scope of this FHCP, unless the Service provides written approval as provided herein. Green Diamond may propose such adaptive management changes by written notice to the Service, specifying the modifications proposed, the basis for them, including supporting data, and the anticipated effects on Covered Species, and impacts to other elements of the human environment. Within 135 days of receiving a notice, the Service will either approve the proposed changes, approve them as modified by the Service, or notify Green Diamond that the proposed changes constitute Permit amendments that must be processed as Major Amendments pursuant to Section 5.3.7.

5.3.7 Implementation Commitments

This section identifies management commitments Green Diamond will adhere to, to ensure that the provisions of this FHCP are implemented as intended. These commitments include the structure and function of an Internal Plan Compliance Team, the process by which Green Diamond will notify the Service of its intent to implement covered activities that may affect Covered Species, the information to be provided to the Service in Sections, and the timing and purpose of scheduled field reviews of FHCP implementation.

Implementation Commitment One (Objective 5A): Internal Plan Compliance Team:

- Green Diamond will designate an internal compliance team including a Plan Coordinator working in conjunction with Green Diamond's internal forestry and wildlife staff.
- Green Diamond will staff this FHCP Coordinator position with an academically trained and experienced wildlife biologist.
- Green Diamond will ensure this FHCP Coordinator reviews each proposed THP during its development and informs the RPF preparing the THP when any special restrictions and/or mitigations occur in the area (e.g., DCA special adjacency requirements or take assessment). Green Diamond also will ensure the RPF completes a pre-harvest checklist during THP development covering all necessary compliance elements.
- The Plan Coordinator or compliance team members will prepare and maintain documentation indicating Plan compliance for internal use for every THP within the Plan Area. Green Diamond maintains and updates an integrated Timberland Management Information System (TMIS) serving as an inventory tool for FHCP implementation and compliance.
- Following state THP review and approval, Green Diamond's RPF will implement the THP as written, prepare a THP post-harvest completion form documenting THP compliance with FHCP provisions and submit this form to this FHCP Coordinator. Green Diamond's FHCP Coordinator will review the form to ensure compliance.
- Green Diamond shall budget and expend such funds necessary to fulfill its obligations under this FHCP's Operating Conservation Program. Green Diamond shall promptly notify the Service of any material change in their financial ability to fulfill its obligations.

Implementation Commitment Two (Objective 5A): THP Notice of Filing and THP Area Map

When submitting any proposed THP within the Plan Area to CAL FIRE, Green Diamond will provide an informational copy of the THP filing notice and a THP area map to the Service. This commitment shall also apply to the Peripheral Area for so long as those lands remain in Green Diamond ownership.

The THP filing notice and its cover letter will be modified from those currently provided to the Service to include specific information relevant to Covered Species under this FHCP, similar to the information already provided for species covered under the AHCP (Green Diamond, 2007). By including information on potential take of FHCP Covered Species, the THP filing notice will function as the notification to the Service regarding anticipated or potential take of listed species, and implementation of FHCP conservation measures intended to reduce the level and effects of anticipated take. During the first year of implementation, Green Diamond will coordinate with the Service regarding specific additions to Green Diamond's current THP filing notice format.

Implementation Commitment Three (Objective 5A): Annual Reports

Green Diamond will prepare and submit an annual report to the Service by March 1 following the first full year after this FHCP's effective date and every year thereafter during this FHCP term. These reports will summarize Operating Conservation Program compliance, results of the Effectiveness Monitoring Measures (Section 5.3.5) and any scheduled field reviews (Section 5.3.7) conducted in the prior year. The annual report to the Service will also include the post-harvest completion forms (Section 5.3.5). Each annual report shall also disclose necessary Green Diamond expenditures for implementing this FHCP's Operating Conservation Program during the prior calendar year and Green Diamond's current-year budget for implementing the Operating Conservation Program.

The annual report will provide a summary discussion of progress of implementation of management commitments identified under Section 5.5. The summary discussion may be organized by general commitment group, as follows:

- Landscape Management Commitments
- Habitat Element Retention Commitments
- Covered Species Protection Commitments
- Barred Owl Research Commitments
- NSO Monitoring Commitments
- Fisher Monitoring Commitments
- Tree Vole Monitoring Commitments
- Adaptive Management Commitments
- Implementation Commitments

The summary discussion under each commitment group will provide a *concise* description of progress toward meeting the commitments; identify concerns or conflicts arising from their implementation that may not have been considered during FHCP development; and conservation measures described in the commitment that Green Diamond may not have been able to complete, if needed, in a timely manner.

The annual report will include a summary of any adaptive management measures in development, or being implemented during the prior year, in response to the provisions of Section 5.3.6. The annual report will include an evaluation of the effectiveness of each implemented adaptive management measure, to ensure that its implementation effectively addresses the biological purposes for its adoption.

The annual report also will explicitly describe any take of Covered Species that has occurred during the reporting period, including both NSO that have been put into the "potential take bucket", and potential takes that have been confirmed as takes from post-covered-activity monitoring, and any that did not occur as a result of monitoring.

The following is an example of anticipated annual report content:

- Introduction
- Forest HCP Conservation Measures and Implementation
    - Summary Post-harvest Habitat Retention for Completed THPs
    - Riparian and Geologic Management Measures
    - NSO DCAs
        - Monitoring, Designation, Spatial Distribution, Replacement
    - Transition from 1992 Set-Asides to DCAs
    - Protection of Covered Species
        - NSO Active Site Locations & associated state identification (master owl) number
        - Summary of NSO Surveys for THPs
        - Fisher Den and Incidental Observations
        - Current and Abandoned Water Tank Monitoring (Fisher)

        - Tree Vole Nests and Incidental Observations

- Effectiveness Monitoring
    - NSO Monitoring
        - Site Occupancy
        - Reproductive Success
        - NSO Banding
        - Juvenile Survival/Dispersal
        - Turnover
        - Owl Density
        - Demography
        - Model Validation
    - Fisher Monitoring
        - Occupancy Surveys and modeling
        - Model Validation
    - Tree Vole Monitoring
        - Occupancy Surveys and Modeling from NSO Pellets
- Barred Owl Research
- Notice of THP Filings
- Land Transactions and Plan Area Adjustments
- Take Summary
    - NSO
        - Take Assessment
        - Take Accounting
        - Projected Takes
        - Direct Harm
    - Fisher
    - Vole
- FHCP Training Programs
- Efficacy of FHCP
    - Expenditures and Budget
    - NSO Regional Comparison (Willow Creek Study Area)
- Adaptive Management Account
- Changed Circumstances
- Peripheral Area Management
- Literature Cited
- Glossary and List of Abbreviations
- Appendices
    - Protocols
    - NSO Detection Probabilities
    - Results of NSO THP Surveys
    - Recolonized and Abandoned NSO Sites
    - Raw Data for Post-harvest Habitat Retention

- Maps/Spatial Data
    - NSO Active Sites
    - NSO Potential Take Sites
    - NSO Pre- and Post-habitat at Potential Take Sites and DCAs
    - NSO DCA Locations and Associated Sites
    - NSO sites associated with Density Study Area and Demographic Study Area
    - Fisher Den Locations and Incidental Observations
    - Current and Abandoned Water Tank Locations
    - Tree Vole Nests and Incidental Observations
    - Barred Owl Site Locations and Removals

Implementation Commitment Four (Objective 5A): Scheduled Reviews

For the first 5 years of this FHCP, Green Diamond will schedule annual meetings with the Service. In the second and fourth years, annual meetings will precede a field review of implemented conservation measures allowing their technical evaluation. In the event Service determines from a field review that conservation measure implementation is not in accordance with this Operating Conservation Program, Green Diamond will develop recommendations with the Service regarding implementation and may schedule additional field reviews.

Implementation Commitment Five (Objective 5A): Assurance of Funding

Green Diamond warrants that it has, and shall expend, such funds as may be necessary to fulfill its obligations under the Operating Conservation Program. In each Annual Report to the Service, Green Diamond will provide a summary of expenditures for implementing this FHCP's Operating Conservation Program during the prior calendar year and Green Diamond's current-year budget for implementing the Operating Conservation Program. Green Diamond shall promptly notify the Service, in writing, of any material change in Green Diamond's financial ability to fulfill its obligations. Upon notification of material changes that restrict Green Diamond's ability to fulfill its obligations, the Service may suspend the Permit until such obligations can be met. The Service shall respond to Green Diamond within 90 days of receipt of the Green Diamond notification.

In the event that CDFW grants to Green Diamond a consistency determination under California law for this FHCP and requires financial assurances under California law, Green Diamond may provide additional security for the performance of this FHCP in the form of a letter of credit or bond benefitting CDFW. This additional assurance of financial performance may also be provided to the Service under a memorandum of agreement with CDFW and Green Diamond for the administration of the financial security. The Service may accept such additional financial security for performance without amending this FHCP and ITP.

Implementation Commitment Six (Objective 5A): Minor and Major Plan Amendments

Green Diamond or the Service may propose minor modifications to this FHCP and ITP ("Minor Modifications") by providing written notice to the other Party. Such notice shall include a statement of the reason for the proposed modification and an analysis of its environmental effects, including its effects on operations under this FHCP and on Covered Species. The Parties shall use reasonable efforts to respond to proposed modifications within 60 days of receipt of such notice. Proposed Minor Modifications shall become effective, and this FHCP shall be deemed modified accordingly, immediately upon the other Party's written approval.

Among other reasons, a receiving Party may object to a proposed Minor Modification based on a reasonable belief that such modification would result in operations, burdens or obligations under this FHCP that are significantly different from those analyzed in connection with the original FHCP; adverse effects on the environment that are new or significantly different from those analyzed in connection with the original FHCP; or additional take not analyzed in connection with the original FHCP approval. An objecting Party shall provide the other Party with written notice of the objection that includes a statement of the reason for the objection. If a Party objects, the proposal is not approved as a Minor Modification but may be processed as a Major Amendment of this FHCP and ITP.

Examples of Minor Modifications to this FHCP and ITP processed pursuant to this subparagraph may include, but are not limited to, the following:

- Corrections of typographic, grammatical, and similar editing errors that do not change the intended meaning
- Correction of any maps or exhibits to correct errors in mapping or to reflect previously approved changes in the ITP or this FHCP
- Minor changes to survey, monitoring or reporting protocols
- Clarifications to vague or undefined language or phrases
- Changes to operational prescriptions pursuant to, and within the foreseen range of changes resulting from, adaptive management
- Provision of additional financial assurances in connection with a consistency determination by the State of California
- Any other modifications to this FHCP that are consistent with the biological goals and objectives described in this FHCP that will not result in operations under this FHCP that are significantly different from those analyzed in connection with this FHCP as approved, adverse impacts on the environment that are new or significantly different from those analyzed in connection with this FHCP as approved, or Take of Covered Species not analyzed in connection with this FHCP as approved, including but not limited to the approval or execution of agreements to facilitate execution and implement of this FHCP, or actions by Green Diamond to delegate (while retaining full responsibility for compliance with) any of its duties under this FHCP to a third party under its direct control.

Green Diamond and the Service each shall maintain a file of Minor Modifications to this FHCP that have been approved by all Parties and Green Diamond shall attach such Minor Modifications to each annual report covering the calendar year in which it is approved.

Any modifications to this FHCP and ITP other than approved Minor Modifications shall be processed as a Major Amendment of this FHCP and ITP. Major Amendments must be approved in accordance with all applicable requirements of federal law, including but not limited to, the ESA, NEPA, and applicable implementing regulations in force at the time of the proposed Major Amendment. The Party proposing the amendment shall provide a statement of the reasons for the amendment and an analysis of its environmental effects, including its effects on operations under this FHCP and on Covered Species.

Implementation Commitment Seven (Objective 5A): Enforcement and Dispute Resolution

Except as set forth below, Green Diamond and the Service each shall have all remedies otherwise available to enforce the terms of this FHCP, ITP, and the Operating Conservation Program.

The Parties acknowledge that the Covered Species are unique and that their loss as species would result in irreparable damage to the environment, and that therefore injunctive and temporary relief may be appropriate to ensure compliance with the terms of this FHCP.

No Party shall be liable in compensable damages to any other Party for any breach of this FHCP or ITP, any performance or failure to perform a mandatory or discretionary obligation imposed by this FHCP or any other cause of action arising from this FHCP and ITP.

Without limiting the applicability of rights granted to the public pursuant to the ESA or other federal law, this FHCP shall not create any right or interest in the public, or any member thereof, as a third-party beneficiary hereof, nor shall it authorize anyone to maintain a suit for personal injuries or damages pursuant to the provisions of this FHCP. The duties, obligations, and responsibilities of Green Diamond and the Service with respect to third parties shall remain as imposed under existing law

Nothing contained in this FHCP is intended to limit the authority of the United States government to seek civil or criminal penalties or otherwise fulfill its enforcement responsibilities under the ESA or other applicable law.

The Parties recognize that good faith disputes concerning implementation of, or compliance with, or suspension, revocation or termination of this FHCP or the ITP may arise from time to time. The Parties agree to work together in good faith to resolve such disputes, using the dispute resolution procedures set forth herein below or such other procedures upon which the Parties may later agree. However, if at any time any Party determines that circumstances so warrant, it may seek any available remedy without waiting to complete dispute resolution. Unless the Parties agree upon another dispute resolution process, or unless an aggrieved Party has initiated administrative proceedings or suit in federal court as provided herein, the Parties may use the following process to attempt to resolve disputes:

- Where the dispute is regarding a Party's compliance with the Operating Conservation Program, the Permit or this Agreement, the aggrieved Party shall notify the other Party of the provision that may have been violated, the basis for contending that a violation has occurred, and the remedies it proposes to correct the alleged violation. Where the dispute is over the proper implementation of the Operating Conservation Program, the Permit or this Agreement, the aggrieved Party shall notify the other Party of the provision over which the issue arises, the basis for contending that implementation is not proper and the changes it proposes to resolve the dispute.

- The Party receiving the notice provided in (a) shall have 30 days, or such other time as may be agreed, to respond. During this time it may seek clarification of the information provided in the initial notice. The aggrieved Party shall use its best efforts to provide any information then available to it that may be responsive to such inquiries.

- Within 30 days after such response was provided or was due, representatives of the Parties having authority to resolve the dispute shall meet and negotiate in good faith toward a solution satisfactory to all Parties, or shall establish a specific process and timetable to seek such a solution.

- If any issues are not resolved through such a process, the Parties shall consider non-binding mediation and other alternative dispute resolution processes and, if a dispute resolution process is agreed upon, shall make good faith efforts to resolve all remaining issues through that process.

Implementation Commitment Eight (Objective 5A): Conditions for ITP Suspension or Relinquishment

The Service may suspend or revoke the ITP for cause in accordance with the laws and regulations in force at the time of such suspension or revocation. Such suspension or revocation may apply to the ITP in whole or in part, and may apply only to specified Covered Species, portions of the Plan Area, or certain Covered Activities.

Green Diamond may relinquish the ITP before expiration of the full term of the ITP in accordance with the regulations in force on the date of such relinquishment and this implementation commitment. The applicable regulations are currently codified at 50 CFR §§ 13.26 and 17.32(b)(7). Unless later modification of these regulations dictates otherwise, to relinquish the ITP, Green Diamond shall, within 30 calendar days of discontinuing incidental take and the exercise of other rights granted by the ITP, return the ITP to the issuing office together with a written statement surrendering the ITP for cancellation. Relinquishment of the ITP will result in termination of this FHCP except that Green Diamond shall carry out the following measures for the duration of the original ITP term:

- When conducting timber operations and related land management activities within the Plan Area (as it exists as of the relinquishment date), prevent and avoid take of animals that are of a species listed as threatened or endangered under the ESA.

- Using this FHCP protocol approved by the Service, continue to survey for the presence of NSO in or near planned timber harvest units and, in the event of a detection, implement the timing and/or buffer restrictions set forth in this FHCP protocol to ensure that nesting NSO are not displaced or otherwise subject to take through those activities.

As designed and as analyzed in this FHCP, the measures provided in FHCP Section 5 and Section 6 are intended to result in Green Diamond having fully and continuously fulfilled its obligations under the ITP such that no additional post-relinquishment mitigation is required. Upon any relinquishment of the ITP, Green Diamond will be deemed to have fully and completely satisfied its obligations under the ITP, including those to minimize and mitigate the impacts of take that may occur incidental to the Covered Activities on the Covered Species within the Plan Area before or as those impacts arise. After Green Diamond relinquishes the ITP, it shall be deemed cancelled. Upon surrender of the ITP, no further take shall be authorized under the terms of the ITP.

5.4 MEASURES FOR CHANGED AND UNFORESEEN CIRCUMSTANCES IN THE PLAN AREA

5.4.1 "Changed Circumstances" means "changes in circumstances affecting a species or geographic area covered by a conservation plan or agreement that can reasonably be anticipated by plan or agreement developers and the Service and that can be planned for (e.g., the listing of new species, or a fire or other natural catastrophic event in areas prone to such events)." 50 CFR § 17.3. Changed circumstances are not unforeseen circumstances.

Changes that will constitute changed circumstances under this Plan are described in this Section 5.4. together with the specific conservation and mitigation measures that Green

Diamond agrees to implement in response to such changed circumstances. Green Diamond shall give notice to the Service within 7 days after learning that any of the changed circumstances has occurred. As soon as practicable thereafter, but no later than 30 days after learning of the changed circumstances, Green Diamond shall modify its activities in the manner described herein to the extent necessary to mitigate the effects of the changed circumstances on Covered Species, and shall report its actions to the Service within 15 days after initiating such modifications. Green Diamond shall make such modifications without awaiting notice from the Service. If the Service determines that changed circumstances have occurred and that Green Diamond has not responded in accordance with this FHCP, the Service shall so notify Green Diamond and shall direct Green Diamond to make the required changes. Within 30 days after receiving such notice, Green Diamond shall make the required changes and report to the Service on its actions. Such changes are provided for in this FHCP, and hence do not constitute require amendment of this FHCP and ITP. If additional conservation and mitigation measures beyond those provided for in this FHCP are deemed necessary by the Service to respond to changed circumstances, the Service may not require any such additional conservation and mitigation measures without Green Diamond's consent, provided that Green Diamond is implementing this FHCP.

This FHCP includes the following nine potential changed circumstances as defined in applicable federal regulations and policies:

- Fire covering more than 1,000 acres but less than 10,000 acres
- Complete loss of 51% or more of previously standing timber within or immediately adjacent to a DCA due to a windstorm or fire
- Earthquakes affecting habitat for Covered Species
- Floods affecting habitat for Covered Species
- Loss of 51% or more of the total basal area within or immediately adjacent to any DCA as a result of Sudden Oak Death or stand treatment to control Sudden Oak Death
- Disease afflicting Covered Species
- Climate change/weather patterns affecting any of the Covered Species
- Lapse of state or federal permits necessary for barred owl removal experiments
- Listing of a species not a Covered Species but affected by the Covered Activities

If changed circumstances occur in the Plan Area, Green Diamond will implement the supplemental prescriptions in this section. In most cases, the conservation measures and adaptive management processes (Section 5.3) are adequate to address changed circumstances. There are no supplemental prescriptions included for those changed circumstances.

5.4.2 Fire

Fire suppression is not a Covered Activity. However, if a fire occurs in the Plan Area during the term of this FHCP, Green Diamond may take all measures reasonably necessary to extinguish such a fire, including measures that deviate from the other measures (Section 5.3). The strategy for responding to and suppressing forest fires is generally established by CAL FIRE, and Green Diamond may have little ability to influence such strategy. However, where reasonably possible and consistent with the primary goal of containing and extinguishing the fire, Green Diamond will encourage developing a fire-response strategy consistent with other measures (Section 5.3) that does not diminish the functions such measures provide. Once it (and/or others) extinguishes such a fire, unless such fire is an unforeseen circumstance (i.e., exceeds 10,000 acres in the Plan Area), Green Diamond will apply the following supplemental prescriptions on its fee-owned lands within the Plan Area:

- Consider for salvage any trees damaged or killed outright by fire, including those in DCAs. Removal of standing dead or damaged trees and downed trees will be conditioned by the application of the conservation standards in TREE.
- Conduct fire-related downed or dead tree salvage in compliance with state law and TREE.

Low intensity or fires of small scale (e.g., <5 acres) are not expected to have a long-term significant adverse impact on DCAs or habitat for any of the Covered Species and may have the beneficial effects of providing structurally complex trees. Thus, low intensity or small-scale fire does not pose so substantial an impact as to threaten an adverse change in the status of any Covered Species, and may actually benefit some species through production of habitat elements that Green Diamond may retain under the TREE (Section 5.3.2).

Within 30 days of its discovery, Green Diamond will provide the Service with information regarding fire causing damage to more than 51% of previously standing timber within or immediately adjacent to a DCA. If Green Diamond and the Service determine the DCA is no longer functional, a new DCA will be designated in the closest available NSO site that meets the necessary criteria for a DCA.

If the DCA remains functional, Green Diamond will apply the following supplemental prescriptions within the Plan Area after concurrence by the Service:

- Other than trees that are downed or dead due to the fire, Green Diamond will not remove more timber than it would have been allowed to remove had no fire occurred in the stand (Section 5.3), unless the Service determines removal of such additional timber would not materially reduce the habitat's functional benefit for any Covered Species.
- Conduct salvage of trees downed or dead by fire in compliance with state law and TREE. In addition, conducting any salvage operations within a DCA will be done to retain structural features that contribute to future habitat for the Covered Species.
- Reforestation of any DCA affected by the fire will be implemented as soon as reasonably possible.

5.4.3 Wind

Small-scale windthrow is not expected to have a long-term significant adverse impact on DCAs or habitat for any of the Covered Species and may have the beneficial effect of providing cover for fisher and some of the prey species of the NSO. Thus, small-scale windthrow does not pose so substantial an impact as to threaten an adverse change in the status of any Covered Species, and may actually benefit some species through production of cover habitat and recruitment of habitat elements that Green Diamond may retain under the TREE (Section 5.3.2).

Within 30 days of its discovery, Green Diamond will provide the Service with information regarding windstorms causing damage to more than 51% of previously standing timber within or immediately adjacent to a DCA. If Green Diamond and the Service determine the DCA is no longer functional, a new DCA will be designated in the closest available NSO site meeting the necessary criteria for a DCA.

If the DCA remains functional, Green Diamond will apply the following supplemental prescriptions within the Plan Area:

- Other than trees that are downed or dead due to the wind, Green Diamond will not remove more timber than it would have been allowed to remove had no windthrow occurred in the stand (Section 5.3), unless the Service determines removal of such additional timber would not materially reduce the habitat's functional benefit for any Covered Species.
- Conduct salvage of trees downed or dead by wind in compliance with state law and TREE. In addition, conducting any salvage operations within a DCA will be done to retain structural features that contribute to future habitat for the Covered Species.
- Reforestation of any DCA affected by the windstorm will be implemented as soon as reasonably possible.

5.4.4 Earthquakes

The Plan Area is in an area well known for frequent but generally small earthquakes. Earthquakes are quite common and generally are of a relatively insignificant magnitude, typically magnitude 2 to 3 on the Richter scale. Occasionally, greater magnitude events occur, but they are impossible to predict. In the forest environment, earthquakes of magnitude 6 or less on the Richter scale produce little, if any, visible change, and no significant impact to wildlife habitat. It is possible that some trees may fall from earthquakes; however, fallen trees in the forest are generally attributed to wind or landslide effects. Regardless of cause, fallen trees are not so significant in number as to require additional mitigations and/or changes in this FHCP's management scenario or restrictions. In fact, minor earthquake damage may contribute to recruiting habitat elements protected under the TREE measures (Section 5.3.2). Earthquakes of magnitude > 6 on the Richter scale substantially altering habitat status or requiring additional conservation or mitigation measures in excess of those already included in this FHCP are not reasonably foreseeable during the life of this FHCP, and would be considered unforeseen circumstances.

5.4.5 Floods

Floods are a natural and necessary component of aquatic and riparian ecosystems but can also cause damage to forest transportation systems (e.g. watercourse crossings, bridges, roads) and forest stands. Flood frequency and relative magnitude are inversely related. Large floods are infrequent while smaller floods may go unnoticed and recur as often as once a year. Severe floods may occur once in 15 or even 100 years. A flood of lesser magnitude than a 100-year recurrence interval event (i.e., less than a 100-year flood) is part of the forest's normal expected ecology. Such floods may cause a relatively small number of trees in RMZs to fall, break or lean due to bank erosion or collision with flood debris. This natural process may enhance the habitat complexity of riparian zones, thereby benefitting Covered Species. Based on historical evidence in the Plan Area, a flood equal or greater in magnitude to a 100-year recurrence interval event is not reasonably foreseeable during the term of this FHCP, and it would be considered an unforeseen circumstance.

5.4.6 Forest Pest or Pathogen Infestation

Careful forest management and proper treatments can usually keep forest insects and diseases under control. Site quality and nutrient availability play a key role in forest health and vigor. Because much of the Plan Area is of high site quality, infestations are less likely to occur within the healthy forests occupying these sites. Infestations by generally recognized types of forest pests or pathogens are not expected to have significant adverse effects on the Covered Species within the Plan Area. The recently identified sudden oak death disease caused by *Phytophthora ramorum* is a possible exception. If 51% or more of the pre-harvest total tree basal area within or immediately adjacent to any DCA is lost due to sudden oak death or stand treatment to control sudden oak death, a qualified wildlife biologist and RPF will conduct an on-site review identifying additional prescriptions compensating for hardwood tree loss. An infestation of sudden oak death that crosses to redwood or other conifers or infestation by other pests causing significant effect on the forest ecosystem within the Plan Area are not reasonably foreseeable and would be considered an unforeseen circumstance.

5.4.7 Disease afflicting Covered Species

All species of wildlife including the Covered Species have the potential to be adversely affected by various diseases. There was considerable concern about the potential impacts of West Nile Virus on NSOs after it was first discovered on the East Coast in 1999 and swept across all of North America by 2004. To assist a study by Dr. Alan Franklin, at Colorado State University, Green Diamond collected blood samples from NSOs in 2004 through 2006, but even though West Nile Virus was documented to occur in Humboldt County by 2005, it was never documented in any NSOs. The known diseases and parasites are not considered to represent a serious threat to NSO populations (USFWS, 2011a) and any disease outbreak that substantially influences survival or fecundity of NSOs would not be reasonably foreseeable and would be considered an unforeseen circumstance.

In contrast, fisher, like all meso-carnivores are susceptible to diseases such as rabies, plague, canine and feline distemper, toxoplasmosis, leptospirosis, trichinosis and a variety of other diseases and parasites. Despite all the diseases and parasites known to occur in fisher populations, none of these diseases or parasites had been thought to constitute a significant source of mortality in fisher possibly because of their solitary nature that results in weak transmission pathways (CDFG, 2010). However, there was evidence that fisher in the Hoopa Valley Reservation went through a dramatic decline from the late 1990's to the mid 2000's followed by an apparent recovery by the late 2000's (Higley and Mathews, 2009). During the same time, Green Diamond found evidence of a decline followed by recovery in fisher occupancy on their ownership (Section 4.4.3). Although the cause of the apparent decline and subsequent recovery was never determined, some putative disease phenomenon provides the best hypothesis given it occurred over such a large area with a short temporal scale. Although it is foreseeable that some disease or parasite agent could cause a substantial decline in the fisher population, it not likely to be a changed circumstance that can be mitigated or remedied by the conservation of habitat managed by Green Diamond. This FHCP provides ample high quality habitat for fisher that should allow the population to recover from any substantial decline brought on by disease. However, if there is required remedial action, Green Diamond will consider Service proposals to treat fisher or pathogens to address a particularly virulent disease outbreak.

Little is known of tree vole demographics including any influence diseases may have on their survival or fecundity. However, it is well documented that small mammals often exhibit cyclic population fluctuations, but the cause or causes of these fluctuations continue to generate many hypotheses and much debate among small mammal ecologists. Therefore, although it is foreseeable that some disease or parasite agent could cause a substantial decline in tree vole populations, Green Diamond does not consider this a changed circumstance that it can mitigate or remedy through habitat conservation or that warrants any conservation strategy changes.

This FHCP provides ample high quality habitat for tree voles that should allow the population to recover from any substantial decline brought on by a disease. However, if it were deemed necessary to take remedial action, Green Diamond will consider Service proposals to treat tree voles or pathogens to address a particularly virulent disease outbreak and provide assistance consistent with the resource emphasis and flexibility measures under the Adaptive Management Program in Section 5.3.6.

5.4.8 Climate Change/Weather Patterns

Rainfall substantially above average in the late winter and spring has a well-documented strong negative impact on NSO reproduction. The specific mechanism by which rain negatively affects nesting is unknown, but Green Diamond biologists have noted that NSO feathers get saturated in the rain and the birds fly with more difficulty and lose the quality of silent flight. Also, prey species are probably less active in the rain, which combined with the reduced flight capabilities lessens overall foraging success of NSOs. Regardless of reason, fluctuations in weather will cause fluctuations in nesting success, potentially leading to temporary NSO population declines. Green Diamond does not consider this a changed circumstance that can be mitigated or remedied by the conservation of habitat managed by Green Diamond and no changes to the conservation strategy would be warranted because there is no known mechanism to ameliorate the effects of weather. This FHCP provides for ample high quality NSO habitat that should allow the population to recover from any previous weather related population declines during periods of favorable weather conditions. In addition, Green Diamond may provide more habitat protection or reduce authorized take if the NSO population suffers a sustained decline. Green Diamond would consider it not reasonably foreseeable and an unforeseen circumstance if climate change causes substantially above average rainfall in the late winter and spring continuously for two decades or more resulting in continuous large-scale NSO nesting failures.

The relationship between weather and the demographics of fisher and tree voles is not known. Presumably, some weather conditions are more favorable, but any attempt to predict how weather changes may influence any of these mammal species is purely speculative. It is foreseeable that fluctuations in weather will cause fluctuations in the populations of fisher and tree voles, but Green Diamond does not consider this a changed circumstance that can be mitigated or remedied by the conservation of habitat managed by Green Diamond and no changes to the conservation strategy would be warranted. This FHCP provides ample high quality habitat for these species that should allow their populations to recover from any previous weather related declines during periods of favorable weather conditions. Therefore, climate change resulting in a long-term shift in weather patterns leading to a continuously declining population in any of the covered mammalian species for two decades or more is not reasonably foreseeable and is considered an unforeseen circumstance.

5.4.9 Lapse of state or federal permits necessary for barred owl removal experiments

This FHCP includes conservation objectives and barred owl removal experiments that contribute to the conservation and recovery of NSO. The experiments require federal and state authorization in addition to the 50-year ITP that would be issued to Green Diamond based on this FHCP. If the barred owl experiments are interrupted by a lapse in federal or state permits, Green Diamond and the Service will confer and work cooperatively to seek reinstatement or reissuance of the necessary state and/or federal permits. Green Diamond will continue to implement all other conservation measures that are beneficial to NSO under this FHCP with assurances under the No Surprises rule.

A lapse in either state or federal permits necessary to conduct removal experiments, if prolonged, could lead to an apparent substantial NSO population decline in terms of NSO sites in the Plan Area. Because there are no known habitat approaches to ameliorate barred owl impacts on NSOs (Dugger et al., 2016), Green Diamond does not consider this to be a changed circumstance that it can mitigate or remedy by changes to the habitat elements of the conservation program. However, Green Diamond will work diligently with the Service to restore the necessary permits and resume barred owl experiments before any long-term negative impacts occur in the NSO population.

The results from Phase One of the barred owl removal experiment on Green Diamond's ownership and other studies throughout the range of the NSO have already demonstrated barred owls have a substantial negative impact on NSO populations (Section 4.3.1) (Dugger et al., 2016; Diller et al., 2016). If additional results and studies confirm these preliminary trends, it will indicate that it may be difficult to achieve some FHCP objectives for the NSO without removal of barred owls from at least portions of the Plan Area. While it would have a short-term detrimental influence on the NSO population of the Plan Area, a lapse in permitting for the barred owl experiment would not threaten NSO conservation in the Plan Area unless it continued for the duration or extended periods (e.g., >10-15 years) of this FHCP. Based on the future quantity and quality of NSO habitat and the results of the Phase One removal experiment showing an increase in the NSO population following the initiation of barred owl removals (lambda (λ) = 1.029 for NSO in the treated areas), Green Diamond projects an increase in the number of NSO sites following approval of this FHCP, and a proposed Plan Area-wide barred owl removal experiment (Section 5.3.1). However, all recent studies of NSO populations throughout the range of the species have indicated that NSO populations will decline, regardless of the amount of high quality habitat, if competition from the barred owl is not controlled (Dugger et al., 2016). If there were to be an extended interruption of either federal or state permits authorizing barred owl removal, the NSO population in the Plan Area is expected to decline.

The decline in NSO sites described above represents territorial owls at NSO sites, but it does not necessarily reflect the total NSO population on a landscape increasingly dominated by barred owls. There is increasing evidence that barred owls primarily impact NSO by displacing them from their territories, but they do not necessarily cause an increase in mortality rates. The presumption is that NSO are displaced into the floater population where they continue to survive but either do not reproduce or at a much-reduced rate. The immediate increase in both apparent survival rates and lambda following barred owl removal supports the hypothesis that displaced spotted owls in the floater population are able to regain territorial status and become available to be detected (Diller et al., 2016). Empirical observations of banded spotted owls recolonizing their original territories provide further support for this hypothesis. A telemetry study by Wiens et al., (2014) also provided strong evidence that barred owls are responsible for interference competition with NSO which limit their access to suitable habitat. This indicates that short term interruptions in permitting (<10 years) would likely allow NSO populations to recover quickly after reinitiating efforts to control barred owls (Diller et al., 2016).

If there is an interruption in permitting for implementation of barred owl experiments, Green Diamond will work diligently with the agencies to quickly restore permits. Green Diamond will also implement the following FHCP measures immediately and for the duration of the lapse in permit(s):

- Upon interruption in state or federal MBTA permit for conducting barred owl removal experiments, Green Diamond will continue or resume (if in post-model validation phase of FHCP) full demographic surveys at NSO sites within the Plan Area (Appendix F).
- Green Diamond will document the number of occupied NSO sites in the next annual report to establish the baseline from which to evaluate NSO population response to barred owl colonization events.
- When the NSO population declines below the initial FHCP baseline (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al. 2016 if pre-model validation or a statistically significant lower occupancy rate if post-model validation, Section 5.3.6.1), Green Diamond will implement additional FHCP measures to identify and avoid taking the most productive NSO sites during the period of permit interruption.
- Green Diamond will conduct an analysis of NSO site histories to evaluate NSO site occupancy and fecundity and those NSO sites affected by barred owls.
- The most productive NSO sites (combination of occupancy and fecundity) from the analysis will be compared to the current suite of 44 DCAs that are no take (Section 5.3.3.4).
- Green Diamond will consult with the Service to determine if the suite of DCA sites should be adjusted to a different suite of 44 DCAs during the period of permit interruption taking into consideration the criteria for determining a DCA (Section 5.3.1.4.4).
- Consistent with Adaptive Management Commitment Two (Section 5.3.6.1), when the NSO population declines below the initial FHCP baseline (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al. 2016 if pre-model validation or a statistically significant lower occupancy rate if post-model validation, Section 5.3.6.1), indicating a negative trend, a preliminary review will attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management. In the event of an interruption in barred owl removal experiment permits and cessation of removal actions, it is likely and foreseeable that the cause of the NSO decline will be related to barred owl colonization events.
- In response to the Adaptive Management Triggers (Section 5.3.6.1), and if warranted by the adaptive management assessment process, Green Diamond will implement changes in the following components of the Conservation Program:

    - Green Diamond may use the established AMRA to fund the management adjustments that may be made during the life of this FHCP.
    - For NSO, the adaptive management account provides for additional habitat protection based on objective performance triggers and empirical understanding of NSO habitat use.
    - The AMRA will be credited with an opening balance of 1068 acres for any combination of expansion of existing DCAs or creation of additional DCAs.

- At the time when the barred owl removal experiment permits are reissued, Green Diamond will consult with the Service to assess the suite of DCA sites in place at that time (a minimum of 44 plus additional NSO sites identified through Adaptive Management).
- Any additional DCAs that may have been created as part of the AMRA will remain in place until the NSO population recovers to levels exceeding the baseline that triggered adaptive management (i.e., 95% confidence interval overlaps 1.0 as described in Dugger et al. 2016 if pre- model validation or a statistically significant higher occupancy rate if post-model validation, Section 5.3.6.1).

- After analysis and consultation with the Service, Green Diamond will delineate and return to the baseline number of 44 DCAs and FHCP measures associated with DCAs (5.3.1.4.4).

This FHCP calls for a diminishing level of take as the number of active NSO sites declines any time throughout the Permit term (Section 6.2.3). In the event of an interruption of barred owl removal, a key question is how rapidly that decline might occur and what would be the projected effect, over time, on the permitted level of take. In the event of a decline in the NSO population within the Plan Area due to barred owl competition, regardless of how rapidly it might occur, this FHCP first reduces, and if the decline continues to a key threshold, eliminates the NSO take authorized under the Permit. The initial rate of take as described in this FHCP (Section 6.2.3) is set at a maximum of 3 takes per 100 NSO sites. However, regardless of the cause, no take is authorized if the number of NSO sites drops to 47. If a lack of permitting for barred owl experiments results in an NSO population decline that triggers adaptive management and delineation of additional DCAs to provide demographic support to the NSO population, there will be no take of additional DCA sites within the plan area occupying up to an additional 1068 acres of habitat from the AMRA.

There are a variety of permitting technicalities or legal challenges that might interrupt the barred owl experiment permitting process for a period to time – most likely of a short 2- to 5-year duration -- which would cause a dip in the NSO population in the Plan Area. However, such a circumstance would not likely be of sufficient duration to require any adjustments to authorized incidental take. The rapid positive effects Green Diamond observed on the NSO population following initiation of barred owl removal within the treated portion of the study area (Dugger et al., 2016; Diller et al., 2016) may not be realized in the future with likely increases in regional barred owl population. It may be difficult to effectively remove barred owls in some of the smaller isolated tracts in the Plan Area, but there are also multiple large tracts from which barred owl removal should be highly effective as seen in the initial removal experiment. Therefore, we anticipate that any declines in the NSO population due to periodic interruption in permits would be offset or ameliorated by increases in the NSO population during periods of implementation of the barred owl removal experiment. We believe it is highly unlikely that the Service and Green Diamond could do nothing to resolve the permitting hiatus for decades while the NSO population declined to 47 sites. Furthermore, if Green Diamond were unable to obtain the necessary permits, presumably other land managers would be in a similar situation and the NSO population would be in precipitous decline range wide. If ongoing and future studies continue to support the conclusion that barred owls are responsible for NSO declines, and additional studies show that barred owl removal is both feasible and effective, it is unlikely that authorizations necessary for barred owl control would be permanently withheld resulting in the Plan Area NSO population declining to the threshold number of NSO sites that would result in suspension of incidental take authorization.

5.4.10 New Listing of Species Not Currently Covered Species

The preamble to the No Surprises rule states that the listing of a species as endangered or threatened could constitute a changed circumstance. Therefore, if a species is listed under the federal ESA subsequent to the effective date of the Permits, and that species (i) is not a Covered Species, and (ii) is affected by the Covered Activities, such listing will constitute a changed circumstance.

In the event that a non-Covered Species that could be affected by Covered Activities becomes listed as threatened or endangered under the ESA during the term of this FHCP and ITP, Green

Diamond shall not have incidental take authority with respect to such newly-listed species unless and until the ITP is amended to include such species or other authorization is provided pursuant to the ESA. Upon receipt of notice of the proposed listing of a species that may occur in the Plan Area but that is not a Covered Species, Green Diamond shall seek the technical assistance of the Service, and the Service shall provide the following assistance, in the event the species is ultimately listed:

(i) Identify possible measures to avoid take and avoid causing jeopardy to such species.

(ii) Determine whether incidental take coverage for such species is appropriate; and, if so.

(iii) Identify any modifications to this FHCP that may be necessary to provide incidental take coverage for the new species and assist Green Diamond in determining whether to amend this FHCP and the ITP to include the newly-listed species as a Covered Species.

Should an unlisted non-Covered Species become listed during the term of this FHCP and ITP, neither such occurrence nor this provision shall be construed to require the Service to reinitiate internal consultation under Section 7 of the ESA with regard to its prior approval of this FHCP and issuance of the ITP, consistent with *Environmental Protection Information Center v. The Simpson Timber Co*., 255 F.3d 1073 (9th Cir. 2001).

5.4.11 Unforeseen Circumstances

"Unforeseen Circumstances" means changes in circumstances affecting a Covered Species or geographic area covered by this FHCP that could not reasonably have been anticipated by Green Diamond and the Service at the time of this FHCP's negotiation and development, and that result in a substantial and adverse change in the status of the Covered Species. (50 CFR § 17.3)

All changes in circumstances affecting a Covered Species or its habitat in the Plan Area that are not described previously as Changed Circumstances are considered not reasonably foreseeable in the context of this FHCP. For the purposes of this Plan, such changes are Unforeseen Circumstances. In the event that Unforeseen Circumstances occur, Green Diamond will make Plan modifications according to the No Surprises Assurances and procedures set forth in the Service's No Surprises rule.

5.4.12 "No Surprises" Assurances" Provided that Green Diamond has complied with its obligations under this FHCP and the ITP, the Service can require Green Diamond to provide mitigation beyond that provided for in this FHCP only in accordance with the ESA "No Surprises" regulations in 50 C.F.R. §§ 17.22(b)(5) and 17.32(b)(5) as they exist as of the Effective Date. If such No Surprises regulations are modified or amended after the Effective Date, such modifications or amendments shall not apply to this FHCP and ITP unless reliance on the regulations in effect as of the Effective Date is prohibited by statute or court order.

If the Service makes a finding of Unforeseen Circumstances, it shall have up to 120 days, or a longer period with Green Diamond's consent, to determine the nature and location of additional or modified mitigation required to address the Unforeseen Circumstances. During such period, Green Diamond agrees to avoid undertaking any activity that would appreciably reduce the likelihood of the survival and recovery of the affected Covered Species.

In the event that Green Diamond is wholly or partially prevented from performing the obligations of this FHCP because of unforeseeable causes beyond the reasonable control of and without the fault or negligence of Green Diamond, including but not limited to third party actions, sudden actions of the elements not identified as Changed Circumstances, or actions of a non-participating federal agency, state agencies or local jurisdictions, Green Diamond shall be excused from whatever performance is affected by such unforeseeable cause to the extent so affected, provided that nothing in this section shall be deemed to authorize any Party to violate the ESA, and provided further that:

- The suspension of performance is of no greater scope and no longer duration than is required by the unforeseeable cause.
- Within 15 days after the occurrence of the unforeseeable cause Green Diamond shall give the Service written notice describing the condition, an estimate of how long Green Diamond expects it to persist, and how Green Diamond plans to remedy the effects of the temporary suspension of performance.
- Green Diamond shall use its best efforts to remedy its inability to perform.
- When Green Diamond is able to resume performance of its obligations, Green Diamond shall give the Service written notice to that effect.

5.5 SUMMARY OF OPERATING CONSERVATION PROGRAM COMMITMENTS

Landscape Management Commitment One (Objective 1A): When planning and seeking approval of THPs for future timber harvests, Green Diamond will incorporate into all THPs measures that provide long-term retention and recruitment of late seral habitat elements that are beneficial to NSOs, fisher and tree voles. Those measures include:

- Riparian management zones and retention associated with geologically unstable areas (Section 5.3.1.3)
- Designation and protection for DCAs (Section 5.3.1.4)
- Group and individual tree retention in harvest units in conjunction with the plan for TREE (Section 5.3.2)

Landscape Management Commitment Two – Riparian and Geological Management Measures (Objective 1A): Green Diamond will implement all of the following measures:

- Class I RMZ Characteristics – Green Diamond will establish a RMZ of at least 150 feet (slope distance) on each bank of all Class I watercourses[10] in the Plan Area. The width will be measured from the watercourse transition line or from the outer Channel Migration Zone (CMZ) edge where applicable.

  Where the floodplain is wider than 150 feet on one side, the outer zone of the RMZ will extend to the outer edge of the floodplain.

[10] Class I watercourse is defined as all current or historical fish-bearing watercourses and/or domestic water supplies that are on site and/or within 100 feet downstream of the intake. The watercourse transition line is defined as that line closest to the watercourse where perennial vegetation is permanently established. The Channel Migration Zone is defined as Current boundaries of bankfull channel along the portion of the floodplain that is likely to become part of the active channel in the next 50 years. The area of the channel defined by a boundary that generally corresponds to the modern floodplain but may also include terraces that are subject to significant bank erosion.

An additional buffer will be added to the RMZ immediately adjacent to a floodplain, as follows:

Slide Slopes	Additional Floodplain Buffer
0-30%	30 feet
30-60%	40 feet
>60%	51 Feet

Green Diamond will establish an inner zone within each RMZ, the width of which will depend upon the streamside slope in accordance with the following:

Side Slopes	Inner Zone Width
0-30%	50 feet
30-60%	60 feet
>60%	70 Feet

Green Diamond will also establish an outer zone within each RMZ, which will extend from the outside limit of the Inner Zone edge to at least 150 feet from the bankfull channel (or CMZ edge) with the additional floodplain buffer set forth above.

- Conservation Measures within Class I RMZs:
  - Single Harvest Entry – During the life of this FHCP, Green Diamond will carry out only one harvest entry within Class I RMZs, which will coincide with the even-aged harvest of the adjacent stand. The only exception will be light thinning conducted with the specific objective of enhancing wildlife structure. If cable corridors through RMZs are necessary to conduct intermediate treatments, e.g., commercial thinning, in adjacent stands before even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stands.
  - Overstory Canopy Closure:
    - Green Diamond will retain at least 85% overstory canopy closure within the Inner Zone
    - At least 70% canopy overstory closure will be retained within the Outer Zone

    CAL FIRE protocol in effect as of the date of this FHCP will be used for sampling overstory canopy cover to determine compliance with the overstory canopy closure requirements.

- Class II RMZ Characteristics – Green Diamond will establish an RMZ of at least 75 or 100 feet on each bank of all Class II watercourses[11], as follows:

  - A 75-foot minimum width will be used on the first 1,000 feet of 1st order Class II watercourses (Class II-1 watercourses[12]). Downstream of this first 1000-foot section, the RMZ will be expanded to at least 100 feet.
  - A 100-foot minimum width will be used on all 2nd order or larger Class II watercourses (Class II-2 watercourses[13]).

    Green Diamond will establish an Inner Zone within the RMZ, the width of which will be 30 feet measured from the first line of perennial vegetation.

    Green Diamond will also establish an Outer Zone within the RMZ, which will extend the remaining 45 feet or 70 feet (depending on whether it is a Class II-1 watercourse or a Class II-2 watercourse, respectively).

  - Conservation Measures within Class II RMZs:

    - Single Harvest Entry – During the life of this FHCP, Green Diamond will carry out only one harvest entry into Class II RMZs, which will coincide with the even-aged harvest of the adjacent stand. The only exception will be light thinning conducted with the specific objective of enhancing wildlife structure. If cable corridors through RMZs are necessary to conduct intermediate treatments, e.g., commercial thinning, in adjacent stands before even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to the cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stand.

    - Overstory Canopy Closure:

      - Green Diamond will retain at least 85% overstory canopy closure within the Inner Zone

      - At least 70% overstory canopy closure will be retained within the Outer Zone

- Class III RMZ Characteristics – Additional tree retention will occur in certain Class III watercourses[14] to maintain stream bank stability, and in geologically unstable areas. However, tree retention associated with unstable areas is a relatively minor component (approximately 10%) of the total riparian retention. Appendix D includes details of the prescriptions associated with Class III watercourses and geologically unstable areas.

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[11] A Class II watercourse is defined as a watercourse that contains no fish, but supports or provides habitat for aquatic vertebrates. Seeps and springs that support or provide habitat for aquatic vertebrates are also considered Class II watercourses with respect to the conservation measures.
[12] A *Class II-1 watercourse* is defined as a subset of Class II watercourses, as illustrated in Appendix C.
[13] A Class II-2 *watercourse* is defined as a subset of Class II watercourses, as illustrated in Appendix C.
[14] A *Class III watercourse* is defined as small seasonal channels that do not support aquatic species, but has the potential to transport sediment to Class I or II watercourses.

- Conservation Measures within Class III Equipment Exclusion Zones (EEZs) – Green Diamond will apply one of two tiers of protection measures within Class III watercourses in accordance with HPA Groups and slope gradient (the average slope as measured with a clinometer, starting from the watercourse bank and running upslope for a distance of 50 feet), as follows:

HPA Group	Slope Gradient
Smith River	<65%=Tier A >65%=Tier B
Coastal Klamath	<70%=Tier A >70%=Tier B
Korbel	<65%=Tier A >65%=Tier B
Humboldt Bay	<60%=Tier A >60%=Tier B

- Class III Tier A Protection Measures:
  - EEZ:
    - Green Diamond will establish a 30-foot EEZ, except for a) existing roads; b) road watercourse crossings; and c) skid trail watercourse crossings.
    - The exception for skid trail watercourse crossings is only applicable when the following conditions are met – Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to using existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.
    - Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
  - Large Woody Debris (LWD) Retention – Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ
  - Site Preparation – Green Diamond will not ignite fire during site preparation within the EEZ

- Class III Tier B Protection Measures:
  - EEZ – Green Diamond will establish a 50-foot EEZ, except for existing roads, road watercourse crossings, and skid trail watercourse crossings.
  - The exception for skid trail watercourse crossings is only applicable when the following conditions are met – Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in

substantially greater impacts to aquatic resources. Preference shall be given to using existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.

- Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
- Hardwood Retention – Green Diamond will retain all hardwoods and nonmerchantable trees within the EEZ except where necessary to create cable corridors or for the safe falling of merchantable trees.
- Site Preparation – Green Diamond will not ignite fire during site preparation within the EEZ.
- Conifer Retention – Green Diamond will retain conifers where they contribute to maintaining bank stability or if they are acting as a control point in the channel.
- A minimum average of one conifer 15 inches DBH or greater per 50 feet of stream length within the EEZ will be retained.
- LWD Retention – Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ.

- Geological Management Measures – Green Diamond will establish a variety of measures to address geologically unstable areas. These measures include retention of trees to minimize and mitigate sediment input from steep streamside slopes, headwall swales, deep-seated landslides and shallow rapid landslides. The criteria for tree retention are relatively complex and often region-specific within the Plan Area so the full details are included in Appendix D under "Slope Stability Measures" (pp D-11 to D-15.)

Landscape Management Commitment Three (Objective 1B): Green Diamond will establish an initial set of 44 DCAs in the IPA immediately upon issuance of the ITP (Table 5-1). Green Diamond designates 44 DCAs in the IPA and will maintain a minimum of 44 DCAs in the IPA throughout the term of this FHCP. Green Diamond selected the initial DCAs because of their demonstrated ability to provide high site occupancy and fecundity for NSOs and because they provide a good spatial distribution across the IPA.

- DCAs are designed to provide a core nesting area for a single pair of NSOs with a minimum no-harvest core area of 89 acres of nesting/roosting habitat where available.
- NSO sites within DCAs will be managed to include within a 0.5-mile circular buffer (502 acres):

  - 89 acres of forest stands 46 years old and older, and
  - 233 acres of stands 31 years old and older

- Clearcut timber harvest immediately adjacent to a DCA (i.e., harvest unit boundary is in contact with the DCA boundary) must comply with adjacency requirements providing a biologically more conservative strategy. These requirements include adjacent stands being at least 6 years old or 10 feet tall, but not < 6 years with other harvest units that are also immediately adjacent to the DCA. This provision essentially doubles requirements of the current (2013) California Forest Practice Rules regarding age and tree regrowth in adjacent stands and by providing time for recolonization of woodrats, is designed to improve foraging habitat conditions in forest stands adjacent to DCAs. This provision does not change FPR for separation of units, or distances of separation, or size of individual harvest units. Should FPRs change during the term of this FHCP, adjacency requirements will be implemented as stated in this section (i.e., based on adaptation of FPRs in place upon signing), or future requirements of revised FPRs, whichever provides more biological conservation value to the covered species. The size of even-age management units, which can be no more than 20 acres for non-shovel yarded ground-based systems, 30 acres for aerial, cable or shovel yarding systems, and 40 acres when justified according to specified criteria (14 CCR 913.1[a][2]).

- The distance between even-age management units, which must be "separated by a logical logging unit that is at least as large as the area being harvested or 20 acres, whichever is less, and must be separated by at least 300 feet in all directions" (14 CCR 913.1[a][3]).
- The timing of the harvest of contiguous even-age management units, which cannot occur unless regenerating stand in a previously harvested, adjacent clearcut unit is at least 5 years of age or 5 feet tall, and three years of age from the time of establishment on the site (14 CCR 913[a][4][A]).

Landscape Management Commitment Four (Objective 1B): Upon approval of this FHCP, timber harvesting within formerly designated set-asides in the Plan Area that are not designated as DCAs will be planned and implemented to delay take of any existing NSO sites within the former set-aside. Owl sites within formerly designated set-asides with a history of high rates of occupancy and/or reproduction (i.e., highly functional) have been included in the initial DCA network, and will be protected consistent with provisions for DCAs. Other owl sites within formerly designated set-asides not included in the initial DCA network may be subject to take, depending on their history of occupancy, and actual scheduling and location of future timber harvest. However, harvest units within these areas will be scheduled in a manner to delay take of NSO sites as long as possible within the constraints of the FPRs adjacency requirements. The harvest unit containing the current NSO site will be the last unit scheduled in the harvesting sequence. Any such taking will be accounted for, according to take accounting procedures described in Section 6.

Landscape Management Commitment Five (Objective 1B): Monitoring, spatial distribution and replacement of DCAs will be governed by the following set of rules:

- Green Diamond can delineate new DCAs to replace existing DCAs, but a replacement DCA must be in the same NSO OMU, or if the DCA is near the border of an OMU, the OMU immediately adjacent.
- Green Diamond will evaluate DCAs for potential replacement if there is reduced biological functionality. A replacement may be warranted, if the new DCA meets or exceeds the DCA functional criteria (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25, averaged over the last four years) or has a substantially higher (approximately 25%) occupancy and fecundity relative to the DCA to be replaced.
- Green Diamond may replace a DCA for economic reasons or to meet other company business objectives if the new DCA meets the DCA functional criteria or has substantially higher (approximately 25%) occupancy and fecundity relative to the replaced DCA with no extenuating circumstances.
- Green Diamond will not replace DCAs for at least five years after the Plan Area-wide barred owl experiment has gone into effect.
- Green Diamond will survey DCAs annually using a protocol designed to achieve an overall 95% probability of detecting NSOs if they are present.
- Green Diamond will designate one additional DCA for each incremental net increase in the Plan Area of 8,000 acres added to the IPA. Each additional DCA will be located

within the scope of the added Covered Lands and will either meet the criteria for a DCA or be designated as a contingent DCA with the concurrence of the Service.

In the past, commercial thinning and unevenaged silviculture under California FPRs was a minor component of Green Diamond's silvicultural treatments. Accordingly, these practices were not evaluated for effects on habitat for Covered Species in the Plan Area. Accordingly, 'silviculture' will be included as a covariate in analyses of site occupancy for NSO and fisher, or an analysis of fecundity, or lambda for NSO. If the 'silviculture' covariate enters any of the top competitive models for any of these analyses, Green Diamond will initiate studies to assess the habitat value of stands generated from other silvicultural prescriptions (Section 5.3.6).

Landscape Management Commitment Six (Objective 1A, 1D): Green Diamond will include 'silviculture' as a covariate in analyses of site occupancy for NSOs and fisher, or an analysis of fecundity, or lambda for NSOs.

- If the 'silviculture' covariate enters any of the top competitive models for any of these analyses, Green Diamond will initiate studies to assess the habitat value of stands generated from silvicultural prescriptions other than regeneration harvest.
- If research indicates that silvicultural prescriptions resulting in retention of important habitat conditions, such as moderate to high canopy closure, multi-layered stands, or understory conditions more favorable to Covered Species, Green Diamond will consider adaptive management options (Section 5.3.6) to implement these silvicultural practices to improve conservation of those species.

Habitat Element Retention Commitment One (Objective 2A): Green Diamond shall implement the TREE Guidelines for Green (Live) Tree and Snag Retention

A. Candidate Tree Selection:

- Retain large defective trees using the TREE's tree retention scorecard
- Retain defective or poorly formed trees, e.g., animal damaged, forked top, broken top, mistletoe broom, etc.
- Retain a mix of conifers and hardwoods (approximately 50/50 mix where possible
- Retain conifer species preference: Douglas-fir, hemlock, white fir, cedar, spruce, redwood
- Retain hardwood species preference: tanoak, Pacific madrone, California laurel, chinquapin
- Consider protection from wind throw and site preparation burning when designating HRA and tree clump locations
- Retain trees with the average diameter equal to or greater than the average diameter of trees in the THP area

B. Retention Guidelines – Evaluate the method and level of tree retention needed within each THP unit as follows:

- Conifer Dominated Harvest Areas[15] with RMZ Retention:

[15] Forest stands with >15,000 board feet of conifer per acre.

- Retain all scorecard trees ≥7
- Retain other evergreen hardwoods at a rate of two trees per clearcut acre where they exist

- Conifer Dominated Harvest Areas without RMZ Retention:

  - Retain all scorecard trees ≥7
  - Retain other conifer at a minimum rate of one tree per clearcut acre.
  - Retain other qualifying evergreen hardwoods at a rate of two trees per clearcut acre where they exist. If the unit lacks hardwoods to meet minimum retention standards, retain an additional conifer up to two trees per acre if harvest unit is in a one or two tree per clearcut acre retention area.
  - Retention should be a combination of approaches (HRA, tree clumps or scattered trees). HRAs are typically prescribed in cable yarding areas since this type of clumped retention is more practical in these areas. Trees retained in Streamside Management Zones (SMZs) and Class III Tier B areas count toward overall tree retention.

- Hardwood Dominated Harvest Areas[16] with RMZ Retention:

  - Retention in all hardwood dominated areas is at least two trees per clearcut acre regardless of the watershed
  - Retain all scorecard trees ≥7
  - Retain scattered or clumped evergreen hardwood trees at a rate of two trees per clearcut acre and also retain conifer trees scoring ≥7

- Hardwood Dominated Harvest Areas without RMZ Retention:

  - Retain all scorecard trees ≥7
  - Retain ½ acre HRA or clumps totaling 0.5 acres and scattered evergreen hardwood trees at a rate of two trees per clearcut acre

C. Relationship with Snag and RMZ Retention – Live tree retention is in addition to snag and RMZ retention. Green trees retained as described in these retention guidelines will augment structure provided by snag retention and within AHCP areas, i.e., Green Diamond will not include retained snags and trees left within RMZs as part of the count for Wildlife Tree Retention.

D. Live Tree Retention Scoring Criteria Used for Identification of Existing Wildlife Habitat Elements (Appendix E, TREE for definitions):

- Dbh – Conifers ≥30 inches and Hardwoods ≥18 inches (3 points)
- Bole features:

  - Trees with an internal hollow or large cavity (4 points)
  - Trees with a small cavity, internal rot or mistletoe broom (2 points)
  - Trees with crevice cover, i.e., loose or deeply furrowed bark (1 point)

[16] Forest stands with <15,000 board feet conifer per acre and dominated by hardwood stems.

- Crown features – Trees with complex crown, lateral large limbs, epicormic branching (1 point)
- Vole nest factor – Tree containing an active or remnant tree vole nest having canopy connectivity with existing RMZ/Geological retention (2 points) and all others (1 point)
- Unit scarcity factor, i.e., post-harvest density of late seral habitat elements, <1 acre (2 points), >1/acre but <2/acre (1 point), >2/acre (0 points)
- Watershed scarcity factor, i.e., planning watershed factor is determined programmatically and is added to the total score, impaired or special wildlife value (1 point), all others (0 points)

Covered Species Protection Commitment One (Objective 3A): According to the NSO survey protocol (Appendix F), Green Diamond will conduct pre-harvest NSO surveys in all harvest units planned for timber harvest during the period when NSOs may be incubating eggs, brooding nestlings or caring for recently fledged juveniles (21 February through 31 August) and will avoid timber harvest in that unit during that period if breeding NSOs are detected, and activities have the potential to harm, kill or injure NSOs.

Covered Species Protection Commitment Two (Objective 3B): If fisher monitoring (Section 5.3.5.2) or other activities reveal an active den, the site will be protected with a 0.25-mile radius no-harvest buffer until it has been determined that the den has been abandoned or the fisher kits have been moved to another den tree more than 0.25 miles from the harvest area. Any confirmed den trees will be retained.

Covered Species Protection Commitment Three (Objective 3B): Green Diamond will ensure all water tanks and pipes used for timberland management in the Plan Area are fisher-proofed to prevent entrapment and/or drowning. Green Diamond will ensure that any such facility or structure found to not be secured in the future will be repaired, retrofitted, or replaced in a timely manner to ensure its inaccessibility to fishers. Included in the first annual report will be a catalog and map of all current and abandoned water tanks within the Plan Area and documentation that each structure has been checked at least once a year to ensure that it is secured against potential entry by fishers.

Covered Species Protection Commitment Four (Objective 3B): Green Diamond will cooperate in any Service- and CDFW-approved fisher capture and relocation/ reintroduction recovery project, following guidelines for fisher protection during the capture and relocation process and provided that removal of individual fisher does not compromise the fisher occupancy and population objectives of this FHCP.

Covered Species Protection Commitment Five (Objective 3C): When, in limited circumstances, Green Diamond conducts partial harvesting activities within RMZs and geological areas, it will avoid felling trees containing tree vole nest(s). Foresters will inspect potential harvest trees before marking to avoid felling trees with active or remnant vole nests.

Covered Species Protection Commitment Six (Objective 3D): To discourage and prevent unauthorized marijuana cultivation and associated abuse of pesticides in the Plan Area, Green Diamond will maintain a system of controlled access for the Plan Area using locked gates on roads, security patrols, and written permits for authorized use of the Plan Area. To detect and remove unauthorized activities, Green Diamond will maintain security patrols for the Plan Area, conduct at least one annual aerial surveillance for marijuana cultivation hot spots where Covered Species are likely to be exposed to pesticide use in the Plan Area, and provide annual safety training for field employees on detection and reporting of suspicious and unauthorized use of the Plan Area. When unauthorized marijuana cultivation and/or pesticide abuse is detected by Green Diamond, it will be reported to local law enforcement. If Green Diamond finds evidence of pesticide abuse that may take Covered Species, it will report the circumstances to the Service for investigation and possible prosecution.

Barred Owl Research Commitment One (Objective 4A): Implement the phase two Plan Area-wide barred owl removal experiment (Section 5.3.4.2). All phases of barred owl experiments and research will require approval from appropriate agencies regarding permits and authorizations.

Barred Owl Research Commitment Two (Objective 4C): Following completion of the phase two experiment and concurrence by the Service, implement the phase three barred owl invasion and co-existence experiments (Section 5.3.4.3).

NSO Monitoring Commitment One (Objective 5B): Using future survey results gathered throughout the Plan Area, Green Diamond will compare the estimated number of occupied NSO sites in the three NSO regions to overall habitat fitness values, in accordance with the procedures and assumptions described in Section 5.3.5.1. Validation of the habitat fitness model will be achieved when the overall observed long term trend in occupied owl sites is statistically shown to be stable or increasing ($P = 0.95$) as predicted by the average of all OMUs within the NSO regions, as agreed upon by Green Diamond and the Service, and consistent with the intent of this section.

NSO Monitoring Commitment Two (Objective 5B): Within three years of signing this FHCP, Green Diamond will construct an initial multi-state site occupancy model. The model will be used to develop projections of NSO occupancy and fecundity. The comparison of expected versus observed occupied NSO sites with successful nesting will not be used as a threshold or trigger for achieving FHCP model validation. However, it will be a requirement to have successfully completed an NSO multi-state site occupancy model before the new FHCP conservation measures contingent on model validation will be implemented, because it will be used to predict where an NSO site is likely to occur for estimating take following model validation (Section 5.3.5.1). It may also lead to a more useful habitat model for management purposes and thresholds for estimating when take may occur. It should be noted that some details of the model-based displacement assessment may change if Green Diamond gains new insight into the response of NSO to timber harvesting during the process of model validation. The Service will have input on model revisions including model selection

NSO Monitoring Commitment Three (Objective 5B): If the NSO population increases in the Plan Area, as predicted, and Green Diamond validates the projections of the habitat fitness model, then direct monitoring of the entire NSO population across the Plan Area will be replaced by monitoring habitat conditions projected by the multi-state site occupancy or some other improved future model along with monitoring all the DCAs and at least 12 additional spatially stratified randomly selected sites. Furthermore, at least 20% of the potential take sites will be monitored annually and site occupancy surveys will continue throughout the Plan Area (Section 6.2.3).

NSO Monitoring Commitment Four (Objective 5B): Unless and until Green Diamond validates a habitat fitness model, Green Diamond will continue the extensive NSO surveys and mark-recapture data collection.

NSO Monitoring Commitment Five (Objective 5C): If the overall NSO population is declining relative to the baseline 6 years after FHCP approval and initiation of barred owl removal, a preliminary analysis in conjunction with the Service will be conducted to attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management. If after 10 years there is evidence of a statistically significant (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al. 2016) decline in the Plan Area NSO population relative to the NSO population at the initiation of barred owl removal, Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken. Adaptive Management measures to be considered are described in Section 5.3.6. The Adaptive Management measures described in that section are intended to anticipate potential future responses. Additional Adaptive Management measures may be considered by Green Diamond, as they may more appropriately address causes of future NSO decline, should declines be documented according to these commitment standards.

NSO Monitoring Commitment Six (Objective 1B, 5C): Green Diamond will annually assess the mean reproductive success of the NSO population in the Plan Area at all DCAs plus a minimum of 12 other NSO sites selected by a spatially stratified random sample will be assessed to determine the mean reproductive success of the NSO population in the Plan Area. The 12 additional sites will be randomly selected at a rate of one per OMU unless additional sites are not available. Sites in adjacent OMUs may be substituted where deficiencies exist in other OMUs. The trend in fecundity over the prior six years within the Plan Area will be compared to the trend in comparable regional averages of fecundity over the same time interval. If the trend in mean fecundity estimate from the Plan Area is statistically lower ($p \leq 0.05$) than the regional mean, adaptive management will be triggered to assess the problem and provide corrective actions if warranted.

Fisher Monitoring Commitment One (Objective 1D): Within 5 years of FHCP approval, Green Diamond will use non-invasive survey results to attempt validation of the fisher occupancy model. Following this initial validation attempt, further refinement will rely on surveys in which at least half of the Plan Area will be surveyed at five-year intervals. During each 5-year period, one half of the current (as of the date of the survey) Green Diamond ownership will be surveyed. In alternate 5-year periods, the remaining half of the ownership will be surveyed, so that each decade 100% of the Green Diamond ownership will have been surveyed, and data contributed toward this modeling effort. This will permit either a validation or refinement of the fisher occupancy model at 10-year intervals. Occupancy model validation requires demonstrating high fisher occupancy ($\Psi > 0.6$) in areas predicted to have high probability of occupancy.

Fisher Monitoring Commitment Two (Objective 5C): Green Diamond will estimate occupancy rates for at least half the Plan Area at 5-year intervals so that the entire Plan Area is surveyed every 10 years, as described in Fisher Monitoring Commitment One. If statistically significant evidence ($p \leq 0.05$) suggests declining fisher occupancy rates for 5 years or more in all or a major portion of the Plan Area, Green Diamond in collaboration with the Service will assess the likely cause of the decline, and if necessary, adaptive management will be triggered and corrective actions taken. An initial list of possible adaptive management measures is included in Section 5.3.6. Green Diamond may consider and propose other adaptive management options, should other responses to fisher declines be more appropriate and effective.

Tree Vole Monitoring Commitment (Objective 1E, 5C): Within 3 years following FHCP approval, Green Diamond will develop an occupancy model to detect changes in tree voles in NSO pellets. Green Diamond will also investigate the feasibility and cost effectiveness of using tree vole bones from pellets to obtain genetic material that potentially can be used in a landscape genetic approach to monitoring tree voles. If the landscape genetic approach is found to be effective and efficient, it may with the concurrence of the Service and Green Diamond, supplement or replace the approach based on collection of NSO pellets. An initial list of possible adaptive management measures is included in Section 5.3.6. Green Diamond may consider and propose other adaptive management options, should other responses to vole declines be more appropriate and effective.

Adaptive Management Commitment One (Objective 5C): Green Diamond will notify the Service within 30 days after an analysis indicates any monitoring threshold (yellow light or red light) has been exceeded, and request technical assistance from the Service to determine the cause of the negative result(s). If Green Diamond and the Service cannot agree on the cause or appropriate corrective action necessary to address a red light trigger, the issue will be taken to a scientific review panel. This panel will consist of independent experts on the subject at hand and include at least three members that are agreeable to both parties**.**

Adaptive Management Commitment Two (Objective 5C): The following triggers will initiate adaptive management measures:

- NSO:
  - As an early indicator of trends, if the NSO population declines in the 6 years following approval of this FHCP relative to the baseline NSO population (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al., 2016), Green Diamond will initiate a preliminary review in collaboration with the Service. The starting point for assessing trends in the NSO population will be the first NSO breeding season after this FHCP is approved (Section 5.3.4). This preliminary review will attempt to understand the potential causes and consider corrective actions without necessarily triggering adaptive management (yellow light).
  - If the NSO population continues to decline in the 10 years following approval of this FHCP relative to the NSO population at the initiation of barred owl removal (i.e., 95% confidence interval of realized population change does not overlap 1.0 as described in Dugger et al., 2016), the adaptive management process will be implemented (red light).
  - If the trend in mean fecundity estimate from the Plan Area is statistically lower ($p \leq 0.05$) than a comparable regional mean, the full adaptive management measures will be implemented (red light).
- Fisher
  - A statistically significant ($p = 0.05$) decrease in occupancy estimates for a major portion (e.g., ~50,000 acres) of the plan area at 5 years after occupancy model development (yellow light). Any yellow light areas must be re-surveyed during the next 5-year interval for occupancy surveys that would otherwise be limited to that half of the plan area that was not surveyed when the yellow light condition occurred.

- A statistically significant decrease in occupancy estimates in the same yellow light area at 10 years (red light).

- Tree voles

  - Although analyses may reveal patterns in tree vole occupancy that merit different metrics, the anticipated default thresholds will be: There is a statistically significant (p=0.05) decrease in occupancy estimates for a major portion (e.g., ~50,000 acres) of the plan area for three consecutive years. This trigger may be replaced with a genetic metric such as a significant reduction in the effective population size if a new genetic approach to monitoring can be developed for tree voles (yellow light).
  - A statistically significant (p=0.05) decrease in occupancy estimates in the same yellow light area for ≥ 5 consecutive years (red light).

Adaptive Management Commitment Three (Objective 5C): Green Diamond will implement one or more of the following adjustments to the Conservation Program and Effectiveness Monitoring Program for Covered Species in response to monitoring outcomes that warrant corrective action, either through mutual agreement between Green Diamond and the Service, or through the assessment of the Scientific Review Panel.

- Number of DCAs – Green Diamond will designate up to a maximum of 12 additional DCAs across the Plan Area that meet the criteria set forth in Section 5.3.1.4.4 (i.e., mean annual occupancy ≥0.75 and mean fecundity ≥0.25 averaged over the last 4 years) if there is evidence that more DCAs are required to achieve NSO objectives. The location and spacing of additional DCAs will be dependent on availability (NSO need to demonstrate the suitability of a site) and where new DCAs would provide the greatest demographic support and add continuity among existing NSO sites.
- Size and/or silvicultural prescriptions of DCAs – Green Diamond may modify the size and/or silvicultural prescriptions of the core or surrounding foraging habitat associated with DCAs if there is evidence that either or both of these factors are limiting the biological effectiveness of DCAs. The upper limit of such changes will be equivalent to not more than 1068 acres (Section 5.3.1.4.1).
- Adjustments of take authorization – Green Diamond will evaluate the authorized rate of NSO take and adjust, in collaboration with the Service, if warranted in response to a population decline detected through monitoring.
- Management related fisher decline – If adaptive management is triggered by a statistically significant decline ($p \leq 0.05$) (Section 5.3.5.2) in the occupancy rate for fisher, and it has been concluded that it is directly or indirectly related to one of the covered activities, Green Diamond will adjust the measures of the TREE or protect other fisher habitat or habitat structural elements up to the $250,000 budget allowance in the AMRA.
- Management related tree vole decline – If adaptive management is triggered by significant reductions in occupancy rates of tree voles in prey remains of NSOs, and it has been concluded that it is directly or indirectly related to one of the covered activities, Green Diamond will adjust the conservation measures of the TREE to promote the retention of additional forest structure anticipated to improve tree vole occupancy and dispersal in regenerating stands up to the $250,000 budget allowance in the AMRA:

Implementation Commitment One (Objective 5A): Internal Plan Compliance Team:

- Green Diamond will designate an internal compliance team including a Plan Coordinator working in conjunction with Green Diamond’s internal forestry and wildlife staff.
- Green Diamond will staff this FHCP Coordinator position with an academically trained and experienced wildlife biologist.
- Green Diamond will ensure this FHCP Coordinator reviews each proposed THP during its development and informs the RPF preparing the THP when any special restrictions and/or mitigations occur in the area (e.g., DCA special adjacency requirements or take assessment). Green Diamond also will ensure the RPF completes a pre-harvest checklist during THP development covering all necessary compliance elements.
- The Plan Coordinator or compliance team members will prepare and maintain documentation indicating Plan compliance for internal use for every THP within the Plan Area. Green Diamond maintains and updates an integrated Timberland Management Information System (TMIS) serving as an inventory tool for FHCP implementation and compliance.
- Following state THP review and approval, Green Diamond’s RPF will implement the THP as written, prepare a THP post-harvest completion form documenting THP compliance with FHCP provisions and submit this form to this FHCP Coordinator. Green Diamond’s FHCP Coordinator will review the form to ensure compliance.
- Green Diamond shall budget and expend such funds necessary to fulfill its obligations under this FHCP’s Operating Conservation Program. Green Diamond shall promptly notify the Service of any material change in their financial ability to fulfill its obligations.

Implementation Commitment Two (Objective 5A): THP Notice of Filing and THP Area Map

When submitting any proposed THP within the Plan Area to CAL FIRE, Green Diamond will provide an informational copy of the THP filing notice and a THP area map to the Service. This commitment shall also apply to the Peripheral Area for so long as those lands remain in Green Diamond ownership.

The THP filing notice and its cover letter will be modified from those currently provided to the Service to include specific information relevant to Covered Species under this FHCP, similar to the information already provided for species covered under the AHCP (Green Diamond, 2007). By including information on potential take of FHCP Covered Species, the THP filing notice will function as the notification to the Service regarding anticipated or potential take of listed species, and implementation of FHCP conservation measures intended to reduce the level and effects of anticipated take. During the first year of implementation, Green Diamond will coordinate with the Service regarding specific additions to Green Diamond’s current THP filing notice format.

Implementation Commitment Three (Objective 5A): Annual Reports

Green Diamond will prepare and submit an annual report to the Service by March 1 following the first full year after this FHCP’s effective date and every year thereafter during this FHCP term. These reports will summarize Operating Conservation Program compliance, results of the Effectiveness Monitoring Measures (Section 5.3.5) and any scheduled field reviews (Section 5.3.7) conducted in the prior year. The annual report to the Service will also include the post-harvest completion forms (Section 5.3.5). Each annual report shall also disclose necessary Green Diamond expenditures for implementing this FHCP’s Operating Conservation Program during the prior calendar year and Green Diamond’s current-year budget for implementing the Operating Conservation Program.

The annual report will provide a summary discussion of progress of implementation of management commitments identified under Section 5.5. The summary discussion may be organized by general commitment group, as follows:

- Landscape Management Commitments
- Habitat Element Retention Commitments
- Covered Species Protection Commitments
- Barred Owl Research Commitments
- NSO Monitoring Commitments
- Fisher Monitoring Commitments
- Tree Vole Monitoring Commitments
- Adaptive Management Commitments
- Implementation Commitments

The summary discussion under each commitment group will provide a *concise* description of progress toward meeting the commitments; identify concerns or conflicts arising from their implementation that may not have been considered during FHCP development; and conservation measures described in the commitment that Green Diamond may not have been able to complete, if needed, in a timely manner.

The annual report will include a summary of any adaptive management measures in development, or being implemented during the prior year, in response to the provisions of Section 5.3.6. The annual report will include an evaluation of the effectiveness of each implemented adaptive management measure, to ensure that its implementation effectively addresses the biological purposes for its adoption.

The annual report also will explicitly describe any take of Covered Species that has occurred during the reporting period, including both NSO that have been put into the "potential take bucket", and potential takes that have been confirmed as takes from post-covered-activity monitoring, and any that did not occur as a result of monitoring.

The following is an example of anticipated annual report content:

- Introduction
- Forest HCP Conservation Measures and Implementation
    - Summary Post-harvest Habitat Retention for Completed THPs
    - Riparian and Geologic Management Measures
    - NSO DCAs
        - Monitoring, Designation, Spatial Distribution, Replacement
    - Transition from 1992 Set-Asides to DCAs
    - Protection of Covered Species
        - NSO Active Site Locations
        - Summary of NSO Surveys for THPs
        - Fisher Den and Incidental Observations
        - Current and Abandoned Water Tank Monitoring (Fisher)
        - Tree Vole Nests and Incidental Observations
- Effectiveness Monitoring

- NSO Monitoring
  - Site Occupancy
  - Reproductive Success
  - NSO Banding
  - Juvenile Survival/Dispersal
  - Turnover
  - Owl Density
  - Demography
  - Model Validation
- Fisher Monitoring
  - Occupancy Surveys and modeling
  - Model Validation
- Tree Vole Monitoring
  - Occupancy Surveys and Modeling from NSO Pellets

- Barred Owl Research
- Notice of THP Filings
- Land Transactions and Plan Area Adjustments
- Take Summary
  - NSO
    - Take Assessment
    - Take Accounting
    - Projected Takes
    - Direct Harm
  - Fisher
  - Vole
- FHCP Training Programs
- Efficacy of FHCP
  - Expenditures and Budget
  - NSO Regional Comparison (Willow Creek Study Area)
- Adaptive Management Account
- Changed Circumstances
- Peripheral Area Management
- Literature Cited
- Glossary and List of Abbreviations
- Appendices
  - Protocols
  - NSO Detection Probabilities
  - Results of NSO THP Surveys
  - Recolonized and Abandoned NSO Sites
  - Raw Data for Post-harvest Habitat Retention
- Maps/Spatial Data
  - NSO Active Sites

- o NSO Potential Take Sites
- o NSO Pre- and Post-habitat at Potential Take Sites and DCAs
- o NSO DCA Locations and Associated Sites
- o NSO sites associated with Density Study Area and Demographic Study Area
- o Fisher Den Locations and Incidental Observations
- o Current and Abandoned Water Tank Locations
- o Tree Vole Nests and Incidental Observations
- o Barred Owl Site Locations and Removals

Implementation Commitment Four (Objective 5A): Scheduled Reviews

For the first 5 years of this FHCP, Green Diamond will schedule annual meetings with the Service. In the second and fourth years, annual meetings will precede a field review of implemented conservation measures allowing their technical evaluation. In the event Service determines from a field review that conservation measure implementation is not in accordance with this Operating Conservation Program, Green Diamond will develop recommendations with the Service regarding implementation and may schedule additional field reviews.

Implementation Commitment Five (Objective 5A): Assurance of Funding

Green Diamond warrants that it has, and shall expend, such funds as may be necessary to fulfill its obligations under the Operating Conservation Program. In each Annual Report to the Service, Green Diamond will provide a summary of expenditures for implementing this FHCP's Operating Conservation Program during the prior calendar year and Green Diamond's current-year budget for implementing the Operating Conservation Program. Green Diamond shall promptly notify the Service, in writing, of any material change in Green Diamond's financial ability to fulfill its obligations. Upon notification of material changes that restrict Green Diamond's ability to fulfill its obligations, the Service may suspend the Permit until such obligations can be met. The Service shall respond to Green Diamond within 90 days of receipt of the Green Diamond notification.

In the event that CDFW grants to Green Diamond a consistency determination under California law for this FHCP and requires financial assurances under California law, Green Diamond may provide additional security for the performance of this FHCP in the form of a letter of credit or bond benefitting CDFW. This additional assurance of financial performance may also be provided to the Service under a memorandum of agreement with CDFW and Green Diamond for the administration of the financial security. The Service may accept such additional financial security for performance without amending this FHCP and ITP.

Implementation Commitment Six (Objective 5A): Minor and Major Plan Amendments

Green Diamond or the Service may propose minor modifications to this FHCP and ITP ("Minor Modifications") by providing written notice to the other Party. Such notice shall include a statement of the reason for the proposed modification and an analysis of its environmental effects, including its effects on operations under this FHCP and on Covered Species. Such modifications may also result from applicable minor modifications of the AHCP after notice to and approval by the Service. The Parties shall use reasonable efforts to respond to proposed modifications within 60 days of receipt of such notice. Proposed Minor Modifications shall become effective, and this FHCP shall be deemed modified accordingly, immediately upon the other Party's written approval. Among other reasons, a receiving Party may object to a proposed Minor Modification based on a reasonable belief that such modification would result in operations, burdens or obligations under this FHCP that are significantly different from those analyzed in connection with the original FHCP; adverse effects on the environment that are new or significantly different from those analyzed in connection with the original FHCP; or additional take not analyzed in connection with the original FHCP approval. An objecting Party shall provide the other Party with written notice of the objection that includes a statement of the reason for the objection. If a Party objects, the proposal is not approved as a Minor Modification but may be processed as a Major Amendment of this FHCP and ITP.

Examples of Minor Modifications to this FHCP and ITP processed pursuant to this subparagraph may include, but are not limited to, the following:

- Corrections of typographic, grammatical, and similar editing errors that do not change the intended meaning
- Correction of any maps or exhibits to correct errors in mapping or to reflect previously approved changes in the ITP or this FHCP
- Minor changes to survey, monitoring or reporting protocols
- Clarifications to vague or undefined language or phrases
- Changes to operational prescriptions pursuant to, and within the foreseen range of changes resulting from, adaptive management
- Provision of additional financial assurances in connection with a consistency determination by the State of California
- Modifications approved through the adaptive management process under this FHCP.
- Any other modifications to this FHCP that are consistent with the biological goals and objectives described in this FHCP that will not result in operations under this FHCP that are significantly different from those analyzed in connection with this FHCP as approved, adverse impacts on the environment that are new or significantly different from those analyzed in connection with this FHCP as approved, or Take of Covered Species not analyzed in connection with this FHCP as approved, including but not limited to the approval or execution of agreements to facilitate execution and implement of this FHCP, or actions by Green Diamond to delegate (while retaining full responsibility for compliance with) any of its duties under this FHCP to a third party under its direct control.

Green Diamond and the Service each shall maintain a file of Minor Modifications to this FHCP that have been approved by all Parties and Green Diamond shall attach such Minor Modifications to each annual report covering the calendar year in which it is approved.

Any modifications to this FHCP and ITP other than approved Minor Modifications shall be processed as a Major Amendment of this FHCP and ITP. Major Amendments must be approved in accordance with all applicable requirements of federal law, including but not limited to, the ESA, NEPA, and applicable implementing regulations in force at the time of the proposed Major Amendment. The Party proposing the amendment shall provide a statement of the reasons for the amendment and an analysis of its environmental effects, including its effects on operations under this FHCP and on Covered Species.

Implementation Commitment Seven (Objective 5A): Enforcement and Dispute Resolution

Except as set forth below, Green Diamond and the Service each shall have all remedies otherwise available to enforce the terms of this FHCP, ITP, and the Operating Conservation Program.

The Parties acknowledge that the Covered Species are unique and that their loss as species would result in irreparable damage to the environment, and that therefore injunctive and temporary relief may be appropriate to ensure compliance with the terms of this FHCP.

No Party shall be liable in compensable damages to any other Party for any breach of this FHCP or ITP, any performance or failure to perform a mandatory or discretionary obligation imposed by this FHCP or any other cause of action arising from this FHCP and ITP.

Without limiting the applicability of rights granted to the public pursuant to the ESA or other federal law, this FHCP shall not create any right or interest in the public, or any member thereof, as a third-party beneficiary hereof, nor shall it authorize anyone to maintain a suit for personal injuries or damages pursuant to the provisions of this FHCP. The duties, obligations, and responsibilities of Green Diamond and the Service with respect to third parties shall remain as imposed under existing law

Nothing contained in this FHCP is intended to limit the authority of the United States government to seek civil or criminal penalties or otherwise fulfill its enforcement responsibilities under the ESA or other applicable law.

The Parties recognize that good faith disputes concerning implementation of, or compliance with, or suspension, revocation or termination of this FHCP or the ITP may arise from time to time. The Parties agree to work together in good faith to resolve such disputes, using the dispute resolution procedures set forth herein below or such other procedures upon which the Parties may later agree. However, if at any time any Party determines that circumstances so warrant, it may seek any available remedy without waiting to complete dispute resolution. Unless the Parties agree upon another dispute resolution process, or unless an aggrieved Party has initiated administrative proceedings or suit in federal court as provided herein, the Parties may use the following process to attempt to resolve disputes:

- Where the dispute is regarding a Party's compliance with the Operating Conservation Program, the Permit or this Agreement, the aggrieved Party shall notify the other Party of the provision that may have been violated, the basis for contending that a violation has occurred, and the remedies it proposes to correct the alleged violation. Where the dispute is over the proper implementation of the Operating Conservation Program, the Permit or this Agreement, the aggrieved Party shall notify the other Party of the provision over which the issue arises, the basis for contending that implementation is not proper and the changes it proposes to resolve the dispute.
- The Party receiving the notice provided in (a) shall have 30 days, or such other time as may be agreed, to respond. During this time it may seek clarification of the information provided in the initial notice. The aggrieved Party shall use its best efforts to provide any information then available to it that may be responsive to such inquiries.
- Within 30 days after such response was provided or was due, representatives of the Parties having authority to resolve the dispute shall meet and negotiate in good faith toward a solution satisfactory to all Parties, or shall establish a specific process and timetable to seek such a solution.
- If any issues are not resolved through such a process, the Parties shall consider non-binding mediation and other alternative dispute resolution processes and, if a dispute resolution process is agreed upon, shall make good faith efforts to resolve all remaining issues through that process.

Implementation Commitment Eight (Objective 5A): Conditions for ITP Suspension or Relinquishment

The Service may suspend or revoke the ITP for cause in accordance with the laws and regulations in force at the time of such suspension or revocation. Such suspension or revocation may apply to the ITP in whole or in part, and may apply only to specified Covered Species, portions of the Plan Area, or certain Covered Activities.

Green Diamond may relinquish the ITP before expiration of the full term of the ITP in accordance with the regulations in force on the date of such relinquishment and this implementation commitment. The applicable regulations are currently codified at 50 CFR §§ 13.26 and 17.32(b)(7). Unless later modification of these regulations dictates otherwise, to relinquish the ITP, Green Diamond shall, within 30 calendar days of discontinuing incidental take and the exercise of other rights granted by the ITP, return the ITP to the issuing office together with a written statement surrendering the ITP for cancellation. Relinquishment of the ITP will result in termination of this FHCP except that Green Diamond shall carry out the following measures for the duration of the original ITP term:

- When conducting timber operations and related land management activities within the Plan Area (as it exists as of the relinquishment date), prevent and avoid take of animals that are of a species listed as threatened or endangered under the ESA.
- Using this FHCP protocol approved by the Service, continue to survey for the presence of NSO in or near planned timber harvest units and, in the event of a detection, implement the timing and/or buffer restrictions set forth in this FHCP protocol to ensure that nesting NSO are not displaced or otherwise subject to take through those activities.

As designed and as analyzed in this FHCP, the measures provided in FHCP Section 5 and Section 6 are intended to result in Green Diamond having fully and continuously fulfilled its obligations under the ITP such that no additional post-relinquishment mitigation is required. Upon any relinquishment of the ITP, Green Diamond will be deemed to have fully and completely satisfied its obligations under the ITP, including those to minimize and mitigate the impacts of take that may occur incidental to the Covered Activities on the Covered Species within the Plan Area before or as those impacts arise. After Green Diamond relinquishes the ITP, it shall be deemed cancelled. Upon surrender of the ITP, no further take shall be authorized under the terms of the ITP.

5.6 SPECIAL MANAGEMENT FOR PERIPHERAL AREA

As explained in Section 1.3.1, the NSO HCP, as amended, incorporated a process of comprehensive review at years 10 and 20 during the 30-year term of the NSO HCP. As a result of the comprehensive review process under the NSO HCP, this FHCP was developed to supersede and replace the NSO HCP. As explained in Section 1.4.9.1, approval of this FHCP will also result in termination of the NSO HCP. Most of the timberlands covered by the NSO HCP will be managed thereafter under this FHCP, but a portion of the NSO HCP plan area, the Peripheral Area, will be subject to special management solely for the prevention of NSO take through timber harvest (Green Diamond, 1992). Special no take management for the Peripheral Area is consistent with Goal and Objective 3A of this FHCP, which call for the prevention of NSO take.

The Operating Conservation Program for this FHCP, described in Section 5.2, is focused on Green Diamond's core ownership within the EPA, which is also managed under the

AHCP/CCAA (Green Diamond, 2007) and constitutes approximately 98% of Green Diamond's timberlands in northern California. The remaining 2% of Green Diamond's ownership in northern California, the Peripheral Area, will not be incorporated into the Plan Area and ITP for Covered Species. Instead, the Peripheral Area will be specially managed for no take of NSO for so long as such non-core lands remain in Green Diamond ownership. This Section 5.6 describes the special management conditions for the Peripheral Area.

5.6.1 No Take Management for NSO

Upon Service approval of this FHCP and termination of the NSO HCP, Green Diamond will relinquish all unused NSO take authorization under the NSO HCP including take authorization that might otherwise have been used in management of the Peripheral Area. Within the Peripheral Area defined in Section 1.4.7.4 and shown in Map 1-2, Green Diamond shall ensure that NSO sites are not taken by timber harvest. Such assurance of no take shall be provided through implementation of pre-harvest survey protocols described in Appendix F. If an NSO site is known to exist or it is detected through surveys, it will be protected by no take seasonal harvest restrictions and by maximum habitat modification limitations within no take spatial buffers around the NSO site, as described in Section 6.2.4. To the extent that pre-harvest NSO surveys may harass NSO, such take incidental to implementation of NSO survey protocols shall be authorized by the Service.

5.6.2 Land Adjustments in the Peripheral Area.

Under the NSO HCP, Green Diamond could add or remove any timberlands or timber harvesting rights from the HCP plan and permit area with simple notice to the Service. Under this FHCP, Green Diamond may not add timberlands to the Peripheral Area, but may remove timberlands from the Peripheral Area with notice to the Service.

The Peripheral Area shall not be part of the Eligible Plan Area or its components, the Plan Area and Adjustment Area. Consequently, adjustments to the Peripheral Area shall not affect the adjustment limits for the Plan Area of this FHCP.

5.6.3 Implementation Training and Reporting.

The following implementation commitments of this FHCP shall also apply to special management of the Peripheral Area.

Implementation Commitment One requiring Green Diamond to maintain an internal compliance team with adequate qualifications, training, and resources to implement this FHCP.

Implementation Commitment Two requiring Green Diamond to provide the Service with notice and a map of each THP filing affecting the Peripheral Area.

Implementation Commitment Three requiring Green Diamond to provide the Service with annual reports, which shall include a summary of the results of NSO pre-harvest surveys and actions taken to prevent take of NSO in the Peripheral Area.

Section 6. Assessment of Potential Effect of Take on Covered Species and Their Habitats

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6.1 INTRODUCTION

Green Diamond's goal is that this FHCP provides a conservation strategy that:

- Avoids or minimizes and mitigates the effects of Green Diamond's Covered Activities on Covered Species to the maximum extent practicable
- Does not appreciably reduce the likelihood of survival and recovery of Covered Species
- Contributes to conservation of Covered Species

Before issuing an incidental take permit under section 10 of the ESA, the Service must consider the influences of the incidental taking of Covered Species and whether this FHCP minimizes and mitigates the influences of such taking to the maximum extent practicable. To facilitate the evaluation of this FHCP by the Service, this section provides an assessment of the potential effects of take incidental to Covered Activities when those activities are implemented in accordance with Section 5.

The term take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct (16 U.S.C. section 1532(19)). Harm in the definition of take means an act which actually kills or injures wildlife. This may include significant habitat modification or degradation that actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering. Harass in the definition of take means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering (50 CFR section 17.3).

For purposes of an incidental take permit application and habitat conservation plan, the Service must assess the influences of take and ultimately determine the quantity and nature of authorized taking based on an estimate of taking that may occur incidental to Covered Activities implemented in accordance with this FHCP. An estimate of potential take is broader than a finding of actual taking. Such an estimate requires a reasonably thorough evaluation of the direct and indirect pathways by which Covered Activities and habitat modifications may individually or cumulatively result in taking of Covered Species over the life of the plan. An appropriate evaluation uses the best available science such as site-specific research, data and experience with take conditions, when available, or guidelines describing conditions that approximate take when more specific data is not available. In this section, this FHCP uses 20 years of site-specific data and experience for the assessment of potential influences of NSO take and behavioral and habitat guidelines for the assessment of potential influences of fisher and vole take.

Not all instances of habitat modification or behavioral disruption for a listed species result in take. For purposes of this FHCP, an evaluation of take and the influences of take require an estimate of potential incidental take scenarios and conditions even if such take is not certain to occur. To assess the influences of take that may result from implementing Covered Activities under this FHCP, we make explicit and conservative assumptions about the conditions or scenarios with potential to cause take over the life of the Permit. Individual minor effects themselves may not cause take, but combined temporally and spatially with other similar closely related effects could cause take of Covered Species. Using conservative assumptions, we provide an estimate of take and its influences, including direct, individual and cumulative effects of take, which may overstate the actual amount of incidental take and influences of take caused by the Covered Activities.

This FHCP covers three species (fisher, red tree vole, and Sonoma tree vole) that were not included in any prior HCP developed by Green Diamond. HCPs completed within the species' western range are only recently including fishers as Covered Species, and limited information exists regarding methods to account for incidental take of this species. Neither vole species has been covered under any HCP, so methods for estimating incidental take of these species also do not exist. Accordingly, Green Diamond proposes methods to estimate take, based on reasonable assumptions, about how these species could be affected by the Covered Activities. Each major subsection, below, describes the basis for take estimation for each Covered Species, the measures implemented to minimize the take, the effects of the anticipated take, and the effects of that take in the larger population for each species. Because it is based on site-specific data, methods, and experience unique to the Plan Area, the method for estimating take under this FHCP may differ, in some respects, from the take guidelines that the Service has used in the past and in other locations.[1] Green Diamond has also included adaptive management measures in Section 5 that address uncertainty associated with the determination and accounting of take.

6.2 NORTHERN SPOTTED OWL

6.2.1 Type of Take

Green Diamond's Covered Activities may incidentally take NSO through habitat modification that harms NSO by interfering with essential behavior, through visual and audible disturbance from activities that harass NSO to the extent of interference with essential behavior, and through inadvertent, but direct, injury or death, which is unlikely, but possible.

Green Diamond seeks an ITP for NSO primarily due to modification of NSO habitat through timber harvesting (i.e., causing abandonment from occupied NSO sites or primary activity centers including nest sites and major roost areas). Each timber harvest event is comprised of a series of Covered Activities that may individually or collectively harm or harass NSO to the extent of interfering with essential behaviors. The series of Covered Activities begins with harvest planning when vehicles and personnel may visit an NSO territory to survey for owls and other sensitive resources (e.g. archaeological sites or wildlife trees), identify unstable slopes and riparian zones, inventory timber, and layout a timber harvesting plan with flagging and regulatory inspections. Next, roads may be built, rebuilt or maintained with operation of heavy equipment, installation or upgrading of stream crossings, and, in some instances, limited timber falling. The actual timber harvest follows with timber falling, yarding, loading, and hauling from the harvest unit across a portion of the Plan Area to market. When harvest is concluded, more Covered Activities ensue such as piling and burning of slash, reforestation, manual management of competing vegetation (i.e., non-herbicide), and, in some instances, pre-commercial thinning of young stands. When an NSO site is taken due to displacement, or reduced fecundity, the take may be caused by any of the entire cycle of Covered Activities associated with a harvest event and not just the cutting of trees.

In limited instances, Covered Activities occur without any association with a particular timber harvest event. For example, NSO monitoring and research and forest road traffic may occur across the Plan Area from time to time without any direct relationship to a particular timber harvest event. Covered Activities of this nature do not modify habitat, but can result in noise that

[1] Other landowners should not assume that the NSO take estimation and determination methods used on Green Diamond land may be directly applied to achieve ESA compliance on other lands that are not managed under the NSO HCP (Green Diamond, 1992) or this FHCP.

is experienced by NSO. NSO within the Plan Area are accustomed to noise from these less intensive and dispersed Covered Activities and are unlikely to modify their essential behavior in response to a baseline of non-intensive human activity distributed throughout the Plan Area over time. Nonetheless, this assessment of potential take also considers the effect on NSO from noise generated by Covered Activities that are not specifically related to a timber harvesting event.

Given Green Diamond's proposed avoidance measures (Section 5.3.3.1), directly killing or injuring NSO is very unlikely. However, isolated unintentional or inadvertent instances of direct harm may still occur. Green Diamond will annually remove some foraging, roosting and nesting habitat that may cause displacement. However, increasing amounts of habitat with the characteristics predicted to promote high fitness potential of NSO (i.e., NSO survival and fecundity sufficient to maintain a stable or increasing population) is expected under this FHCP. Areas where timber harvest reduces the habitat fitness potential are regenerated by a mosaic of maturing younger timber stands and retained older forest structure associated with habitat retention areas, riparian management zones and geologically unstable areas.

The NSO take assessment in this second generation FHCP is based on 20 years of comprehensively monitoring NSO occurrences and the direct, indirect, and cumulative effects of Covered Activities on NSO across Green Diamond's ownership in addition to other information regarding NSO gained during range-wide research and monitoring through many independent investigations. This experience and associated data provide Green Diamond with a sound basis for estimating future take of NSO under this FHCP. Green Diamond estimates a rate of future take based on the implementation of Covered Activities (Section 2) and specified expectations about rates of future timber harvest. That rate of take is initially expressed as a specific number of takes proportional to the number of active NSO sites per year. An active owl site is an occupied or unoccupied perennial owl site; not an abandoned owl site. A perennial owl site is an active owl site that has been established for at least two consecutive field seasons. For example, if a site is established in year 1 as newly colonized, it is not perennial. If the site is again occupied in year 2, it is designated as a perennial site.

Green Diamond will continue to annually monitor and account for individual NSO sites, and incidental take, until it validates its NSO habitat and occupancy models, a process anticipated requiring approximately 10 years. Thereafter, Green Diamond will use models to estimate the influence of timber harvest on NSO site occupancy and fecundity as a means to monitor and account for incidental take. To ensure future consistency between the initial habitat and occupancy models, and actual future NSO response to changing habitat conditions, Green Diamond will continue to monitor a sample of NSO take sites. This ongoing monitoring will refine the models and ensure the amount of take does not exceed authorized levels. Full details regarding model development and future modification are presented in Section 5.3.5 and Appendix I, along with contingencies until model development is completed and verified. Application of those models towards estimation and tracking of take associated with Covered Activities is described in Section 6.2.2.4.

The following is Green Diamond's estimate of the level of potential take which is anticipated to result mostly from habitat modification and NSO displacement and/or reduced fecundity, and only very rarely from direct harm. Whether timber harvesting activities, with the concomitant habitat modification, will actually result in harm or harassment constituting take depends on circumstances involved in each case. In addition, conservation measures identified in this FHCP minimize harm and harassment possibility (e.g., nest site protection during the nesting and fledging season). Nevertheless, Green Diamond seeks a permit for any take that may result from implementing Covered Activities.

For purposes of estimating and permitting incidental take, this FHCP utilizes biological criteria to postulate that take will occur when timber stands within or near occupied NSO sites are harvested where such harvesting causes resident NSO to be displaced from their nest site or activity centers, or in the absence of displacement results in a significant reduction in fecundity. Green Diamond makes this assumption based on NSO research and monitoring pursuant to the 1992 HCP which showed that timber harvesting within or near occupied NSO sites and causing resident NSO displacement resulted in reduced site occupancy and mean fecundity but had no measurable effect on NSO survival (Appendix C.2).

6.2.2 Background on Estimated Level of Take

6.2.2.1 Information Gained During Implementation of the NSO HCP

The NSO HCP estimated take from direct and indirect NSO site displacement. It expressed take in annual rates based on the number of NSO sites potentially affected by timber harvest operations over the NSO HCPs first 10 years (Green Diamond, 1992). This was a static approach based on known NSO locations, densities and planned timber harvest locations. Given the relatively short time frame, original take estimates did not address NSO density changes or potential modifications in timber management objectives. It was postulated that direct displacements of NSO would occur when future harvests contained a known NSO site. The status of some NSO sites was unknown at the time. Consequently, the proportion of known sites projected to be taken was applied to unconfirmed sites (activity center not confirmed) and this was added with known sites to estimate total direct displacements, which were postulated to constitute take.

Subsequently, Green Diamond derived an indirect take estimate using the results of a Master's thesis (Folliard, 1993) based on 60 NSO nest sites from across the ownership. The analysis quantified the amount of different stand age classes and cover types within a 0.5-mile radius circle (502 acres) of each nest tree. Green Diamond projected an indirect displacement occurred when the ratio of important (i.e., in greater amounts around NSO sites compared to random sites) age classes fell below calculated thresholds. These age classes were ≥31 years (foraging habitat plus some roosting and nesting) and ≥46 years (roosting and nesting habitat). The thresholds, estimated as 233 acres of ≥31 years, and 89 acres of ≥46 years, respectively, were calculated from the mean totals for the 60 nest sites minus 1 standard deviation.

To estimate the amount of take during the first 10 years of the NSO HCP, Green Diamond used a 10-year projection of timber harvest to estimate overlap between these circles and timber harvest. From this analysis, Green Diamond estimated that nine of 60 (15%) nest sites fell below these thresholds due to timber harvesting in the initial 10 years. Green Diamond applied this percentage (15%) to all known active NSO sites (146) on or immediately adjacent to the property to estimate total indirect displacements during the initial 10 years. Using these calculations, Green Diamond estimated 30 direct and 20 indirect displacements would occur during the NSO HCP's initial 10 years. Green Diamond and the Service also determined such displacements only affected a relatively small proportion of total Plan Area NSO sites. The resulting ITP authorized 50 takes in the initial 10 years.

Contrary to initial assumptions, however, Green Diamond's NSO monitoring over the NSO HCP's initial 15 years revealed timber harvest triggering these HCP displacement thresholds did not necessarily result in actual displacement of NSO or alteration of their normal behaviors. As a result, Green Diamond adjusted its take monitoring and reporting to reflect actual NSO behavior. It focused on mean occupancy and reproduction of resident NSO at sites subjected to timber harvesting exceeding established thresholds within 0.5 mile of nest sites or activity centers. If site occupancy and reproduction, regardless of individual NSO present at the site, was equal or greater than average estimates throughout the ownership, Green Diamond and the Service determined no take occurred.

6.2.2.2 Forms of Take Anticipated to Occur Under FHCP

Green Diamond's studies and monitoring conducted during the period 1992 until the present provided significant new insights into the relationship between the cycle of Covered Activities related to timber harvest and other management activities on Covered Lands, NSO biology and harm to NSO. Results of those studies (Appendix C.2) showed that timber harvest and related Covered Activities could potentially harm NSO, in the forms described below.

6.2.2.2.1 Direct Harm

Unintended direct harm to NSO may occur when they are not detected during pre-harvest surveys and their nest stand is cut during the breeding season without knowledge of their presence. Adult NSO likely abandon these stands and avoid direct physical harm, but this activity may kill eggs, nestlings or fledglings with limited ability to fly. However, this occurrence is very unlikely because Green Diamond's NSO survey is designed to achieve a minimum 95% detection probability (Appendix F).

Since Green Diamond began pre-harvest surveys in 1990, there is not a single known instance of harvesting an occupied nest stand that pre-harvest surveys had concluded was unoccupied by NSO. However, Green Diamond documented a few very rare (< 0.2% of surveys) instances where early season occupancy surveys failed to detect NSO at a given site and then without detecting adults, fledged juveniles were detected later in the breeding season. This indicates adult NSO were present and reproduced successfully.

During the period 1992 through 2008, Green Diamond conducted approximately 3,200 cumulative active NSO site-years (i.e., the annual number of NSO sites times 17 years of surveys) of surveys for NSO occupancy within Green Diamond's study area. An average of 188.2 active sites were surveyed per year. Through this period, Green Diamond documented five cases (~0.156%) where NSO surveys failed to detect nesting owls. Detection probabilities of NSO are known to drop substantially when barred owls are present, which could increase the proportion of nesting NSO not detected. However, a Plan Area-wide barred owl removal program will be implemented upon approval of this FHCP and detection probabilities have been shown to return to pre-barred owl rates following their removal (Diller et al., 2016). Should interruptions of the necessary permits result in a temporary halt to the barred owl removal, the NSO survey protocol was designed to account for the reduced NSO detection probabilities when barred owls are present by increasing the number of survey visits required (Appendix H). As a result, it remains a reasonable assumption that only a very low percentage of nesting NSO sites will be undetected and it will be highly unlikely for direct take to occur due to pre-harvest surveys failing to detect nesting NSO. The proportion of future harvested stands that could result in this form of take can be approximated by assuming that the NSO densities and harvest rates in the future will remain comparable to the past. To estimate this form of direct take, Green Diamond multiplied the rate of documented occurrences of undetected nesting attempts (0.156%) by the number of future NSO sites that are projected to have annual harvest within 0.5

mile. Since 1992, annually, an average of approximately 17% of active NSO sites had some timber harvest within 0.5 mile. Projecting 50 years through the permit life, Green Diamond estimates 9,410 cumulative NSO site-years (i.e., the annual number of NSO sites times 50 years) with 1,600 (17%) of these sites having harvest within 0.5 mile. Multiplying 1,600 sites by the 0.156% non-detection ratio provides an estimate of approximately 2.5 NSO sites that could be subjected to direct harm from timber harvest over the 50-year term. If a pair of NSO and two eggs, nestlings or fledglings occupied each site, this possible form of take could affect 10 individual NSO during this FHCP's 50-year term. As noted above, interruptions of the necessary permits resulting in a temporary halt to the barred owl removal could have the potential to reduce NSO detection probabilities and increased direct harm, but the NSO survey protocol was designed to account for the barred owl effect by increasing the number of survey visits required (Appendix H)

6.2.2.2.2 Indirect Harm

Timber harvesting and the Covered Activities that precede and follow timber harvesting have the potential to indirectly cause harm to NSO, in two situations. Indirect harm can occur when there is adequate habitat in an area, but a nest stand is harvested and the NSO are forced to relocate to a new nest site in subsequent breeding seasons. Based on Green Diamond's observations (Appendix C.2), this timber harvest type appears less likely to affect continued occupancy somewhere within the NSO's home range. However, in some cases, it did result in reduced fecundity or occupancy.

Indirect harm can also occur when timber harvest does not necessarily affect the NSO nest site or primary activity center, but reduces the total amount of nesting, roosting or foraging habitat available around the nest site or activity center below a critical threshold. If this occurs, in some instances NSO may abandon their site or remain at the site with lower fecundity. Based on NSO monitoring under the NSO HCP, timber harvest depleting habitat below a critical threshold appeared to be more likely to reduce fecundity or site occupancy (Appendix C.2).

6.2.2.3 Summary of Past Take Accounting

The prior approach to estimating potential future take used a static view of NSO sites relative to the amount and location of timber harvest units. The estimate was valid because it only projected take for 10 years and it was based on a stable or increasing NSO population in the Plan Area from 1992-2001 (Forsman et al., 2011). After 2001, the NSO population declined in Green Diamond's study area, which can best be explained due to the barred owl invasion and potentially exacerbated by cold wet weather during the nesting season (Dugger et al., 2016). The NSO population rapidly rebounded from 2009 to 2013 in experimental areas where Green Diamond removed barred owls (Section 4.3.2, Diller et al., 2016). Although it has been shown that the barred owl threat can be controlled during the early phase of the invasion when their numbers are relatively low, there remains uncertainty about the density of future barred owl populations and the ability to control the threat with potentially increased levels of barred owl immigration. Furthermore, projected increases in future high quality NSO habitat throughout the Plan Area, which could be offset by unpredictable weather patterns preclude precise predictions of the future density and distribution of NSO sites. Thus estimating potential future take based on an estimated static number of NSO sites is unreliable.

Rather than speculate on specific future NSO site locations relative to future timber harvesting activities, Green Diamond estimated the annual mean level of potential future take through a retrospective assessment of past takes incidental to displacement by timber harvest. Using empirical data from 1993-2007, Green Diamond determined that displacement may occur as a result of timber harvesting within NSO home ranges, causing site abandonment or reduced fecundity. Figure 6.1 illustrates there was considerable variation in annual take amount that was influenced by NSO site locations relative to annual scheduled timber harvest, intentional take avoidance by Green Diamond, lumber market conditions and fluctuations in NSO site numbers. But the long-term average from 1993-2012[2] was 2.35 (SE = 0.33) takes by displacement each year from an annual average of 153.8 active NSO sites, which equates to an annual rate of 1.53 takes per 100 NSO sites. The accuracy of projecting this same rate over the next 10 years relies on the following two projections:

- Green Diamond will manage future displacements similar to what was learned and applied under the NSO HCP to avoid unnecessary take where timber harvesting activities are planned around NSO sites.
- The average future timber harvest amount and type will not substantially change across the Plan Area.

Green Diamond believes that the average rate of take estimated based on1992 HCP results is conservative and the actual rate of take under this FHCP will likely be less for several reasons. First, the overall amount of the highest quality NSO habitat (high habitat fitness) is projected to almost double over the term of this FHCP (Section 4.4.1). This increase will result from ingrowth of even aged harvest units along with establishing riparian and geologic protection areas (Section 5.3.1.3). As predicted in Green Diamond's Forest Management Plan (2012), this will create a future landscape with an estimated 27% or more in older forest age classes (https://greendiamond.com/responsible-forestry/california/reports/FMP_Final_11-8-17.pdf)

Along with smaller clearcuts distributed over time and space as required by FPRs, the net effect will be greater open edge density and higher overall habitat heterogeneity levels that is highly beneficial to NSO in the Plan Area (Section 4.3.1). If this prediction of greater amounts of higher quality habitat is correct, then it will require less habitat to support a pair of NSO, and it will require relatively greater loss of habitat around an NSO site before take will occur.

[2] Displacement data were analyzed through 2015, but there is a minimum three-year lag in assigning take so the latest available year when take could be quantified was 2012.

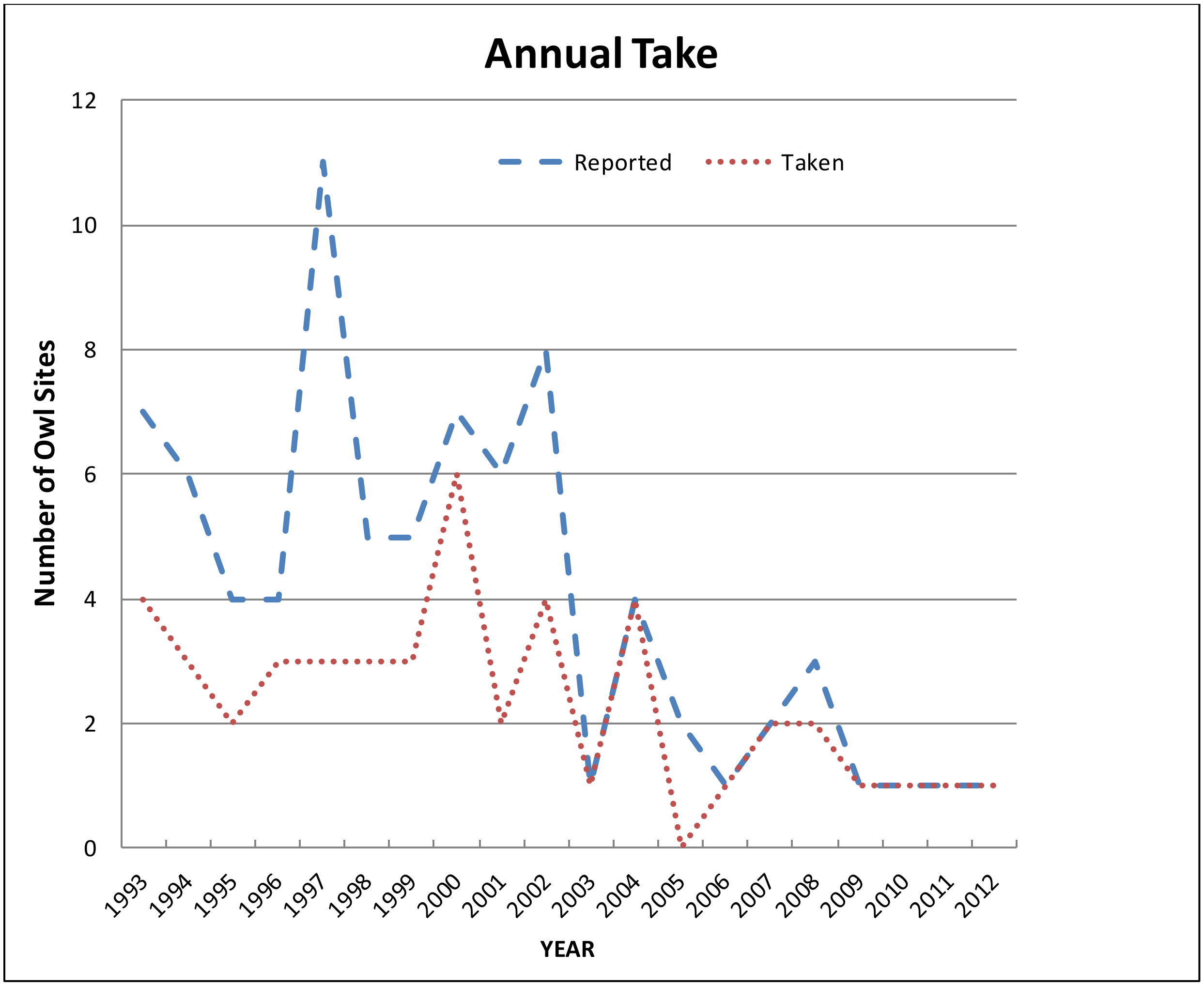

Figure 6-1. Annual reported take, harvest exceeding habitat thresholds and actual number taken, i.e., NSO site occupancy and fecundity negatively affected, on Green Diamond's ownership, 1993-2012[3]

Second, an analysis of the factors (covariates) associated with NSO site abandonment (including take), showed a decreasing trend in the probability of site abandonment (i.e., increasing trend that occupied sites will continue to be occupied). The goal of this analysis was determining the primary proximate factors leading to site abandonment given that NSO occasionally abandon sites with and without timber harvest occurring in their home range (Appendix C.2). The site abandonment analysis indicated mean patch size and the proportion of stands 41 to 60 years old within a 1,000-acre circle around the NSO site were the only significant variables included in the top statistical model. (The lowest probability of abandonment was with smaller mean patch size and approximately 50% of the 1,000-acre circle in the 41- to 60-year age class.) To project the probability of site abandonment on future landscapes, Green Diamond held take at a mean rate and used the abandonment model to project various categories of predicted probability of site abandonment at 10-year intervals from 2010-2060. As seen in Figure 6-2, the proportion of Green Diamond's ownership projected to be in the lowest abandonment category (i.e., best for continued probability of occupancy by NSO) increased

[3] Displacement data were analyzed through 2015, but there is a minimum three-year lag in assigning take so the latest available year when take could be quantified was 2012.

from 168,105 acres (58% of ownership) in 2010 to 271,151 acres (93% of ownership) in 2060. Although newly emerging threats such as controlling barred owls and climate change prevent Green Diamond from estimating the actual future mean annual abandonment rates at NSO sites, including those with or without timber harvest, the mean annual abandonment rate in the past (1990-2005) was 0.0725 (7.25%). Based on Green Diamond's future habitat projections, and assuming no unforeseen interactions between new threats and the habitat factors associated with site abandonment, projections of the abandonment model indicate a substantial drop in future abandonment rates. This suggests habitat factors associated with promoting continued NSO occupancy will substantially increase, making it less likely that timber harvest will cause site abandonment.

The final and possibly the most important factor in reducing future takes relate to future NSO site locations. In the past, NSO sites on Green Diamond's young managed landscape were most often associated with concentrations of older residual structure, such as trees retained from prior timber harvesting. Because this historical retention was largely inadvertent due to factors like ease of access and timber value, the residual structure was generally scattered across the landscape from lower slope positions along creeks to ridge tops. As a result, NSO sites were often encountered in the middle of areas scheduled for harvest, making take avoidance impossible without leaving substantial amounts of otherwise available harvest units. In the future, most of the substantial amounts of retention will be associated with robust riparian zones established pursuant to this FHCP, which will mean the best habitat for NSO sites will also tend to be associated with riparian zones. The selection of Dynamic Core Areas (DCAs) associated with riparian zones (Section 5.3.1.4) will accelerate this trend. As noted in that section, new NSO sites have already been colonized in riparian areas that will be ideally suited for future new DCAs. That is, over time, the allocation of the core area and buffer area of 233 acres would be increasingly included in RMZs and other protection areas that will be increasing in age. However, in some cases, take may occur if some of the habitat essential to an NSO pair is harvested within the remainder of the 0.5 mi radius circle.

Considering these factors collectively, Green Diamond believes that the current rate of NSO site abandonment due to timber harvesting is likely less than the rate determined by monitoring under the NSO HCP (1.85 per 100 NSO sites per year), and will drop substantially throughout the term of this FHCP and approach zero at the end of the 50-year term of this FHCP..

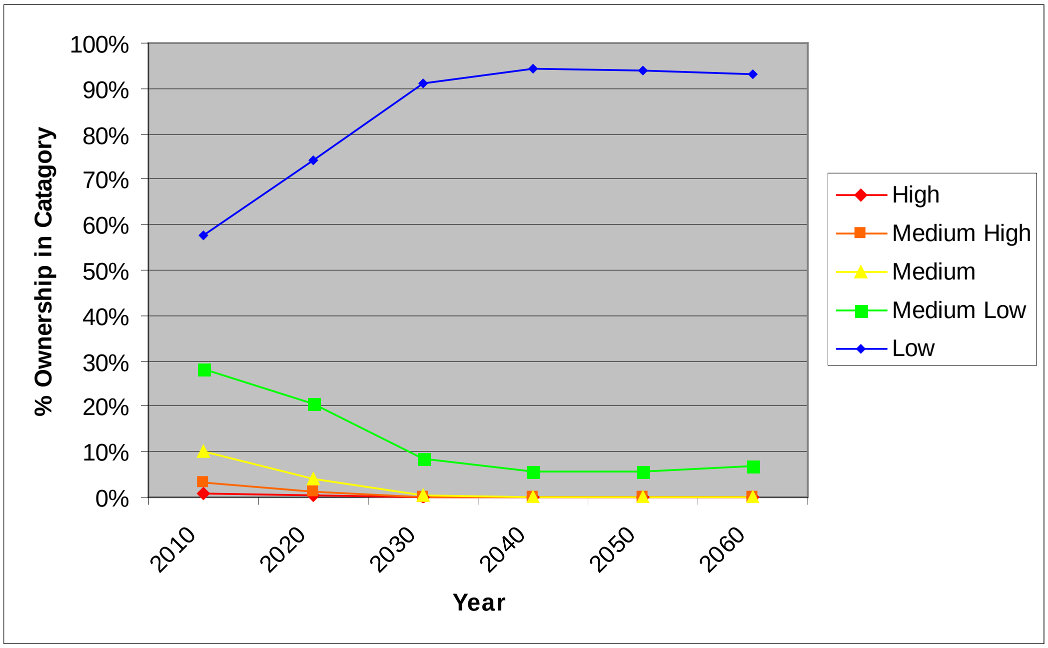

Figure 6-2. Percentage of Green Diamond land projected in 2010, 2020, 2030, 2040, 2050 and 2060 in different site abandonment categories as follows: *Low* – best for owls, p < 0.20; *medium low* – p = 0.20-0.40; *medium* – p = 0.40-0.60; *medium high* – p = 0.60-0.80; *high* – worst for owls, p > 0.80. This is not an annual rate, but rather abandonment probability during the 1993-2005 study.

6.2.2.4 Annual Accounting of Take

Green Diamond conducts extensive NSO surveys in conjunction with every THP in order to determine when timber harvesting resulted in NSO displacement or reductions in fecundity. While Green Diamond intends with this FHCP to transition to a landscape plan which does not involve such intensive monitoring of every NSO site (Section 5.3.5.1), that transition first requires validation of the habitat model Green Diamond constructed using the data already collected. To achieve that, Green Diamond will collect model validation data through continued NSO surveys (property-wide and DCAs) and the ongoing demographic mark-recapture study. Since model validation will require approximately 10 years, during that initial period Green Diamond will continue to monitor individual NSO site displacement using the extensive survey approach.

There was a tremendous amount of data collected and analyses done as part of the Ten-Year Report (Green Diamond, 2010). Green Diamond expected to propose developing and testing new habitat thresholds to measure when site displacement will occur in the future. However, Green Diamond's fecundity analysis indicated that annual variation in fecundity was very high and related to a complex suite of variables including the following that entered the best statistical model (Green Diamond, 2010):

- Four non-habitat variables:
  - Spring weather conditions
  - Even-odd year effect
  - Age class of the NSO

  - Take classification at site (displaced/not displaced)

- Five habitat variables:

  - Whether or not the NSO site was associated with a set-aside
  - Natural log of the percentage of 41- to 60-year-old stands in a 600-meter radius buffer
  - Natural log of the percentage of 21- to 40-year-old stands in a 600 to 921-meter annulus
  - Average foraging habitat within a 600-meter radius buffer
  - Average open edge density in a 600-meter buffer

Because habitat variables associated with fecundity were too complex to use as thresholds for displacement assessment, Green Diamond also considered using site abandonment to potentially develop a habitat threshold for displacement assessment. A site abandonment analysis indicated that mean patch size and the proportion of stands 41 to 60 years old within a 1,000-acre circle were the only significant variables included in the model. Patch size was not a useful variable to be used as a threshold for assessing displacement, because evenaged timber harvesting tends to decrease patch size which has a negative influence on abandonment probability. That is, dispersed small patches that include each forest age class increase the probability of site occupancy, potentially due to the increased availability of the primary prey species (woodrats) in an optimal distribution of nesting and roosting habitat with high quality prey habitat. The proportion of stands 41 to 60 years old within a 1,000-acre circle was also not a useful threshold, because the relationship was quadratic with an inflection of increased abandonment probability at approximately <20% or >80% of the 1,000-acre circle in this age class (Green Diamond, 2010).

In past management, displacement was postulated to occur when timber harvesting occurred within a 500-foot radius of an NSO site, or when the harvest resulted in there being < 89 acres of stands ≥ 46 years old and < 233 acres of stands ≥31 years old within a 0.5-mile radius of an NSO site. Although monitoring of NSO under the HCP later determined that these thresholds were too conservative, in the absence of an adequate substitute, Green Diamond will continue to employ these thresholds under this FHCP to monitor and account for take until such time as the habitat and occupancy models are validated (Section 6.2.3).

6.2.3 Authorized Amount of Take

6.2.3.1 Initial Period – Prior to Model Validation

During the initial implementation period, prior to model validation, Green Diamond estimates that the mean annual rate of take, based on a prediction of a continuation of past harvest rates, would be approximately 2 NSO sites (maximum four adult NSO) per 100 active NSO sites per year, based on the take rate observed to date of 1.85 per 100 NSO sites. To allow for operational flexibility in harvest rates within the limits of Green Diamond's Option A sustained yield plan requiring a balance of growth and harvest, and the FPRs harvest adjacency restrictions (Green Diamond, 2012), Green Diamond seeks authorization for a maximum take rate of 3 NSO sites (maximum six adult NSO) per 100 active NSO sites per year.[4] Although subject to review as described below, this rate of take will stay in effect throughout the life of the

[4] "NSO Sites" include all active sites (i.e., occupied in at least one of the last three years) located within a 0.5-mile buffer of the Plan Area boundary. The 0.5-mile buffer will be included since it defines all NSO sites where owl displacement could occur as a result of timber harvesting activities within the Plan Area.

plan assuming the NSO objectives are being met and the population is stable or increasing as predicted in Section 5. Should the number of active NSO sites in the Plan Area unexpectedly decline (i.e., active sites become vacant with no NSO occupancy in three consecutive years) in the future, the rate of take per 100 active NSO sites would decline, according to the schedule indicated in Table 6 1. The intent of this declining rate of take is to reduce the rate and effect of subsequent take, ultimately reducing the overall degree of effect on remaining NSO sites. Should the number of NSO sites ultimately decline to 47 or fewer, no additional take would be allowed under the proposed accounting methods.

Table 6-1. Schedule of Annual Take Related to Active NSO Sites within the Plan Area and Buffer

Active NSO Sites	Takes per Year per 100 Sites	Mean Annual Take Rate as Proportion of Active Sites	10-Year Hypothetical Takes Range
>100	3	0.30	≥30
75 - 100	2	0.015 – 0.020	15 to 20
48 - 74	1	0.005 – 0.007	5 to 7
≤47	0	0	0

As of 2015, 166 active NSO sites are known to occur within the Plan Area and 0.5-mile buffer (Green Diamond may affect sites within 0.5 mile of its property). Applying the rate of take described above (3 NSO sites per 100 NSO sites per year) to this total number of active NSO sites within the Plan Area results in proposed take at FHCP inception of 5 NSO sites (maximum of 10 adult NSO) per year.[5] If the current number of active NSO sites remained static, Green Diamond could displace 50 sites (maximum 100 adult NSO) in 10 years.

The rate of take will be reduced from 3 per 100 active owl sites, when the total number of known active NSO sites is > 100, to a rate of 2 per 100 active owl sites, if the number of NSO sites declines to within the range of 75 to 100, and to a rate of 1 per 100 active NSO sites, if the range of active NSO sites declines to within the range of 48 to 74. If the number of active NSO sites were to decline to 47 or less, no take would be allowed. This declining rate of take would not only result in a decline in the number of takes, but would reduce the proportion of the population subject to take each year (Table 6.1). Although Green Diamond does not anticipate a declining trend in the NSO population, this change in the rate of allowable annual take is provided as an adaptive management measure to provide a “safety net” for the NSO population covered under this FHCP.

During the initial period, annual monitoring of all active sites would continue, so that Green Diamond would base its take rate on the number of NSO sites currently active on the Plan Area. Failure to conduct full surveys across the Plan Area would ultimately penalize the company, since an underestimate of known active NSO sites would translate into a reduced amount of take permitted annually across the Plan Area.

[5] For take calculations, estimated number of takes will be based on rounding, up or down, to the nearest integer number of takes, for each annual calculation. For example, 4.59 would be rounded up to 5; 4.35 would be rounded down to 4.

6.2.4 Take Assessment Prior to Model Validation

6.2.4.1 Habitat Conditions Triggering Take Accounting and Monitoring

Take accounting and monitoring will be triggered when timber harvest or other covered activity results in one or more of the following conditions:

- Suitable nesting, roosting or foraging habitat is removed or destroyed within a 500-foot radius of an NSO site center
- less than 89 acres of stands ≥ 46 years old remain, post-harvest, within a 0.5-mile radius of an NSO site
- less than 233 acres of stands ≥31 years old within a 0.5-mile radius of an NSO site (Section 5.3.5.1)
- Timber harvest within a 0.5-mile radius of an NSO site that is currently below thresholds or that reduces habitat below thresholds (<89 acres of stands ≥ 46 years old and < 233 acres of stands ≥31 years old) post-harvest

Should any of these conditions occur, a potential take will have occurred, and monitoring triggered. A take will not be counted against the take limitation until the site meets the biological criteria listed as documented through monitoring, as described below.

6.2.4.2 Performance Criteria to Document Take

A designation of take will be based on the post-harvest demographic performance of NSO within the home range or home ranges where Covered Activities prior to, during, and after harvest triggered the assessment of take. The performance criteria are based upon occupancy and/or reproduction of any NSO at a site (i.e., different NSO occupying a site will be judged as if the same individual NSO continuously occupied and reproduced at the site). The final determination of the take assessment can occur beginning at the third and ending at the fifth breeding season following the last harvest that triggered the assessment. The criteria for concluding that a take did not occur are as follows:

- In the third breeding season following trigger of take assessment:

  - NSO nest (whether successful or not) in at least 2 years; or
  - NSO nest in 1 year with 2 years occupancy (at least 1 year of pair occupancy for sites with pair occupancy prior to timber harvest or single NSO at sites without pairs)

- In the fourth breeding season following trigger of take assessment:

  - NSO nest in at least 2 years; or
  - NSO occupancy of the site for four years (at least two years of pair occupancy for sites with pair occupancy prior to timber harvest or single NSO at sites without pairs)

- In the fifth breeding season following trigger of take assessment:

  - NSO occupancy of the site four out of five years (at least two years of pair occupancy for sites with pair occupancy prior to timber harvest or single NSO at sites without pairs)

The requirement of pair occupancy at a site after the timber harvest that triggers a take assessment is conditional upon pair occupancy at the site in pre-harvest conditions. In other words, pair occupancy must be observed at a site in the period 3 to 5 years prior to timber harvest for pair occupancy to be considered as a post-harvest criteria for determining whether incidental take has occurred. Pair occupancy would not be required in the post-harvest evaluation at sites where only single NSO were detected prior to take evaluation. Also, a newly colonized or recolonized site occupied by a single NSO will be evaluated based on simple occupancy of a single NSO post-harvest. The more restrictive criteria of post-harvest pair occupancy can also support a determination of no displacement on sites that were occupied by single NSO prior to timber harvests that triggered take assessments. At any point that the above criteria cannot be met (e.g., site is unoccupied for two consecutive years following the trigger of take assessment), the site will be considered to have been taken and the take will be recorded for the initial year in which the timber harvest (i.e., tree felling) triggered the take assessment. This delay in reporting takes means that Green Diamond cannot have more potential takes in the assessment “bucket” than their total allotment of takes at any given point in time since there will be the possibility that all assessments will lead to a determination of take.

6.2.4.3 Spatial and Temporal Elements of Designating Take

Although administration of take based on NSO sites is the most practical solution, it also creates both spatial and temporal complications. The spatial complication occurs when NSO within a given territory shift their primary activity center or nest site. Minor shifts of a few hundred meters are expected and it is reasonable to consider it the same territory, but dilemmas are created with larger moves that potentially constitute creation of new territories. In other words, how far can a pair of NSO shift their territory center before it should be considered a new territory?

On the temporal scale, a take is determined to occur when timber harvesting of a particular stand leads to impairment of occupancy or fecundity at a site. At that point, the site has been taken since it no longer is capable of supporting a fully functional pair of NSO and subsequent harvesting of other stands within the territory is not considered to be an additional take. In other words, over a limited time interval, a specific NSO site that supports a particular pair of NSO can only be taken once. However, over some longer interval of time, the habitat will regrow and the site will once again be capable of supporting another pair of NSO, at which point another take can occur. If all the evenaged timber harvesting at a given NSO site occurred in a discrete continuous interval associated with the rotation age of the stand, the ‘take clock’ would be reset for each new harvesting cycle at the site. However, a potential dilemma results because for a variety of silvicultural, economic and logistical reasons, some of the timber harvesting associated with an NSO site may be delayed for decades. Following the original take of an NSO site, this could create a situation where the site is once again suitable to support a new pair of NSO and it becomes necessary to define the temporal criteria that resets the potential for take to occur at a given site.

Neither the spatial nor temporal elements of take were considered in the NSO HCP. The prevailing scientific view at the time was that NSO sites were relatively static, and the initial authorization of take was for only 10 years so the dynamic nature of NSO sites in both space and time was not considered (Green Diamond, 1992). However, Green Diamond’s NSO monitoring and research on a managed landscape over the last two decades has provided extensive data that can be used to estimate both the movements of nest sites and activity centers within the core of the territory and the minimum time for regrowth of stands that will support occupation by NSO.

Spatial Limits of Take:

Green Diamond used a 95% adaptive kernel estimator (Kie et al., 1996) around nest site locations from 1990 through 2007 to determine the core roosting and nesting areas around NSO sites. This produced an estimate of 153 acres at the 95 percentile, and a circular radius of 0.276 miles (1,457 feet). If the owls occupying this site moved their territory all around the periphery of the site, the total assessment area using a 0.5-mile radius would be approximately 1,210 acres, which is roughly equivalent to the average home range of NSO in the Plan Area.

Based on this analysis of spherical core areas, it would appear that movements of the territory center or nest site > 0.276 mile from the geometric center of the original core area would constitute a new NSO site for purposes of estimating levels of take. However, in the analysis described above, many of the NSO territory centers were not spherical, but were more linear particularly if the site occurred along the lower slopes of some major drainage. In these more linear core areas associated with riparian areas, a 153-acre core area could result from points on the long axis up to 0.5 mile, and 0.13 mile (689 feet) on the short axis from the geometric center. Therefore, Green Diamond proposes that if the NSO core area is associated with a more linear riparian area, movement of the territory center > 0.5 mile would constitute a new NSO site. To account for the non-spherical nature of many of the NSO core areas, Green Diamond will buffer the known nest sites, or if no nest sites are known, the activity centers such that a polygon of 153 acres is created. The buffered area will be created as a probability surface similar to an adaptive kernel algorithm, but the total area will be based on a polygon of 153 acres rather than some percentage of an adaptive kernel.

If the NSO move their nest site or activity center outside the perimeter of the 153-acre polygon following a timber harvest that triggers a take assessment, the site will be considered for designation of a new NSO site. Additional factors that will be considered are topographic features such as whether or not the new site is in the same drainage or separated by some type of acoustical barrier. In other words, to be designated a new site, it has to be feasible that the original site and the new site could simultaneously be occupied by pairs of NSO assuming habitat around both sites had not been adversely impacted by timber harvest. In marginal or borderline situations, Green Diamond will seek concurrence from the Service relative to their determination of the need to establish a new site based on spatial criteria.

In situations where the NSO move their activity center or nest site to a new location that is deemed be a new NSO site, future timber harvesting within the assessment area of the new site could result in an additional take. However, continued harvesting in the assessment area of the original NSO site will not lead to additional takes within the temporal limits described below.

Temporal Limits of Take:

There are no *a priori* criteria to determine the temporal limits for a given NSO site so Green Diamond used empirical data to estimate the minimum time necessary for NSO to recolonize a site. During the last two decades of monitoring, Green Diamond documented the recolonization of 23 NSO sites that were previously heavily impacted by timber harvest. Much of the impacts by timber harvest occurred before the NSO HCP so Green Diamond did not have direct evidence of when take might have actually occurred relative to the current sites that were recolonized. Therefore, for each of these sites, Green Diamond used current stand ages to reconstruct the harvesting history and estimate the time when timber harvesting reduced the habitat below the NSO HCP take threshold in a 0.5-mile radius circle (<233 acres of ≥31 of which <89 acres are stands ≥46) around the current recolonized nest or activity center. Green Diamond knows that this threshold often predicts take before it actually happens, but this should only result in a minor bias due to past more extensive and frequent clearcut timber harvesting (i.e., larger clearcut size and shorter adjacency periods). Based on this retrospective estimate of time when take occurred, Green Diamond subtracted the number of years when regrowth of the stands was sufficient to allow recolonization by a single or pair of NSO. For the sites analyzed, the minimum time between the retrospective estimate of take and recolonization was 10 years with a mean of 21.5 years. Figure 6-1 shows the distribution of years to recolonization.

Although experience indicates that harvested NSO sites are typically not recolonized for timeframes of 10 to 30 years, Green Diamond will adopt a more conservative approach to assessment of take such that any time an NSO site is recolonized once it is abandoned, it will initiate a new take assessment procedure.

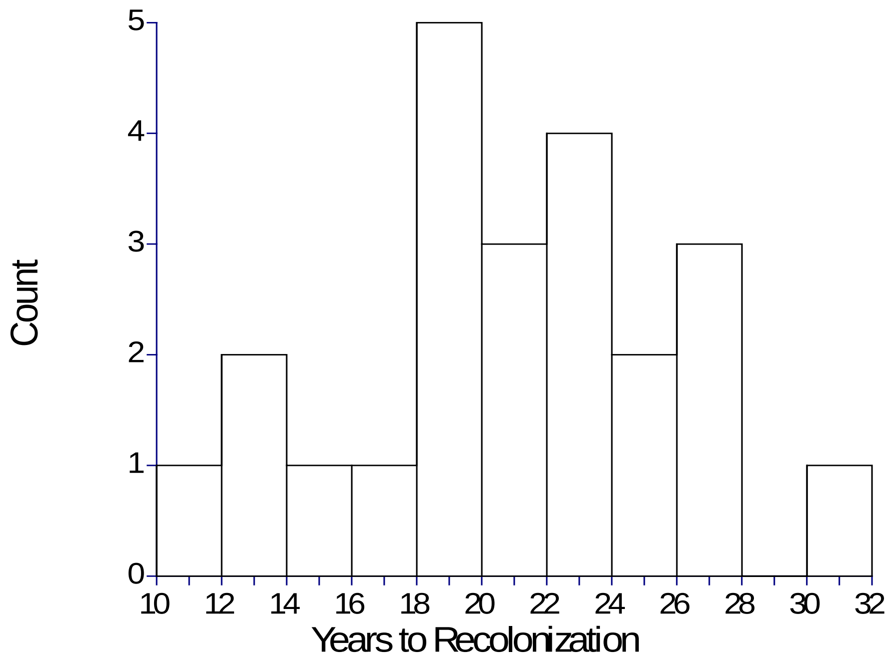

Figure 6-3. Histogram of the number of years from estimated time of take to recolonization of 23 individual NSO sites.

6.2.4.4 Determining New NSO Sites for Take Assessments

In other words, when an NSO site is taken based on the criteria in Section 6.2.4.2 and the site has been classified as abandoned, but timber harvest has not been completed within the “home range” of the NSO, Green Diamond will initiate a new take assessment procedure for NSO that recolonize and occupy the site based on criteria in Appendix F and for which timber harvest triggers a take evaluation based on habitat thresholds described in Section 6.2.4.1. Consider a hypothetical example in which an NSO site was taken and became abandoned (based on site occupancy criteria in Appendix F) at 5 years after the initial harvest that triggered the take assessment. In year 6, NSO surveys discover a single NSO occupying the site and in year 7 the site is again occupied and becomes a perennial site. The site will count toward the total number of active sites used to determine the total number of takes for that period, and if Green Diamond conducts a timber harvest within 0.5 mile of the NSO site that triggers a take assessment, the site will again be placed in the authorized incidental take "bucket" and evaluated for temporary displacement or abandonment based on the established performance criteria.

In areas where a NSO site has not been previously designated, a new activity center will be designated based on the follow-up visits for a NSO response if, during the breeding season (21 February[6] to 31 August) any of the following applies:

- A pair is detected at least two times in the same core area over at least 1 month (30 days)
- A single NSO is detected in the same core area over at least 2 months (60 days)
- An NSO response obtained during a THP survey is not followed-up adequately using the protocols described previously in Section 6.2.1. (Note: this designation of site status only applies relative to take assessment; for demographic purposes, the site status would be "unknown")

The NSO responses will not lead to the designation of an activity center, if three adequate protocol site visits at least five days apart all result in no NSO being found within 30 (pair) or 60 (single) days of the initial response. If the initial response occurs in March, then at least one of the three site visits will be done in April.

First responses of NSOs late in the survey season will not be used to determine an NSO site when the required number of surveys and/or follow-ups visits cannot be completed. However, without assuming the location of the response constitutes a new activity center, the area will not be cleared for timber harvest until after surveys are conducted in the subsequent breeding season. If the required number of night surveys and follow-up visits are conducted before the end of the breeding season and the results are negative, the area can be cleared for harvest.

6.2.4.5 Special take assessment circumstances

A take assessment based on direct impacts will not be triggered if NSO establish a site during the breeding season within 500 feet of an area where timber falling has already been completed. If NSO establish an activity center during the breeding season within 500 feet of an active THP unit where timber falling has not been completed, timber harvest will be suspended until the appropriate HCP measures have been implemented and protocols completed to determine reproductive status, and protect nesting NSO as may be required. If harvesting is not suspended until this occurs, a take assessment will be triggered.

If Green Diamond resumes timber harvesting after complying with the HCP measures, the following shall apply: if < 10 acres remain to be felled, a take assessment will not be triggered, and if more than 10 acres remain, Green Diamond will consult with the Service to determine whether a take assessment is warranted.

Take assessments based on indirect impacts are based on the location of all known NSO sites at the time that falling is initiated. Any subsequent movements of NSO sites during the falling and harvesting period are not assessed for potential take. If any other situation arises in which the determination of whether a take assessment is questionable, the Service will be consulted to resolve the determination.

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[6] The 21 February start to the NSO breeding season provides a 3-week buffer period prior to the earliest known nest initiation date of 12 March on the Plan Area.

6.2.4.6 Carryover of Unused Takes to Subsequent Years

In the first year of FHCP implementation, take cannot exceed the maximum annual rate of take. Thereafter, any allocated but unused take from prior years is considered to be “reserved” and can be used in subsequent years, so long as the total amount of take in any individual year after year 1 is no more than twice the amount of take allocated during the subsequent year for which the take is anticipated due to Covered Activities. That is, take may be expended at a maximum of twice the rate allocated during the year when the taking activity is implemented, not at twice the rate for the year under which it was initially allocated. If, for example, the number of allocated takes in year X is 3, then the maximum number of anticipated takes that can be expended for year X is 6, regardless of the number of “reserved” takes available, or the allocated number of takes during the year when the reserved takes were first allocated. For example, if Green Diamond has used two fewer takes per year than were allotted for 5 years for a total of 10 takes “reserved.” In the sixth year, if the allotted annual rate of take were four, then Green Diamond would be allowed to add four of the reserved takes for a total of eight takes in the sixth year.

Take of NSO is assumed to occur when Covered Activities impair the occupancy or fecundity through loss of nesting, roosting or foraging habitat. Although take occurs at the level of individual NSOs, the administration of take (i.e., accounting and physical location) operates at the level of a NSO site (nesting and roosting core and surrounding foraging habitat). The rationale is based on the concept that an NSO site provides for the needs of a pair of NSO and loss of a site results in impairment of a pair of NSO. While it might appear that the administration of take would be more appropriately focused on individual NSO, this is not feasible because NSO disappear from a site for a variety of reasons including mortality, emigration to a new site or loss of territorial pair status to a more dominant individual (i.e., former resident NSO becomes a ‘floater’). Given that it is not possible to directly estimate the impact of timber harvesting on the persistence of individual NSO at any given site, take is estimated based on the occupancy and fecundity of whatever NSO may occupy a given site. This removes natural turnover rates from the estimation of take so that take can be assumed to occur when an NSO site is no longer capable of supporting occupancy and fecundity within normal levels.

6.2.4.7 Considerations for Noise Disturbance

Covered Activities have the potential to indirectly cause harm to NSO, in several ways. Indirect harm can occur when there is adequate habitat in an area, but a nest stand is harvested and the NSO are forced to relocate to a new nest site in subsequent breeding seasons. Based on Green Diamond’s observations (Appendix C.2), this timber harvest type appears less likely to affect continued occupancy somewhere within the NSO’s home range. However, in some cases, it did result in reduced fecundity or occupancy.

Indirect harm can also occur when timber harvest does not necessarily affect the NSO nest site or primary activity center, but reduces the total amount of nesting, roosting or foraging habitat available around the nest site or activity center below a critical threshold. If this occurs, in some instances NSO may abandon their site or remain at the site with lower fecundity. Based on NSO monitoring under the NSO HCP, timber harvest depleting habitat below a critical threshold appeared to be more likely to reduce fecundity or site occupancy (Appendix C.2).

Covered Activities also have the potential to indirectly harm NSO through some type of noise disturbance associated with timber operations. Novel loud noises may harm NSOs through changes in essential behaviors such as flushing an NSO from its daytime roost or nest or increasing stress resulting in elevated corticosteroid levels. Both situations have the potential to result in take due to changes in site occupancy, survival or fecundity. Green Diamond's evaluation and documentation of take through implementation of the NSO HCP included potential effects of noise disturbance from Covered Activities. The potential take from all Covered Activities is included in the Authorized Amount of Take (Sections 6.2.3 and 6.2.5) under the Forest HCP:

- Nesting NSOs at sites near THP units scheduled for timber harvest that could result in take (i.e., habitat thresholds may be exceeded) are protected from noise disturbance from timber operations due to a 0.25-mile buffer around the nest site, or following fledging, a 500-foot buffer around the roosting area of the owlets. These potential NSO take sites will be monitored post-harvest to determine if a take has occurred, and if a take has occurred, it would most likely be due to habitat loss, but it could include the potential effects of noise disturbance.

- Non-nesting NSOs at sites near THP units scheduled for timber harvest that could result in take will be evaluated for take post-harvest, and again, if take has occurred it most likely includes habitat loss but it could include potential effects of noise disturbance.

6.2.4.8 Determining Site Vacancy

Under the NSO HCP, Green Diamond defined sites that were unoccupied for three or more years as "abandoned" and no take was reported if the historical owl site was subjected to timber harvest (Green Diamond, 1992). However, if the habitat has not been substantially impacted, there are no biological criteria to establish an NSO site is "abandoned" in the sense that owls will no longer use the habitat. Even if a site was shown to be unoccupied for 10 to 15 years or more, there is still a non-zero probability that it will be recolonized in the future. In truth, the concept of "site abandonment" is biologically questionable in this context since it implies something that is discarded or forsaken when all Green Diamond knows is that the site has been unoccupied for multiple years and is currently vacant. As such, the term "vacant" is the best biological description of a site that has been unoccupied for multiple years. Furthermore, the significance of designating NSO sites "vacant" in the Plan Area is not related to any harm to NSOs. A site that has been designated unoccupied has multiple years with multiple surveys with no NSO detections so the probability that an NSO actually occupies the site but has been undetected is extremely low. Since timber harvesting in and around a vacant NSO site does not trigger a take assessment, the only significance of designating a NSO site as vacant relates to reporting take. It also does not have an impact on the overall amount of habitat since it is highly dynamic in the Plan Area, and on average, harvested sites can be recolonized in approximately 20 years (Section 6.2.4.3). Ultimately, it is most important that the designation of site vacancy be generally consistent with the criteria used under the NSO HCP for site abandonment, since future takes were projected based on the average rate of take from the past. If the vacancy criteria were substantially changed for the proposed FHCP, the projected level and authorization of take would be biased.

For a perennial NSO site (occupied in multiple years) to be considered vacant (unoccupied for three consecutive years), which means timber harvest or other forms of potential take can occur in or around the historical NSO site without triggering a take assessment, it has to meet the definition for being unoccupied in at least three consecutive breeding seasons. If the site is influenced by a barred owl that for some reason cannot be removed, or barred owls recolonize the site so rapidly that NSO have a limited opportunity to colonize the site, the NSO site has to be unoccupied for five consecutive breeding seasons before it is considered vacant. A newly colonized site occupied by a single NSO or a non-nesting pair that is unoccupied after the year of colonization will not be considered an NSO site so the vacancy criteria do not apply. A NSO site is considered influenced by a barred owl if one or more of the following conditions are met:

- A pair of barred owls are detected within the NSO site (a male and female barred owl detected during the same visit)
- A single barred owl is detected within the NSO site more than once during the same breeding season and detections are separated by at least two weeks
- A single barred owl is detected within the NSO site over multiple consecutive breeding seasons

Since there are no plans in place to conduct demographic (mark/recapture) surveys for barred owls, barred owl detections will be reviewed by a qualified wildlife biologist in order to make determinations on the number of individuals and the location of the detections. Similar to the determinations for NSO sites, additional factors that will be considered are topographic features such as whether or not the new site is in the same drainage or separated by some type of acoustical barrier. Green Diamond may refine the above criteria as more data is collected through implemention of this FHCP with concurrence by the Service.

6.2.4.9 Permanence of Owl Sites

Only the most current NSO site within the territory (defended core area) is considered for evaluation of displacement. The current site will be defined based upon the most recent nest site found in the last 3 years. If NSO have not nested in an established site in the past three years, the most recent activity center will be used to define the current site.

If no NSO are detected in a home range after conducting FHCP surveys in each year, the following scenarios will apply: if in the previous year the site was either newly colonized by a pair that nested, perennial, or newly discovered, and the site was not influenced by barred owls (Section 6.2.4.8)), the site will be maintained as active regardless of the outcome of surveys in the subsequent year. However, if the site remains unoccupied by NSO for three consecutive breeding seasons, it will be considered vacant and past nest sites or activity centers will no longer be considered and timber harvesting may occur in the area without triggering a take assessment.

If the site is influenced by barred owls which means they are repeatedly seen or heard at the site without being removed, or barred owls recolonize the site so rapidly that NSO have a limited opportunity to colonize the site the site must be unoccupied by NSO for 5 consecutive years before it is considered vacant.

If the NSO site was established the previous year as a newly colonized site where NSO did not nest, that site will be maintained for one breeding season. If the site is found to be unoccupied in the following breeding season, then that site will no longer be considered an NSO site, because it did not meet the criteria for a perennial site.

6.2.5 Take Assessment Following Model Validation

Following model validation, (i.e., NSO population responds favorably to barred owl removal and improving habitat conditions), and concomitant changes in NSO survey protocol (Section 5.3.5.1), the authorized annual take rate would continue to be used or accumulate at 3 NSO sites (maximum 6 adult NSO) per 100 NSO sites per year. However, the number of NSO sites present within the Plan Area will no longer be directly determined by annual 100% surveys of all NSO sites in the Plan Area, but will instead be determined most likely based on the site occupancy model that is scheduled to be developed following approval of this FHCP. Recent advances in site occupancy models have generated reliable methods to estimate density/abundance based on the heterogeneity of detection probabilities of replicated presence-absence (detection/non-detection) surveys (Royle and Nichols, 2003; Ramsey et al. 2015). While it would be reasonable to be cautious of the outcome of newly developed statistical models, and there may be additional statistical advances resulting in alternative approaches, it is important to remember that development of the occupancy model will overlap with traditional estimates of NSO abundance within the Plan Area. This will allow Green Diamond to validate the new occupancy model with traditional data and the new model will not be adopted unless it can estimate NSO abundance within a 95% CI of a traditional mark-recapture estimate of abundance. Furthermore, model validation means that the conservation plan is working, the NSO population is significantly increasing across the Plan Area and minor fluctuations in estimating the rate of take will be inconsequential to the continued success of the NSO population.

After model validation, the rate of authorized take will remain the same (three per 100 active NSO sites), but the total amount of authorized take will fluctuate in proportion to fluctuations in the NSO population within the Plan Area. For purposes of analyzing the potential effects of this FHCP on NSO, however, Green Diamond predicts that rate and amount of take projected for the first 10 years of this FHCP (i.e., displacement of up to 50 NSO sites, and thus take of up to 100 adult NSO) will continue in the subsequent 40 years of this FHCP (i.e., displacement of up to an additional 200 NSO sites, and thus take of up to 400 adult NSO over 50 years).

Even after Green Diamond refines and validates the habitat and occupancy models, and confirms that the actual rate of take is at or below projected levels, NSO will continue to be protected from direct harm to adults, owlets and nests with eggs. This means that if a Covered Activity with the potential to cause direct harm is scheduled to occur during the breeding season (February 21 to August 31), standard FHCP NSO surveys will be required and FHCP protections applied if nesting NSO are detected (Appendix F). Once the site no longer requires measures to protect NSO from direct harm, the Covered Activity (generally some form of timber harvest) can proceed at Green Diamond’s discretion. Whether or not the timber harvest will be judged to have caused take of the NSO site will not be dependent on the traditional approach of assessing take thresholds (Section 6.2.4.1) and monitoring the NSO site over 3 to 5 years (Section 6.2.4.2). Instead, Green Diamond will assess the probability of take by comparing estimates, before versus after timber harvest, of overall habitat quality within 0.5 mile of the NSO site relative to its estimated ability to support high occupancy and fecundity.

Again, there may be additional advances in statistical methods that will provide superior methods, but currently, Green Diamond believes the best management-applicable approach to estimating habitat quality will be a multi-state occupancy model (Nichols et al., 2007). This model will be based on the same presence-absence (detection/non-detection) surveys used to develop the initial occupancy model, but it will also include whether or not successful reproduction occurred at a site (i.e., there will be two states assessed in the model – detection/non-detection of NSO and detection/non-detection of fledglings). Habitat and forest management-related covariates will also be included in the model building and selection process such that the top model(s) will include the covariates that best correlate with NSO sites having high occupancy and fecundity.

An example of how Green Diamond could use the multi-state occupancy model output to predict when timber harvest will result in take of an NSO site are as follows. First, the multi-state occupancy model will be run centered on the NSO site with the associated habitat covariates before and after the planned Covered Activity (timber harvest). Take will be deemed to occur when the product parameter (occupancy X fledgling estimate) at the NSO site following the timber harvest is below the lower limit of the 95% confidence interval for the occupancy/fecundity product parameter before timber harvest. As a hypothetical example, Green Diamond will assert that take has occurred if the multi-state product parameter drops from 0.45 (95% CI = 0.40–0.50) pre-harvest to 0.38 (95% CI = 0.36–0.42) following harvest. This is a conservative estimate of displacement since the 95% CI of the estimate following timber harvest was not included in the determination of displacement (i.e., the two 95% CI's may still overlap, but a displacement would be presumed if the point estimate of the post-harvest estimate fell outside the 95% CI of the pre-harvest estimate). It should be noted that some details of the model-based displacement assessment may change if Green Diamond gains new insight into the response of NSO to timber harvesting during the process of model validation. Commitments to develop and revise this model have been identified in the Adaptive Management portion of this FHCP.

In other situations, Green Diamond may schedule a timber harvest or other Covered Activity outside the breeding season when direct harm to NSO is sufficiently unlikely that NSO surveys are not required. In this case, take assessment will be based on the presence of a historical NSO site (i.e., active site that was never determined to be vacated) within 0.5 mile that has not already been taken through habitat alteration. Using historical NSO sites is reasonable, because by the time model validation will be achieved, most areas in the Plan Area will have a history of 30 years or more of surveys and it will be highly unlikely that any NSO sites exist without prior knowledge. As described above, take will be determined based on a significant decline post-harvest in the product parameter of the multi-state occupancy model.

If timber harvesting or another Covered Activity occurs outside the breeding season, and there are no historical NSO sites within 0.5 mile, NSO surveys and take assessment will not be required. The probability of a newly colonized site being established after 30 years of survey for most areas is so low that it would have an unmeasurable effect on the overall estimate of annual take. The only exception will be for potential acquisition and addition of Covered Lands into this FHCP, which do not have at least a 10-year history of surveys. In these cases, full NSO surveys will be required even if the Covered Activity occurs outside breeding season.

As a safeguard to ensure that the multi-state occupancy model predictions of take are accurate, Green Diamond will continue to survey a sampling of at least 20% of potential NSO take sites in order to compare model predictions with actual ground-truthed results. Green Diamond will evaluate the performance of these models, and report the results of that performance to the Service in every annual report. If necessary, based on these monitoring data, adjustments to the threshold for take accounting will be made to insure model predictions of take accurately reflect the actual influence of timber harvesting or other Covered Activities on NSO site occupancy and fecundity. For example, if the initial default threshold (i.e., lower 95% CI) underestimates the amount of take based on the biological criteria, the threshold will be raised (e.g., raised to the lower 98% CI). Using this adaptive management approach, the model-based accounting of take will continue to be refined. If Green Diamond and the Service determine that prediction of take using a model based approach is unreliable, Green Diamond will resort to monitoring all NSO sites that are potentially displaced through timber harvest.

6.2.5.1 Contingencies in the Event the Model is not Validated

Until the habitat fitness model is validated and occupancy model developed and refined, Green Diamond will continue the extensive NSO surveys and mark-recapture data gathering. The authorized annual rate of take will remain at those specified in Table 6.1, and Green Diamond will determine the NSO site number from surveys across 100% of the Plan Area.

If the overall NSO population within the Plan Area declines after FHCP approval, despite barred owl removal and projected habitat fitness improvements, Green Diamond will assess the cause of the decline, and the assessment could conclude that it is not possible for the habitat fitness model to be validated. Whether or not the NSO decline is related to habitat, Green Diamond in consultation with the FWS will re-evaluate the authorized rate of take and will adjust it as one adaptive management measure considered to reverse a population decline detected through monitoring. The maximum reduction of take will be dictated by potential decreases in the NSO population as illustrated in Table 6.1. The failure to validate the habitat model will require full monitoring of the NSO population to continue and within another six years the influence of take will continue to be assessed. Green Diamond may be required to implement additional reduction in take as described above. This scenario is highly improbable, but under a scenario of a continuously declining NSO population, take authorization will cease if the number of active NSO sites drops to 47.

6.2.6 Influence of Take on Plan Area and North Coastal Region NSO Populations

The intent of this section is to estimate the influence of authorized future take on the Plan Area NSO population. The overwhelming conclusion is that this is a complex exercise for a dynamic managed landscape where high quality NSO habitat (young stands juxtaposed with mature stands) fluctuates spatially and temporally as a direct result of harvesting and regrowth of forest stands. The estimation of take influences is further complicated by the fact that the majority of vacant sites (74.5%) became vacant (i.e., not occupied for three successive years) for a variety of natural reasons unrelated to timber harvest. Finally, it is complicated by a wide range of NSO responses to timber harvest from no apparent biological influence to abandonment of the site. Despite these complications, Green Diamond used the best available data gathered under the NSO HCP to estimate the biological influence of timber harvesting to the Plan Area NSO population.

Section 6.2.2.3 above provided data indicating that the long-term average annual number of takes by displacement from 1993-2012[7] was 2.35 (SE = 0.33) from an annual average of 153.8 active NSO sites, which equates to an annual rate of 1.53 takes per 100 NSO sites (1.53%) in the Plan Area. Furthermore, Green Diamond predicted that the future rate of take will remain approximately equal to the past rate. If take were assumed to operate in a simplistic additive manner, the future influence of take will be the loss of approximately 2% of the NSO sites per year or 20% per decade and 100% by the end of the permit period. However, as noted previously, NSO sites are highly dynamic within the Plan Area's managed landscape, and with or without timber harvest, NSO sites will become vacant and new ones will be established. Green Diamond calculated empirical estimates of 7.25% for mean annual site vacancy (unoccupied)for all NSO sites from 1990-2005, which was partially offset by an average rate of 3.7% new NSO sites being established annually. With higher mean vacancy than colonization, the overall number of occupied sites in the study area declined. The most likely primary cause

[7] Displacement data were analyzed through 2015, but there is a minimum three-year lag in assigning take so the latest available year when take could be quantified was 2012.

of the decline in occupied NSO sites was the negative influence of barred owls. Results of a removal experiment indicated that barred owls caused a four-fold increase in the NSO site extinction rate, which resulted in a declining NSO occupancy rate in areas where barred owl numbers were not controlled (Diller et al., 2016). This experiment indicated that barred owls also negatively influenced apparent survival and the population growth rate, which indicates that a substantial portion of the vacant NSO sites were due to the effects of the invasive barred owls.

In addition, the Lower Mad River Case Study demonstrates that the downward trend in occupied NSO sites was reversed with improving habitat conditions in an area maintained free of negative barred owl effects (Section 4.3.1.7). Regardless of habitat conditions and available prey base, the maximum density of NSO sites in any area is ultimately set by each pair of resident NSO defending their territory from colonization by other NSO. At the OMU scale (i.e., 20,000 to 60,000 acres [Section 5.3.1.1.1]), the interaction of these factors along with the trend in habitat fitness over time should result in a cyclic pattern in the number of occupied NSO sites. Starting with a sub-basin at the peak of habitat fitness (i.e., about equal amounts of mature and young stands with high overall habitat heterogeneity), timber harvesting will cause habitat fitness to drop and displacement of NSO sites will result in vacancy exceeding colonization and the number of occupied NSO sites will decrease. After most of the timber harvesting has been completed in the sub-basin, habitat fitness will be on the increase due to the development of more mature stands, and no sites will be displaced, so that colonization will now exceed vacancy and the number of sites within the sub-basin will increase. Based on the Mad River example (Section 4.3.1.7), Green Diamond believes the data support a hypothesis that the displacement of NSO sites will cause the low point of the cycle to be somewhat lower, but it will have no effect on the high point. This hypothesis will be tested during the habitat fitness model validation process (Section 5.3.5.1).

The length of the cycle in the number of occupied NSO sites within any given sub-basin will be equal to the average rotation age of stands within that sub-basin. For most Plan Area regions, this is approximately 50 years. As of 2016), Green Diamond started its 27th year monitoring NSO. This means Green Diamond has only documented about half the full cycle of timber harvest. The Lower Mad River Case Study provides Green Diamond the best example to verify its assumptions about how NSO sites will change throughout the cycle (Section 4.3.1.7).

The Lower Mad River Tract had an estimated maximum of approximately 25 NSO sites before concentrated second growth timber harvesting in the 1980's began displacing NSO and reduced the NSO sites to 10 by 1993. Operating under the NSO HCP, only two additional NSO sites were displaced in the Lower Mad River (one in 1999 and one in 2000), but six other NSO sites were not displaced since they occurred within set-asides. This indicates the majority of NSO sites potentially taken within the Lower Mad River Tract occurred before NSO listing and timber harvest at NSO sites would have been take under the ESA.

The Lower Mad River Tract also happened to be in the Korbel/Mad River treatment area of Green Diamond's barred owl removal experiment (Diller et al., 2016). Green Diamond removed all barred owls from the area beginning in 2009 and ending in 2014 at the conclusion of the Phase One experiment (Section 5.3.4.1, Diller et al., 2016). This allowed NSO to start recolonizing the area based on newly emerging habitat suitability. In spring 2009, there were 13 occupied NSO sites within this area, and from then until spring 2015, 13 new NSO sites were established in the area). The barred owl removal experiment may have contributed to a very sharp increase in NSO sites, which potentially would have been more gradual if the barred owl numbers had not been allowed to increase beginning in the early 2000's. Nevertheless, with 26

NSO sites in approximately 22,000 acres, the region will likely soon reach its maximum carrying capacity with NSO densities higher than anything previously reported (Diller and Thome, 1999)

The Mad River example provides evidence that as predicted by the habitat fitness model, NSO habitat throughout the Plan Area will be dynamic (Section 4.3.1.7). For this particular example, which is not directly comparable to future landscapes with a higher proportion of retained riparian zones, the low portion of the approximately 50-year cycle extended for 15-20 years. However, most importantly, the Mad River example also provided evidence the cumulative influence of take (displacement) had no effect on the number of occupied NSO sites when habitat quality within the sub-basin was increasing. The predictions of the habitat fitness model indicates that this pattern will be repeated in other sub-basins in the future, and this is a testable hypothesis that will be explored as part of the model validation process (Section 5.3.5.1)

Green Diamond's NSO survival and fecundity analysis indicated displacement negatively affected fecundity, but had no measurable effect on individual NSO survival (Green Diamond, 2010). Therefore, Green Diamond concluded the estimated biological influence of displacement can only be estimated in terms of reduced fecundity of individuals associated with displacement sites. To estimate what this influence will be for the Plan Area and regional NSO populations, it was necessary for Green Diamond to make the following testable assumptions:

- The rate of displacement within the Plan Area due to timber harvest will be approximately equal to the past rate despite discussion above concerning reasons for expecting reduced displacement in the future, and
- Displacement will have the same influence on fecundity in the future as it had in the past, and
- Average weather conditions will not change substantially since early nesting weather conditions are the single biggest driver of annual fecundity rates, and
- Barred owl removal in the Plan Area will result in positive responses by the NSO population

Lacking barred owl control, the NSO population in the Plan Area is anticipated to repeat the pattern documented throughout the Northwest with NSO going into an increasing population decline as barred owl numbers continue to increase despite stable or improving habitat conditions (Dugger et al., 2016).

Although the actual number and location of future occupied NSO sites are unknown, Green Diamond used the proportional reduction in fecundity to estimate the biological influence of displacement on the future NSO population in the Plan Area. Based on the assumptions stated above, the estimated biological influence of displacement during the time interval from t to t_{+1} was estimated as a reduction in fecundity derived from the negative coefficient of displacement in Green Diamond's fecundity model. From this model, average fecundity (number of female young produced per resident female NSO) was 0.077, 0.100, and 0.305 for S1 (1st year sub-adult), S2 (2nd year sub-adult), and adult NSO (≥3 years old), respectively. As an illustration, assume 100 occupied NSO sites in a given future year in the Plan Area (the average from 1993-2007 was 155.5 sites per year). Furthermore, the age distribution of females occupying NSO sites is the same as in the past with 4.2% S1, 7.6% S2 and 88.2% adult. In an average year, the 100 resident female NSOs would produce 28 female or 56 total owlets fledged per year.

Based on Green Diamond's fecundity model, inclusion of the *take* (displacement) covariate lowered fecundity of females associated with displaced sites, i.e., females at a site displaced during any time in her life, by 63.6%, 49.2% and 15.2% for S1, S2 and adult NSO, respectively.

Reducing fecundity by these percentages for all 100 females, and based on the same female age class distribution, average reproduction would drop to 46.6 total owlets fledged per year. Therefore, Green Diamond estimates reduced production of 9.4 owlets per year (16.8% reduction) if every female in the population had been subjected to displacement sometime during her life. Not every female in the population will be subjected to displacement during her life. However, if there are 100 occupied NSO sites in a given year and displacement in the future is equal to the past, an average of 2.87 sites (2.87%) will be displaced each year with 28.7% of the females displaced in 10 years.

However, there is turnover in the NSO population as individuals die or move off the study area and are replaced by new birds. The best approach for estimating the maximum proportion of females that will be displaced is to consider past cumulative NSO displacement. Based on the 2009 NSO meta-analysis, 16.7% of the capture histories from 1990-2008 were from females subjected to displacement during their life. This suggests the maximum cumulative effect of displacement equates to 1.57 (= reduction of 9.4 owlets/100 females times 16.7% females displaced) fewer owlets per year or a reduction in Plan Area mean fecundity of 2.80%. The displacement influence on the NSO population in the Plan Area is very small and dwarfed by the annual fecundity variation amount. For example, annual fecundity estimates commonly ranged from 0.45 to 0.15 or a 66.7% reduction in fecundity in high relative to low reproductive years, resulting from covariates such as weather and the variable year effect.

In addition, the estimated influence of uncontrolled barred owl expansion in the Plan Area will also likely dwarf the impacts of displacement due to timber harvest. In the most recent NSO meta-analysis of the 11 NSO demographic study areas, NSO population declines of 55-75% in Washington, 31-68% in Oregon and 32-55% in California were reported (Dugger et al., 2016). Although the meta-analysis indicated that the amount of suitable NSO habitat, local weather, and regional climatic patterns contributed to declines in some study areas, there was strong evidence that barred owls were primarily responsible for much of the declines. In the Plan Area within the Redwood Region, the barred owl population is currently rapidly expanding based on Green Diamond's recent survey results. The impacts of Green Diamond's estimated take, which has only been shown to have a minor negative impact on fecundity, will likely be completely dwarfed due to uncontrolled barred owl effects, which have been shown to have a strong negative affect on NSO apparent survival and site extinction rates (Dugger et al., 2016).

To define a regional NSO population, Green Diamond used known juvenile NSO dispersal distances from its 1990 to 2009 study area. Green Diamond documented dispersal distances ranging from 0.5 to 93 miles (mean = 7.7 miles) for 152 males and 0.8 to 87.4 (mean = 10.4 miles) for 147 females. However, these mean dispersal estimates were biased because juveniles dispersing long distances tended to locate somewhere away from the study area and were not available for recapture, while those dispersing short distances had high recapture probability. Therefore, Green Diamond defines the regional NSO population by maximum known dispersal distances, biased low for the same reason as described above, or an area approximately 90 miles surrounding the Plan Area. This includes a large portion of the Coastal California and California Klamath Provinces as defined by the 2011 Revised Northern Spotted Owl Recovery Plan (USFWS, 2011a). Based on the California Natural Diversity Database compiled from 1970 to 2009, there were 1,183 NSO sites within a 90-mile buffer of the Plan Area reported between 2000 and 2009. However, particularly on federal ownerships, few surveys occurred in this area during the last decade. If the 1990 to 1999 sites were included, there were an additional 1,075 sites for a total of 2,258 sites in this same area. This area's actual NSO site number is presumably between these two values. The upper number is likely over-estimated since barred owls now occupy some of the sites, but this error is likely offset since a major portion of the total area was never surveyed. Splitting the difference between the upper and lower number yields an estimated 1,720 NSO sites in the regional population, i.e., NSO sites within dispersal distance of the Plan Area and occupied by NSO sharing a common gene pool. If the average displacement effect only reduces Plan Area fecundity by 1.57 owlets per 100 females per year, the influence on the regional population would reduce overall fecundity by < 0.1%.

6.2.6.1 Reporting Requirements

In each annual report, Green Diamond will disclose where timber harvesting occurred within 0.5 mile of an active NSO site and where harvesting reduced habitat below prescribed thresholds (Section 6.2.3). The assessment of occupancy and reproduction at NSO sites will occur annually following established protocols (Appendix F). Using criteria established under the NSO HCP and refined with additional data (Appendix F), Green Diamond will assess whether timber harvesting potentially reduced site occupancy or fecundity. If site occupancy and fecundity meets or exceeds established criteria, Green Diamond will not report the NSO site as displaced. If occupancy and fecundity fail to meet established criteria, Diamond will report this NSO site displaced and count it towards the total 50 permitted before model validation. Green Diamond will count the number of active NSO sites annually (and reported annually) to forecast potential displacement rate in the subsequent year.

6.3 FISHER

6.3.1 Type of Take

Similar to NSO, it is highly unlikely timber harvesting will harm a mobile adult fisher directly, but the risk to dependent kits is somewhat greater. A long-term fisher study on the nearby Hoopa Reservation found female fishers exhibit denning behavior from March 9 to July 5. During this time, females successfully rearing at least one kit used an average of 3.1 (range 2-6) different den trees averaging 426 meters apart (Higley and Mathews, 2009). During this denning period, female fisher and their kits are at greatest risk of direct harm or take. However, fisher are very sensitive to human activity and have a natural tendency to move their kits to new den sites, making it unlikely any timber harvesting activities directly kill or injure fisher. An adult fisher would most likely vacate an area with any active timber falling, and even a female with an occupied natal or maternal den tree would likely move her kits if tree falling began anywhere nearby. Even if a female did not vacate her den tree, fisher only use relatively large conifers or hardwoods with cavities for denning and these trees are retained under this FHCP conservation measures (Section 5.3.2), which minimizes their risk of direct harm. However, any disturbance causing forced abandonment of a den tree would likely increase the risk of mortality due to exposure, predation, road kill, etc., to the female or her kits. Green Diamond has documented fisher deaths on paved public highways, but no known instances of mortalities have occurred on logging roads where traffic speed and density are much lower. Few data are available to determine actual rates of mortality due to predation or exposure, as a result of forced movements prompted by disturbance.

Green Diamond also documented fisher deaths at abandoned or unmaintained water storage tanks. Fishers may enter water tanks or other structures, becoming entrapped or drowning. Green Diamond's AHCP/CCAA (2007) requires it maintain fisher-proof water tanks with permanent structures sealing the tank from inadvertent fisher entry. Nevertheless, there is still some potential that fisher will access a water tank and die due to human error despite all efforts to eliminate this accidental harm. Section 5.3.3.2 presents a management commitment to secure all such structures, and maintain, repair, or replace such structures as needed to ensure future compliance.

The primary source of potential fisher harm is habitat modification through timber harvesting. However, unlike NSO, fishers do not exist as territorial pairs nor have well-defined activity centers where this activity can displace them. Fisher are solitary, and although females may use a single natal den tree (where the kits are born), they use multiple maternal dens (where the kits are kept while they are still too young to move with the female) within a general area and many rest trees scattered throughout their home range. As a result, Green Diamond cannot readily identify fisher displacement from their home range. Presumably, however, timber harvesting at some level sufficiently modifies fisher habitat forcing individual fisher to attempt relocation to a new home range. This likely decreases survival and fecundity as fisher attempt to find suitable habitat not already occupied by a resident fisher.

As noted above, fisher are also very sensitive to human presence and disturbance, potentially leading to adverse influences. Green Diamond's fisher telemetry studies indicated fisher often fled the area when a human approached on foot. This means disturbance associated with timber harvesting such as humans walking through the forest, noise from chain saws and heavy equipment may disrupt essential behavior patterns and cause harassment.

6.3.2 Estimated Level of Take

Unlike NSO, estimating fisher take amount or influence is very difficult. Green Diamond does not know how many fishers are in a particular area because fishers do not have defended activity centers or readily surveyed den sites. In addition, without using radio telemetry Green Diamond cannot know when timber harvesting displaces or affects a fisher. Furthermore, Green Diamond knows of no demographic data or methodology to estimate how timber harvesting may affect fisher survival or fecundity rates.

The only feasible, cost-effective way to quantify fisher take amount and effect, at a landscape scale, is through projected changes in habitat quality for fishers. With respect to potential fisher denning and rest site habitat, the forecasted result of FHCP implementation represents an overall increase in the amount of older stands and individual wildlife trees suitable for fisher denning and resting. The trend in stand age class distribution of riparian areas and other forms of retention under Green Diamonds Forest Stewardship Council (FSC) California Timberlands Forest Management Plan indicates approximately 27% of the Plan Area will be in some forms of reserve (Green Diamond, 2017), and that the average age of these riparian stands will increase from 44 to 94 years old by the end of the permit period (Figure 6-4). Retention will occur within required riparian management zones and geological protection areas and the TREE implementation (Section 5.3.2). This is important since large denning and resting trees are generally in much lower numbers on managed landscapes, which may be a limiting factor for fisher (CDFG, 2010).

Despite efforts to retain and recruit denning and resting structures, Green Diamond anticipates that some existing denning and resting habitat will be lost and harvesting of adjacent trees will result in a low level of displacement of fishers when Covered Activities occur in older forests. Adult fishers without dependent young are highly mobile, and would have a low probability of being directly harmed or injured by those activities. Local reductions in extent or quality of suitable habitat are anticipated in the short term, but these localized short-term declines will be offset over the life of this FHCP as a result of ingrowth of suitable habitat in evenaged harvest units and continued stand development in RMZs and other limited entry stands. Female fishers with dependent young, if forced to move young kits, may be subject to predation or other forms of harm. Very young kits, entirely dependent on maternal feeding and care, may be particularly vulnerable to exposure or predation, and be harmed or injured if moved in response to Covered Activities. The rate of harm or injury resulting from this forced movement is anticipated to be not more than the number of acres of suitable denning habitat entered each year to conduct Covered Activities.

Although most of the denning and resting habitat will occur in riparian and other forms of retention areas, which as noted above will represent approximately 27% of the Plan Area, the remaining 73% of the Plan Area will be actively managed and represent much of the foraging habitat for fishers. As noted on Figure 6-5, forest ingrowth will exceed harvest, which suggests that stands available for foraging will increase. However, Green Diamond postulates that the potential effects from harvesting fisher foraging habitat is best estimated using its fisher occupancy model. This model predicts the probability of a fisher occupying a particular point within the Plan Area for general movement or foraging purposes. Although Green Diamond does not believe foraging habitat availability limits fishers in the Plan Area, timber harvesting and its associated activities within fisher foraging habitat potentially have adverse effects. These include disturbance, vacating rest sites or changing normal movement patterns or in the extreme case, abandoning a home range and relocating to a different area. To assess these potential influences, Green Diamond projected the probability of fisher occupancy in the Plan Area at 10-year intervals from 2010 to 2060. Occupancy projections are dynamic across the ownership, but in general, occupancy probability declines with increased amounts of recent timber harvesting in an area, i.e., occupancy declines with increasing amounts of 6- to 20-year-old stands. The Plan Area trend indicates habitat associated with the highest projected occupancy (> 0.80) declines from 135,592 acres (47% of ownership) in 2010 to 103,826 acres (36% of ownership) in 2040 and then stabilizes for the next 20 years. However, if Green Diamond combines the two highest projected occupancy categories, the Plan Area proportion in these two categories only declines by 26,044 acres (12.6%) from 206,292 acres (71% of ownership) in 2010 to 180,248 acres (62% of ownership) in 2060 (Section 4.3.3.4).

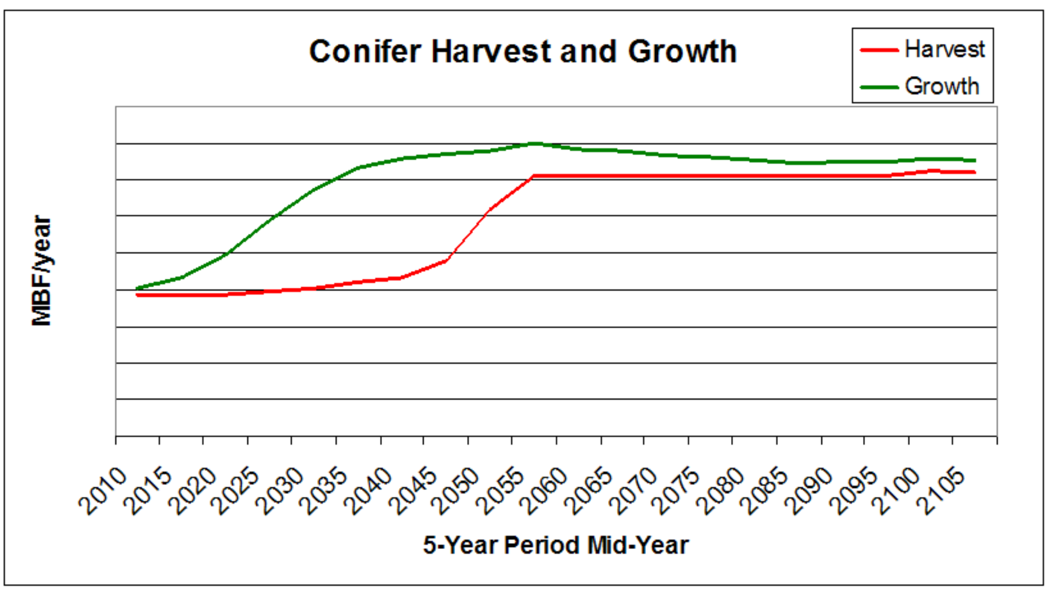

Figure 6-4. Conifer harvest and growth, by 5-Year Periods, 2008-2107

Source: Green Diamond, 2017

Note: For proprietary reasons, the units are omitted from the vertical axis

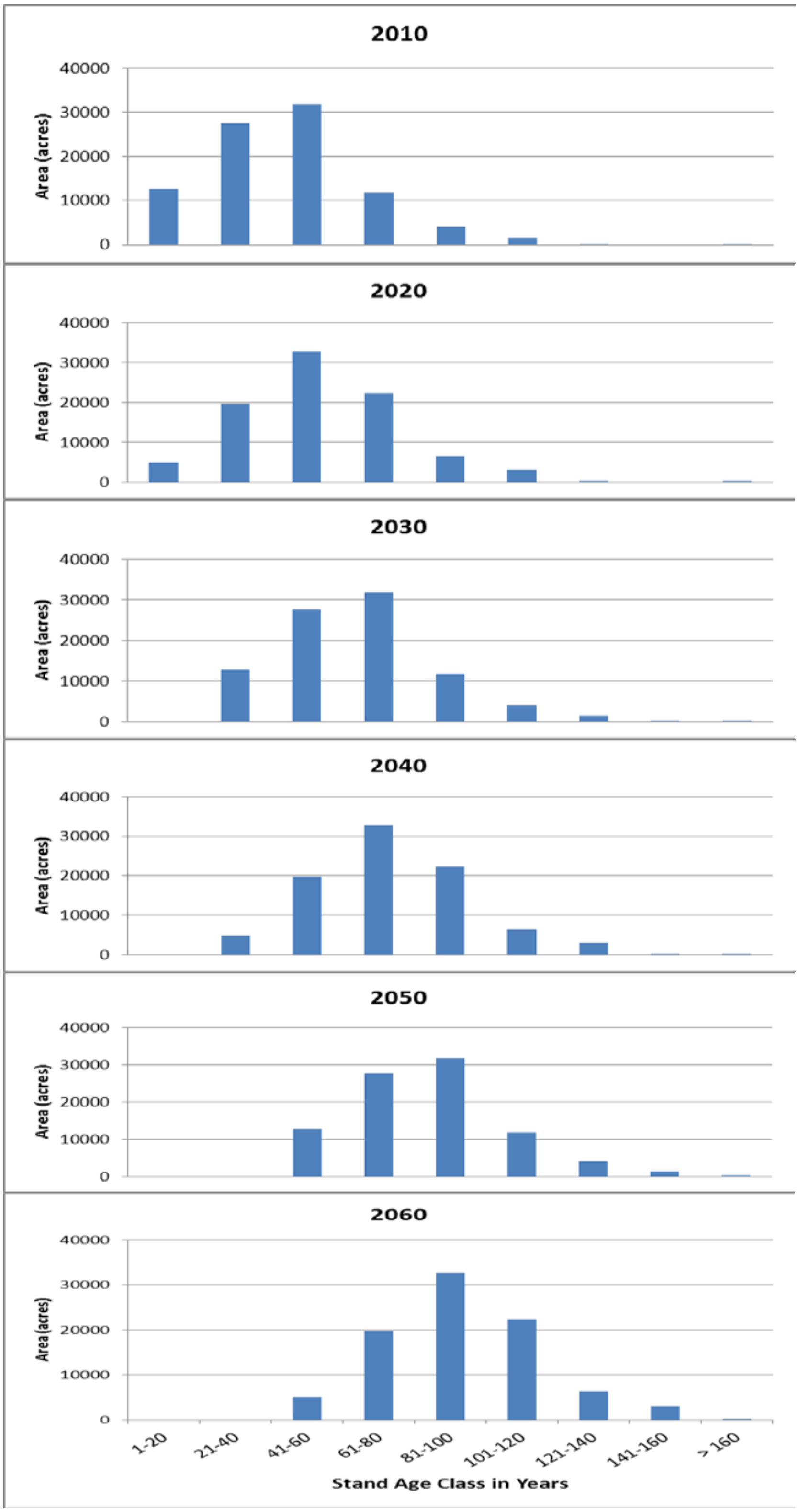

Figure 6-5. Trend in the Age Class Distribution of Timber Stands within Riparian Zones.

The estimated population density of fishers on Green Diamond's ownership based on two study areas and two estimation techniques was 0.23 fisher/km^2 (sexes combined). Applying this average across the Plan Area, Green Diamond estimates a population of 335 fisher. Because timber harvest averages approximately 2% of the ownership per year, annual timber harvest could harm an average 6.7 fisher (2% of 335=6.7). Presumably, the potential timber harvesting adverse influences will vary substantially depending on a complex suite of variables, including location of the harvest units relative to the core of the animal's home range, time of year, sex of the animal and reproductive condition if it is a female. However, Green Diamond cannot predict any of these variables relative to projected future timber harvesting. Consequently, Green Diamond postulates that timber harvesting may adversely affect 6.7 fisher annually.

6.3.3 Influence of Take on Plan Area and North Coastal Region Fisher Populations

Unlike NSO, Green Diamond has not collected data suitable for estimating the potential influence of take on any fisher demographic parameters. Green Diamond made the assumption that annual harvesting of 2% of the Plan Area potentially adversely affected 2% of the fisher population (approximately four female and three male fisher). However, the adverse effects could range from a fisher forced to alter its travel route by a few hundred meters to avoid human activity, to a female fisher abandoning her kits in their natal den because of a stand being felled. Except for abandoned water storage tanks, which have been addressed, there is no evidence timber harvesting activities will directly harm any adult fisher. However, Green Diamond conservatively predicts that all female fisher affected by timber harvesting have reduced reproductive success, with the worst case being none of these affected females successfully rear kits. Continuing with this rationale suggests take reduces reproduction by 2% in fisher, similar to NSO estimates (i.e., 2.8% reduced NSO fecundity). Green Diamond has no data on the annual variation in fisher reproduction or what factors influence it, but postulates that this level of take associated with timber harvesting will minimally affect fisher in the Plan Area. This assertion's most compelling evidence is the response of the fisher population in the region including the Plan Area to extensive and intensive timber harvesting performed in the mid- to late- 1900s. The first surveys for fishers in the mid 1990's indicated a well distributed fisher population in the Plan Area within a landscape produced by timber harvesting regulations allowing much larger clearcuts with less restrictive adjacency requirements and very little late seral structure retention.

To estimate effects on the regional fisher population, Green Diamond used estimates from literature on juvenile fisher dispersal distances. The maximum reported was approximately 62 miles (100 kilometers) in an eastern population, but most estimates were 18.6 to 31 miles (30 to 50 kilometers) (Callas and Figura, 2008). Green Diamond believes maximum known dispersal distances best define the regional fisher population, an area of approximately 12 to 25 miles (19 to 40 kilometers) surrounding the Plan Area. This is approximately 3,317 to 5,447 square miles (8,592 to 14,109 km^2). When applying the same Green Diamond estimated mean density of fisher to this area, the regional population is approximately 1,976 to 3,245. If take influence reduces Plan Area reproduction by only an average 2%, regional population fecundity influence is < 0.3%.

6.4 TREE VOLES

6.4.1 Type of Take

Most tree voles live in a single nest tree and make short forays into neighboring conifers with interlocking branches. They live their entire lives within a small home range and presumably only have very limited dispersal abilities. Therefore, they are highly vulnerable to the direct effect of timber harvesting if they reside in a tree felled during timber harvest. If the vole survived this activity, it would force them to disperse and make them highly vulnerable to predation. Although survival during timber harvesting is possible, survival of displaced tree voles is certainly much lower than resident voles and constitutes take.

Tree voles are also highly vulnerable to take through habitat modification caused by timber harvesting. On the scale of a tree vole's home range, a clearcut unit eliminates habitat for at least 20 years and a harvest unit treated with some form of unevenage silviculture may adversely modify their habitat by opening up the canopy or direct felling of an occupied tree. Until the canopy redevelops, the interlocking branches would be reduced making foraging more difficult and voles likely more vulnerable to predation.

6.4.2 Estimated Level of Take

For tree voles, the approximate level of take is equal to the proportion of suitable habitat harvested each year. This is projected to average 2% of the vole habitat harvested each year and changes little with a low of 1.2% in 2050 to a high of 2.1% in 2060 (Figure 6-6). However, habitat generates as rapidly as it is lost, so there is no substantial net change in the total amount of habitat through time. Therefore, Green Diamond projects it will take an average 2% of the tree vole population annually.

Green Diamond used data from field work conducted during 2001-2005 (Section 4.3.4) to estimate density of tree vole nests in suitable habitat on Green Diamond's plan area. However, the ground-based surveys underestimate density of vole nests in at least two ways. A certain proportion of nests remain undetected, and other nests detected are misclassified because evidence of tree vole use was not apparent from the ground (resin ducts not found). Swingle (2005) conducted ground based surveys in young (22 to 55 years) and old (110 to 250 years) forests in Oregon and then used tree climbing and telemetry to locate additional tree vole nests. The quantity of active or recently occupied vole nests he located increased 104% when using the additional techniques. The number of active or recently occupied vole nests overestimates the number of resident tree voles in an area because voles may have 1-6 nests within their home range (Swingle, 2005).

The Green Diamond data from 2001-2005 estimated an average density of 0.06 tree vole nests/acre in young stands (23 to 75 years). Using data from young stands in Swingle (2005), Green Diamond inflated estimates of vole nests by 100% to account for vole nests not visible from the ground and then divided the estimates of nest density by 2.2 which was the average number of nests used by tree voles in young stands in Oregon. Green Diamond applied this average to the average annual amount of vole habitat in the plan area from our habitat model (Section 4.3.4) and estimated a population of approximately 11,833 tree voles. Timber harvesting of approximately 2% of vole habitat annually would potentially influence approximately 237 tree voles (11,833 times 0.02). Green Diamond cannot predict the exact amount of vole habitat that will be harvested annually over a 50-year permit term since the precise location of harvest is not known beyond a few years. Therefore, we cannot provide detail at the forest stand level (i.e., age and Douglas-fir basal area), so we must rely on the overall level of harvest predicted on the ownership based upon long term harvest forecasts and the vole habitat model. We predict that, on average, approximately 2% (~4,000 acres) of stands that meet the Douglas-fir minimum basal area (≥20% Douglas-fir) and age requirements (45 years) will be harvested annually. The actual influence of timber harvesting on tree voles will vary on an annual basis given the location of harvesting relative to tree vole habitat and the number of active vole nests present in any given year. Green Diamond cannot predict with certainty the actual influence of timber harvesting on the vole population given the highly variable density of nests on the landscape, changes in nest occupancy through time and other environmental factors, so Green Diamond postulates that timber harvest under this FHCP could negatively influence approximately 2% of vole nests on an annual basis.

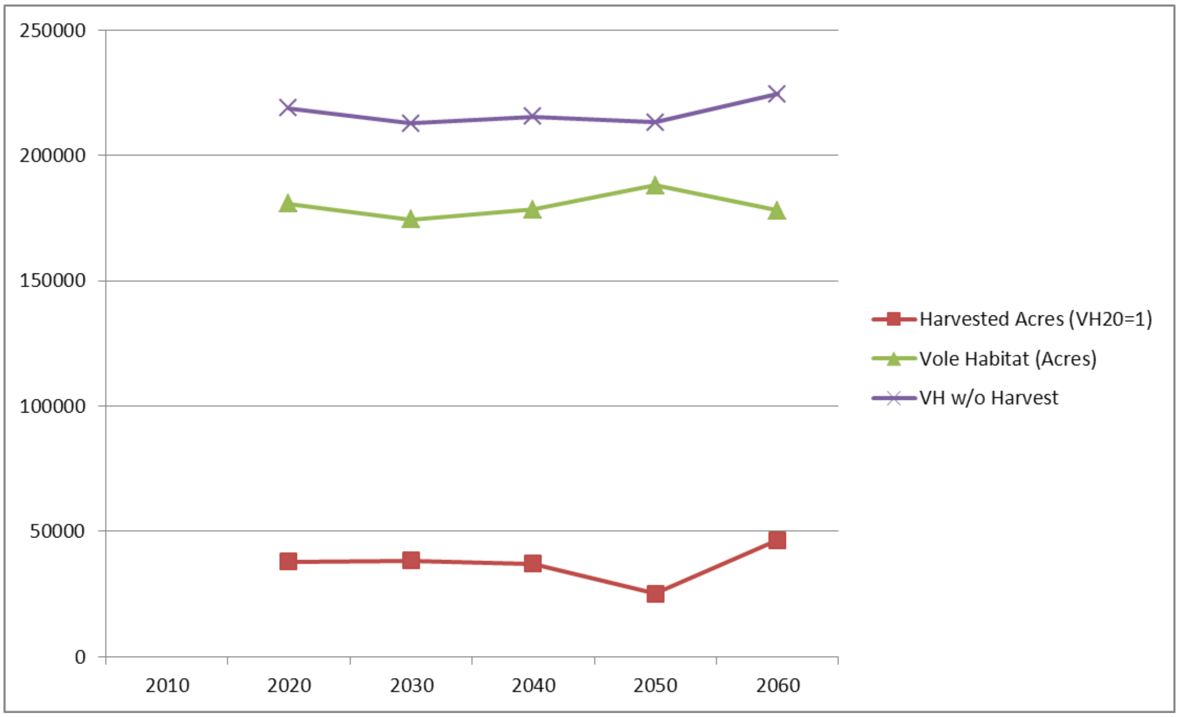

Figure 6-6. Projected Amounts of Available Tree Vole Habitat and Acres Harvested by Decade.

6.4.3 Influence on Plan Area and North Coastal Region Tree Vole Populations

Although population monitoring data for tree voles do not exist, the fact that tree voles continue to persist suggest that the tree vole population in the Plan Area has been sustained through several cycles of habitat loss followed by recolonization. Following this assumption, there should be no net influence associated with timber harvest unless the ability to recolonize suitable habitat diminishes. However, Green Diamond believes the TREE and riparian retention will enhance persistence and potential future stand recolonization. Therefore, the influence of take is neutral or positive relative to tree vole populations in the Plan Area.

Given presumed very low tree vole dispersal ability, the Plan Area and region populations are essentially equal and therefore equally affected.

6.5 ADAPTIVE MANAGEMENT

It should be noted that some details of the model-based displacement assessment may change with the Service's collaboration and approval, if Green Diamond gains new insight into the response of NSO to timber harvesting during the process of model validation. The Service will have input on model revisions including model selection.

6.6 SUMMARY OF KEY TAKE ASSESSMENTS

The following summarizes the conclusions of the take assessment analyses which are detailed earlier in this section:

- NSO:
  - The potential for unintended, direct take under this FHCP has been estimated based on Green Diamond's experience with NSO surveys (performed under the NSO HCP) that failed to detect owls when they were present. Although no unintended, direct take was documented, a limited number of NSO surveys failed to detect nesting NSO. Such detection failures could result in unintended direct take. Green Diamond estimates that over the 50-year term of the Permit, 2.5 NSO sites or a maximum of 10 individual NSO could suffer unintended, direct harm (i.e., death or injury to an adult NSO, its eggs, nestlings or fledglings) from timber harvesting (Section 6.2.2).
  - For purposes of estimating and permitting incidental take caused by habitat modification, this FHCP postulates that take will occur when a series of Covered Activities associated with harvesting stands within or near occupied NSO sites results in displacement of resident NSO from their nest sites or activity centers and/or a significant reduction in fecundity (Section 6.2.2).
  - The amount of future take has been estimated based on past levels of such take as determined by intensive NSO monitoring under the NSO HCP (Green Diamond, 1992). The annual rate of future NSO incidental take is estimated to be 1.53 per 100 active NSO sites (if NSO pairs occupy all active sites) during the first 10 years of the Permit. There is compelling evidence based on future habitat projections that this is a conservative estimate and that the rate of take will be lower in the future (Section 6.2.2.4). Upon approval of this FHCP, Green Diamond will account for annual take using the same habitat thresholds, based on a study of nesting NSO in the Plan Area (Folliard, 1993), to trigger an assessment of take as applied in the NSO HCP. The thresholds for assessment include timber harvesting within a 500-foot radius of a NSO site or having < 89 acres of stands ≥ 46 years old and < 233 acres of stands ≥31 years old within a 0.5-mile radius of an NSO site. The final determination of take at an NSO site that has exceeded the threshold for an assessment will be based on an evaluation of occupancy and reproduction by the NSO at the site. Using criteria established under the NSO HCP and refined with additional data (Appendix F), Green Diamond will assess whether timber harvesting reduces site occupancy or fecundity below the established criteria (Appendix F). If occupancy and fecundity fail to meet established criteria, Green Diamond will report the occurrence as a take and count it towards the total take authorized under the Permit.
  - This annual accounting of take using the NSO HCP methodology will be used to validate this FHCP projection of future takes, until such time (approximately 10 years) that Green Diamond's habitat and occupancy models are validated. Thereafter, annual accounting of take will be performed using a mixed approach including the

traditional NSO surveys, used on historical NSO sites and a habitat approach based on the validated multi-state site occupancy model, which will estimate changes in fecundity and occupancy due to timber harvesting around an NSO site. In this later case, take will be predicted to occur when the model-based point estimate incorporating site occupancy and fecundity at the NSO site following the timber harvest is below the lower limit of the 95% confidence interval for either of those parameters before timber harvest (Section 6.3.2). For the model-based evaluation of take, Green Diamond will use the 1992 HCP methodology to annually monitor at least 20% of potentially displaced NSO sites to confirm the accuracy of the model-based approach to evaluate and further refine estimates of take.

- Green Diamond seeks authorization for take of three NSO sites per 100 NSO sites per year, or a total of approximately 5 takes per year (approximately 250 over the 50-year term of this FHCP) based on the current number of active NSO sites (166) (Section 6.2.3). Green Diamond may reserve unused takes from a prior year(s), but no more than double the allotted rate may be used in the current year.
- If the rate of take due to timber harvesting remains the same in the future as in the past, it is estimated that the biological influence of loss of 5 NSO sites per year will equate to 1.57 fewer owlets per 100 adult females per year or a reduction in mean fecundity of 2.80% in the Plan Area. This influence on fecundity is substantially exceeded by the amount of annual variation in fecundity due to covariates such as barred owls, weather and the even-odd year effect (Section 6.2.2).
- An estimated 1,720 NSO sites occur within dispersal distance of the Plan Area (Figure 6-2), which represents a potential regional population of 3,440 resident NSO. If on average, the take effect only reduces Plan Area fecundity by 1.57 owlets per 100 females per year, the regional population effect is less than a 0.1% overall fecundity reduction (Section 6.2.4).

- Fisher:

  - Timber harvesting and improperly maintained water tanks may adversely affect fishers through direct unintended harm (i.e., death or injury) to an adult fisher or its kits (Section 6.3.1). Measures implemented under the Section 5 Conservation Program will prevent the death or injury to fishers, through well maintained, fully secured structures to prevent entrapment and/or drowning. However, timber harvest has the potential to cause direct harm to fishers.
  - The most common adverse effect to fishers from timber harvesting is habitat modification to the extent it forces a fisher to attempt relocation to a new home range. This would likely decrease survival and fecundity as fisher attempt to find suitable habitat not already occupied by a resident fisher. In addition, disturbance associated with timber harvesting (i.e., humans walking through the forest, noise from chain saws and heavy equipment, etc.) may disrupt essential behavior patterns and result in harm (Section 6.3.1).
  - Because timber harvest averages approximately 2% of the Plan Area per year and the population of fishers was estimated to be approximately 335 individuals within the Plan Area, annual timber harvesting could disrupt essential behavior for an average 6.7 fishers per year (Section 6.3.2).
  - Annual adverse effects to 6.7 fishers in the Plan Area are not significant to the regional population (i.e., fisher within dispersal distance of the Plan Area and sharing a common gene pool), an estimated minimum of 1,976 fishers. Applying the same

take influence to the region, the effect is < 0.3% on the regional population from Plan Area timber harvesting operations (Section 6.3.3).

- Tree voles:
  - Due to their small home ranges and limited dispersal ability, tree voles are likely to be adversely influenced by both direct and indirect influences of timber harvesting (Section 6.4.1).
  - Because very few tree voles will likely survive if their nest trees occur in a harvest unit, the level of take is approximately equal to the proportion of suitable habitat harvested each year. Green Diamond projects timber harvesting will harm an annual average of 2% of the tree vole population or approximately 237 tree voles (Section 6.4.2).
  - The 2% annual vole population take is not significant compared to the estimated large number of voles inhabiting the Plan Area.

Section 7. Assessment of the Conservation Strategy's Effectiveness

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7.1 INTRODUCTION

This section discusses how this FHCP's operating conservation program described in Section 5 fulfills ESA requirements and provides the Service with the basis for authorizing take of Covered Species pursuant to an ITP.

For an HCP to be approved under ESA Section 10, the Service must find the applicant will "*to the maximum extent practicable, minimize and mitigate the impacts of such taking [incidental to otherwise lawful actions],* and the taking *will not appreciably reduce the likelihood of the survival and recovery of the species in the wild."* In addition, the Service must receive assurances the applicant will implement the plan and "*will ensure that adequate funding for the plan will be provided"* 16 U.S.C. 1539(a)(2)(A) and (B).

The Service prepared an HCP Handbook (1996 and 2016) explaining these approval criteria. The Handbook also describes the process an applicant should follow with the Service to develop an HCP fulfilling ESA requirements.[1] In addition to addressing the essential statutory criteria, the HCP Handbook requires an HCP to:

- Include and expressly state the biological goals and objectives of the plan for the Covered Species
- Incorporate an adaptive management program addressing conservation program uncertainties and potential adjustments to the conservation program over the life of the plan

The HCP Handbook provides that an HCP may address unlisted species as well as listed species, provided that the unlisted species are addressed as though they are listed and the same criteria for approval are applied to all Covered Species.

Section 6 examines the impact of Plan Area Covered Activities on Covered Species, including the estimated type, quantity and effect of incidental take. This section describes how individual FHCP measures will:

- Avoid or minimize potential Covered Species take caused by Plan Area Covered Activities
- Mitigate potential effects of Covered Species take caused by Plan Area Covered Activities
- Ensure Covered Activities do not cause any appreciable reduction in Covered Species survival and recovery likelihood in the wild
- Examine all potential individual and cumulative take effects and all conservation benefits, together with their relative significance, for each Covered Species

Generally, the Plan achieves these requirements by one or more of the following:

- Avoiding or minimizing an environmental effect that could cause incidental take and its associated impacts

[1] The FHCP was developed using the guidance provided by the Service's first Habitat Conservation Planning Handbook (1996) as well as guidance provided in the updated HCP Handbook released in 2016. Both documents provide non-binding guidance on the ESA's statutory and regulatory provisions applicable to the development and approval of the FHCP.

- Identifying specific measures designed to mitigate incidental take effects (both in the nature and extent of impact)
- Providing other Covered Species conservation benefits

In addition to measures designed to avoid or address specific effects, the Plan includes actions to improve conditions for the Covered Species. These additional measures provide a mitigation level that fully offsets and exceeds anticipated take effects.

The 1996 HCP Handbook requires that an HCP "*will not appreciably reduce the likelihood of the survival and recovery of Covered Species and does not explicitly require an HCP to recover listed species, or contribute to their recovery objectives outlined in a recovery plan"* (USFWS, 1996:3-20). It further states *"however, recovery is nevertheless an important consideration in any HCP effort"* (USFWS, 1996:3-20). Accordingly, the 1996 HCP Handbook advises "*[t]o put this in practical terms, applicants should be encouraged to develop HCPs that produce a net positive effect for the species or contribute to recovery plan objectives"* (USFWS, 1996: 3-20). The 2016 HCP Handbook provides similar guidance distinguishing between recovery as a desired goal, but not a legal requirement for approval of an HCP; "*we encourage applicants to develop conservation plans that are consistent with the recovery plans and contribute to the recovery of the covered species*" USFWS, 2016:2-5.

The NSO is the only Covered Species listed and addressed by a Service recovery plan. This section describes this FHCP conservation program's consistency with the Revised NSO Recovery Plan. This consistency provides added confidence this FHCP meets and in some cases exceeds the ESA Section 10 standards applicable to each identified impact on NSO. Stated another way, the extra measures supply added assurance that a sufficient level of conservation is being provided to address any concern about the sufficiency of any particular measure to address the extent of a particular type of impact. Furthermore, these measures improve conditions beyond the ESA Section 10 minimize and mitigate standard. This FHCP achieves properly functioning habitat and contributes both to the recovery of the NSO and to efforts to preclude or remove the need to list the unlisted Covered Species.

Finally, this section:

- Provides assurances that Green Diamond will provide adequate resources for this FHCP implementation
- Justifies Green Diamond's reasonable conclusion that this FHCP conservation measures minimize and mitigate take to the maximum extent practicable
- Verifies that this FHCP includes an adaptive management program meeting the intent of the HCP Handbook Addendum

Table 7-1. Summary of Plan Elements and ESA Approval Criteria.

ESA Approval Criteria for Covered Species	Biological Goals & Objectives (Section)	Measures to Minimize & Mitigate Take Effects (Section)	Conservation & Recovery Measures (Section)	Adaptive Management Measures (Section)
NSO	Increase Habitat Fitness (5.2.2.1)	Manage for Mosaic of Mature Stands and Young Forest Edges (5.3.1.1.1; 5.3.1.2; 5.3.1.3)	Manage for Mosaic of Mature Stands and Young Forest Edges (5.3.1.1.1; 5.3.1.2; 5.3.1.3)	Monitor all NSO Sites/Fecundity Until Habitat Fitness Model Validated (5.3.5.1)
	Protect/Develop Highly Productive NSO Sites (5.2.2.1)	Protect/Develop DCAs (5.3.1.4)	Protect/Develop DCAs (5.3.1.4)	Monitor Fecundity of All DCAs Plus 12 additional Sites (5.3.5.1.4)
	Retain and Recruit Complex Habitat Elements (5.2.2.2)	Retain and Recruit Complex Habitat Using TREE (5.3.2)	Retain and Recruit Complex Habitat Using TREE (5.3.2)	Maintain Compliance Monitoring Through THP and Annual Reporting (5.3.7)
	Avoid NSO Direct Take (5.2.2.3) Conduct Experimental Barred Owl Management (5.2.2.4)	Conduct Pre-harvest NSO Survey and Avoid Direct Take (5.3.3.1)	Conduct Experimental Barred Owl Management (5.3.4)	Conduct Barred Owl Removal & Coexistence Experiments (5.3.4)
		Controlled Access Enforcement (5.3.3.4)		Triggers Could Add DCAs or Reduce Take Authorization (5.3.6)
		No Take Management in Peripheral Area (5.6.1)		
Fisher	Maintain and Improve Fisher Denning and Resting Habitat (5.2.2.1)	Manage for Mosaic of Mature Stands and Young Forest Edges (5.3.1.1.2; 5.3.1.2; 5.3.1.3)	Manage for Mosaic of Mature Stands and Young Forest Edges (5.3.1.1.2; 5.3.1.2; 5.3.1.3)	Noninvasive Surveys to Validate/Monitor Fisher Presence (5.3.5.2)
	Maintain and Improve Fisher Foraging Habitat (5.2.2.1)	Retain and Recruit Complex Habitat Using TREE (5.3.2)	Retain and Recruit Complex Habitat Using TREE (5.3.2)	Respond to Trigger by More Intensive Occupancy Surveys, Mark-Recapture, Disease Screening (5.3.6)
	Retain and Recruit Complex Habitat Elements (5.2.2.2)	Prevent Direct Fisher Take (5.3.3.2)	Cooperate as Source Population and Assist with Fisher Capture for Reintroduction and Recovery Outside Plan Area (5.3.3.2)	
	Avoid Direct Fisher Take (5.2.2.3)	Controlled Access Enforcement (5.3.3.4)		
Tree Voles	Maintain and	Manage for Mosaic of	Manage for Mosaic	Conduct Owl Pellet

Table 7-1. Summary of Plan Elements and ESA Approval Criteria.

ESA Approval Criteria for Covered Species	Biological Goals & Objectives (Section)	Measures to Minimize & Mitigate Take Effects (Section)	Conservation & Recovery Measures (Section)	Adaptive Management Measures (Section)
	Improve Tree Vole Nesting Habitat (5.2.2.1)	Mature Stands and Young Forest Edges (5.3.1.1.3; 5.3.1.2; 5.3.1.3)	of Mature Stands and Young Forest Edges (5.3.1.1.3; 5.3.1.2; 5.3.1.3)	Surveys to Validate/Monitor Vole Occupancy (5.3.5.3)
	Retain and Recruit Complex Habitat Elements (5.2.2.2)	Retain and Recruit Complex Habitat Using TREE (5.3.2) and protect vole nests in RMZs (5.3.3.3)	Retain and Recruit Complex Habitat Using TREE (5.3.2)	Respond to Trigger by More Intensive Occupancy Surveys / Vole Research to Determine Cause of Decline (5.3.6)

7.2 NORTHERN SPOTTED OWL CONSERVATION BENEFITS

7.2.1 Measures to Avoid and Minimize NSO Take

This FHCP includes Goal Three (Section 5.2.2.3) and several measures to avoid and minimize incidental NSO take. These measures focus on protecting nesting owls and young during the breeding season and providing long-term protection for the most productive nest sites throughout the Plan Area. Section 5.2.2.3 requires that Green Diamond survey any planned timber harvest during the NSO breeding season, i.e., 1 March – 31 August, to determine whether NSO are present. If so, Green Diamond must refrain from any timber harvest at or near an active NSO nest site during the nesting season. Section 5.6.1 also requires Green Diamond to avoid any incidental take of NSO on Green Diamond's California timberlands outside the Plan Area. These measures avoid and minimize take by preventing interference with the essential breeding behavior and reproductive success of nesting NSO pairs, and protecting young from direct harm by felling a nest tree.

Green Diamond also avoids and minimizes NSO take through long-term protection of the most productive NSO nest sites throughout the Plan Area. As described in Section 5.3.1.4, there are 44 designated DCAs around the most productive NSO nesting sites throughout the IPA. Green Diamond protects these DCAs as long-term no harvest zones within an 89-acre core area and as no-take within a 0.5-mile buffer, and not just during the nesting season. The DCAs are designated based on proven productivity of nest sites selected by NSO pairs that successfully reproduce. Green Diamond may release these nest sites from protection only if replaced by protection for another highly productive site in the same portion of the Plan Area (an OMU) or the site is no longer productive and a substitute site of equal or greater productivity is designated for protection in the same or adjacent OMU. Further protection for DCA's is afforded by restrictions on timber harvest frequency and timing adjacent to designated DCAs so that Covered Activities outside the DCA do not disturb essential NSO breeding and rearing behavior and contribute to site productivity through increased habitat heterogeneity. Finally, take is prevented and minimized through Green Diamond's commitment to enforcement of controlled access measures (Section 5.3.3.4). Green Diamond provides gates, security, monitoring, and enforcement to exclude unlawful and unauthorized activities for the production of drugs. Intensive and unlawful use of pesticides has been associated with these activities and there is strong evidence of lethal and harmful injuries to NSO from use of pesticides in association with marijuana growing on adjacent lands.

7.2.2 Measures to Mitigate NSO Take and Contribute to NSO Conservation and Recovery

As explained in Section 6, the most likely form of NSO incidental take is habitat disturbance caused by timber harvest near an NSO site center, resulting in:

- Reduced reproduction by an NSO pair remaining at the site or
- Displacement of an NSO pair not returning to a former nest site

When displaced, the NSO pair may relocate to a new site and successfully reproduce, but there is a risk their reproduction may temporarily halt or decline.

This FHCP includes several habitat management objectives designed to mitigate the direct, indirect and cumulative effects of incidental take due to disruption or displacement of reproducing NSO pairs. Those objectives include:

- Maintaining and improving NSO habitat fitness throughout the Plan Area (Section 5.1.2.1)
- Protecting and developing highly productive NSO nest sites throughout the Plan Area (Section 5.1.2.1)
- Retaining and recruiting specific structural habitat elements beneficial to NSO (Section 5.2.2)

This FHCP Operating Conservation Program accomplishes these objectives through several measures. First, as described in 5.3.5.1, this FHCP mitigates NSO incidental take by integrating timber harvest planning with a habitat fitness model for NSO. Integrated harvest planning protects and recruits mature and late seral forest stands suitable for NSO nesting and roosting while also producing a mosaic of young forest stands where NSO are more successful in foraging along nesting stand edges. RMZs (Section 5.3.1.3) and DCAs (Section 5.3.1.4) are two mechanisms protecting and recruiting nesting stands. RMZs are no harvest and light harvest zones along rivers and streams across more than 25% of the Plan Area, where mature and late seral forests grow and create mature forest structure that NSO favor for nesting and roosting. DCAs are no-harvest zones around 44 of the most productive NSO nest sites in the Plan Area. They are dynamic because they are well distributed throughout the Plan Area (Figure 5-1), and they can be replaced by new DCAs when productivity declines for any reason or another productive DCA is established providing distributional requirements are maintained in the Plan Area.

Second, as described in 5.3.2, this FHCP also mitigates incidental NSO take by preserving and recruiting specific structural habitat elements like snags, large hardwood trees, and decadent or defective trees. These structural habitat elements provide habitat complexity conducive to healthy prey species populations and are more likely to provide and recruit future NSO nest sites.

Green Diamond can carefully plan and mitigate the adverse effects of timber harvest on NSO with protection of no harvest and light harvest zones and retention and recruitment of complex habitat elements throughout the Plan Area. Timber harvest units occur in small patches and appropriate disturbance intervals around the RMZs and DCAs distributed across the Plan Area. The DCAs provide a protected and stable refuge for the most productive NSO sites in the Plan Area. RMZs provide an expansive, growing and well-distributed network of maturing timber stands where more NSO pairs (both dispersing young owls and any existing NSO pairs displaced by harvest activities) can establish productive and protected nest sites. As stable and productive NSO nest sites are maintained and established throughout the Plan Area, Green Diamond expects incidental NSO take by displacement and site abandonment to decline (Figure 6-2). Simultaneously, Green Diamond's timber harvest pattern between and around DCAs and riparian management areas will produce young growth edges for optimal NSO foraging. In this manner, the likelihood of incidental take declines and the direct and cumulative impacts of incidental take are mitigated as Green Diamond manages for a positive trend in NSO habitat fitness across the Plan Area (Figure 4-3). Barring non-habitat factors outside Green Diamond control, this FHCP conservation program's habitat outcomes fully mitigate the individual and cumulative impacts of incidental take of NSO by Covered Activities.

An important non-habitat factor adversely affecting the NSO is barred owl range expansion. The barred owl competes with and displaces the NSO from high quality habitat Green Diamond protects and grows in the Plan Area. Although barred owl competition is not an impact caused by Green Diamond's Covered Activities, this FHCP operating conservation program addresses barred owl competition as an added NSO benefit and contributor to its conservation and recovery.

Goal Four of this FHCP is to conduct experimental barred owl removal followed by an experiment to determine whether there is a threshold of barred owl persistence in the Plan Area that does not compromise the conservation of the NSO (See 5.2.2.4). A Phase One pilot barred owl removal experiment to determine the effect of barred owls on NSO occupancy, survival and reproduction was completed in 2014 (Diller et al., 2016). Accordingly, this FHCP operating conservation program Section 5.3.4 includes two experiments:

- Conduct a Phase Two Plan Area barred owl removal experiment to protect the most productive NSO pairs in the Plan Area DCAs and to allow for validation of the NSO habitat fitness model so that Green Diamond and the Service can have confidence that habitat can be managed for the benefit of NSO
- Perform a Phase Three barred owl invasion and co-existence experiment to determine the NSO's threshold tolerance for sharing of habitat with barred owls so that barred owl persistence in the Plan Area is balanced against successful conservation of NSO in the Plan Area

These barred owl removal and co-existence experiments go beyond mitigating Green Diamond's habitat effects and provide a substantial positive benefit for NSO conservation and recovery.

7.2.3 No Appreciable Reduction in Likelihood of NSO Survival and Recovery

Although an HCP may be approved if it results in a reduction, but not an appreciable reduction, in the likely survival and recovery of a species, this FHCP positively contributes to NSO survival and recovery. Green Diamond developed an NSO habitat fitness model based on 20 years of landscape-specific research under the NSO HCP (Green Diamond, 1992). Green Diamond will manage the Plan Area to produce a positive trend in NSO habitat fitness over this FHCP term (Figure 4-3). To promote habitat fitness, Green Diamond will plan timber harvests to protect and recruit mature and late seral forest stands suitable for NSO nesting and roosting while also producing a mosaic of young forest stands where NSO are more successful in foraging along nesting stand edges. The Revised NSO Recovery Plan specifically recognizes this management strategy, rather than *large, homogeneous expanses of older forests,* as more appropriate for NSO recovery in provinces such as California Coastal and Klamath, where woodrats are a key NSO prey species (USFWS, 2011a). Green Diamond expects that management for habitat fitness will produce a positive trend in the NSO population within the Plan Area. Green Diamond also expects Plan Area NSO fecundity equal to or better than regional NSO population fecundity (Section 5.3.6.1). The proposed DCA protection and specific habitat elements retained and recruited under the TREE reinforce these expected benefits. Green Diamond will monitor the Plan Area NSO population and fecundity to validate the habitat fitness model, and, if required, rely on adaptive management to protect more DCAs and/or reduce the amount of authorized NSO incidental take each year or both.

As explained in Section 6.2.2, Green Diamond estimates incidental NSO take, caused by Covered Activities subject to this FHCP, will have a minimal effect (at 0.1%) on regional NSO population fecundity. In fact, the expected fecundity effect is far less than the natural variation in NSO fecundity. Were Green Diamond to manage the Plan Area with no incidental take, the added benefit to the fecundity and conservation of the NSO would be of almost no significance. However, no amount of habitat fitness or habitat set aside will prevent a catastrophic NSO population decline of 50% or more in the Plan Area and region (Figure 6-3) if Green Diamond does not implement the proposed FHCP barred owl control measures.

In sum, this FHCP contributes positively to NSO survival and recovery and is consistent with the Revised NSO Recovery Plan. In Recovery Action 10, the Service recommends land managers conserve NSO sites and their high value habitat (USFWS 2011a). The Service explains that priority should be given to NSO site protection where reproduction was successful and long-term occupancy will provide demographic support (USFWS 2011a). In addition, land managers should protect habitat where late seral and structurally complex habitat exists or may develop (USFWS 2011a). In Recovery Actions 14 and 20, the Service recommends that these NSO conservation measures be implemented through voluntary habitat conservation plans on private lands (USFWS 2011a). This FHCP NSO conservation strategy protects the highest priority, most productive NSO sites in the Plan Area. It designates no-harvest DCAs promoting continued long-term occupancy and reproductive success, providing demographic support for the Plan Area and region NSO population. This FHCP conservation strategy also increases high-quality NSO habitat amounts in RMZs where mature and complex forest stands develop and protect new or displaced NSO pair nesting and roosting habitat. Consistent with Recovery Action 32 (USFWS 2011a), the TREE, with its complex habitat element retention prescriptions, enhances high quality habitat recruitment for future use by NSO.

In addition to habitat management, this FHCP addresses several Recovery Actions related to experimental management and barred owl removal. In Recovery Actions 24 and 25, the Service recommends land managers develop reliable methods for detecting barred owls when barred and spotted owls are present together. Under this FHCP, Green Diamond will test and refine its barred owl and NSO survey and detection methods. In Recovery Actions 29 and 30, the Service recommends large-scale barred owl control experiments to assess the effects of barred owl removal on NSO occupancy, reproduction and survival (USFWS 2011a). Under this FHCP, Green Diamond will complete Plan Area barred owl removal studies and assess NSO benefits. In Recovery Action 26, the Service encourages experimental management of sympatric barred owls and NSO to determine whether NSO conservation and recovery can occur with some barred owl presence (USFWS 2011a). In this FHCP, Green Diamond proposes a third phase barred owl invasion experiment assessing whether NSO and barred owls can share habitat to some degree. Finally, in Recovery Action 31, the Service recommends private landowners participate in barred owl management. This includes habitat conservation plans, and Recovery Actions 22 and 28, expedited state and federal permitting for barred owl management measures (USFWS 2011a). With this FHCP, Green Diamond proposes a structured experimental approach providing valuable scientific information on barred owl management and barred owl effects on NSO and benefitting independent NSO habitat fitness management by controlling barred owl effects. Green Diamond anticipates barred owl measures will increase Plan Area NSO presence and success, but Green Diamond will not suffer additional harvest impairment. Because the Service provides federal regulatory assurances under this FHCP, Green Diamond is willing to undertake several Recovery Actions positively contributing to NSO survival and recovery.

7.3 Pacific Fisher Conservation Benefits

7.3.1 Measures to Avoid and Minimize Fisher Take

Under this FHCP, Green Diamond avoids and minimizes fisher take in four key ways:

- Prevention of entrapment and drowning
- Protection of known den sites
- Protection for denning and resting areas distributed throughout the Plan Area
- Controlled access enforcement

This FHCP includes goal 5.2.2.3 and specific measures to avoid fisher take by unintended physical injury or death. Because fishers are highly mobile and avoid human activity areas, such incidental take is highly unlikely. It is impractical for Green Diamond to survey and locate all fisher dens. However, when den discovery occurs during fisher monitoring, Green Diamond will retain the den tree into the future and protect fisher dens from the effects of active timber harvest within a 0.25-mile circular radius until the den is abandoned and/or the kits move to a new den more than 0.25 miles from timber harvest activities (Section 5.3.3.2). Although fishers are mobile, young kits in a natal or maternal den are less mobile and depend on their mother to move them away from human activity. Manmade confined spaces such as water tanks used for fire suppression and road watering are known to entrap fishers. Green Diamond will prevent this unintended take by maintaining fisher-proof water tanks (Section 5.3.3.2). Green Diamond also minimizes incidental fisher take under this FHCP by providing forested areas such as RMZs and DCAs where fisher may engage in denning, resting and foraging behavior without human disturbance. Finally, take of fisher is prevented and minimized through Green Diamond's commitment to enforcement of controlled access measures (Section 5.3.3.4). Green Diamond provides gates, security, monitoring, and enforcement to exclude unlawful and unauthorized activities for the production of drugs. Intensive and unlawful use of pesticides has been associated with these activities and there is strong evidence of lethal and harmful injuries to fisher from use of pesticides used in association with marijuana growing on adjacent lands.

7.3.2 Measures to Mitigate Fisher Take

Because fisher are at risk of incidental take by harassment when human activities disturb their essential behavior, this FHCP has an objective of maintaining and improving landscape scale habitat essential for Fisher denning, resting and foraging throughout the Plan Area (Section

5.2.2.1) This FHCP also has a retention and recruitment objective for specific structural habitat elements including decadent trees benefitting fisher denning and resting (Section 5.2.2.2).

At the landscape scale, this FHCP Operating Conservation Program addresses these objectives by providing RMZs (Section 5.3.1.3) and DCAs (Section 5.3.2) throughout the Plan Area. Green Diamond retains and recruits mature and late seral forest conditions in these areas providing more complex forest structure favored for fisher denning and resting. The result is the same mosaic of late seral forest stands surrounded by patches of younger forest stands that provide a positive trend in NSO habitat fitness (Section 5.3.1.1 and Figure 4-3).

The positive NSO habitat fitness trend should provide similar benefits to fishers, which forage in younger stands for many of the same prey species as NSO, but use more mature denning and resting stands. This FHCP produces more mature and complex forest habitat in riparian zones across the Plan Area (Figure 6-5). With a network of abundant and connected riparian forest zones distributed throughout the Plan Area, Fisher disturbance is less likely while denning, resting or foraging in those areas. They also have proximate access to refuge in riparian forest areas and DCAs when they are foraging in younger forest stands where they are more likely to be disturbed by human activities or exposed to predators.

In a managed forest, there is some risk that fisher behavior will be adversely impacted by a scarcity of defective trees and snags that are not desirable for timber production, but would otherwise provide more opportunities for fisher denning and resting areas. As described in 5.3.2, this FHCP mitigates this specific potential take by preserving and recruiting particular structural habitat elements such as snags, large hardwood trees, and decadent or defective trees that fisher may use for denning or resting. Green Diamond applies the TREE protocol to retain and create more complex habitat elements when planning and implementing timber harvests. These elements may result in higher fisher use and greater prey species abundance.

7.3.3 No Appreciable Reduction in Likelihood of Fisher Survival and Recovery

From 2004 until April 2016, the Pacific or West Coast fisher was a candidate for ESA listing. In April 2016. However, the Service determined that listing of the West Coast fisher was not warranted under the ESA. The Service noted that the northern California population of West Coast fishers was stable or improving. In the Plan Area, fishers are relatively abundant and appear to thrive with population density comparable to the healthiest western North American fisher populations (Fuller et al., 2001; Jordan et al., 2011). A healthy population of fisher has been sustained within the Plan Area throughout decades of intensive forest management by Green Diamond and its predecessors. Green Diamond estimates that there are approximately 370 fisher present in the Plan Area and only 2% (about 7 fishers) would be taken through habitat alteration in their home range during a given year. While this may affect fisher behavior, Green Diamond does not expect it to be lethal for any individual animal.

Green Diamond has collected fisher occupancy data since 1994, finding fisher present in over half the Plan Area with a bias toward inland and higher elevation forests containing more Douglas-fir and less redwood. Fisher occupancy will very likely continue in more than half the Plan Area. Green Diamond expects the Plan Area fisher population will continue to be healthy as Green Diamond's forest management under this FHCP preserves and recruits more late seral habitat and complex habitat elements. The recruitment of late seral habitat and complex habitat elements within RMZs and Geologic zones will increase the number of potential den and rest sites across the Plan Area during the permit term while evenage management outside of the RMZs and geologic areas will result in younger seral habitat that will provide foraging habitat for fisher. Under these circumstances, fisher survival within the Plan Area is not in doubt and fisher recovery within the Plan Area is not required. Consequently, the Plan Area fisher population is and will likely continue as a source for reintroducing and recovering fisher outside the Plan Area (Section 5.3.5.2). By protecting and conserving a healthy source population for Pacific fisher recovery projects, this FHCP makes a positive contribution to fisher conservation and recovery.

7.4 SONOMA AND RED TREE VOLES CONSERVATION BENEFITS

7.4.1 Measures to Avoid and Minimize Red and Sonoma Tree Vole Take

Because Green Diamond is engaged in the lawful business of timber harvest and tree voles colonize trees throughout the Plan Area, it is not practical for Green Diamond to completely avoid impacts to tree voles. Sonoma and red tree voles inhabit nests high in Douglas fir and whitewood stands, also making it impractical to survey for and locate vole colonies, and reducing harvest-targeting options to avoid or minimize incidental take of voles. Accordingly, this FHCP includes measures mitigating tree vole incidental take by providing sufficient, connected vole habitat to sustain a large population throughout the Plan Area that will recolonize harvest areas.

7.4.2 Measures to Mitigate Red and Sonoma Tree Vole Take

A key FHCP tree vole objective is maintaining an average 50% of forest stands in the Plan Area in condition suitable for tree vole occupancy (Section 5.3.1.1.3). Green Diamond research found suitable tree vole habitat requires at least 20-year-old forest stands, comprised of at least 20% basal area in whitewood species. After harvesting a timber stand, it takes at least 20 years for the stand to become suitable habitat for tree vole recolonization. This means that a large portion of the Plan Area must remain suitable vole habitat that is distributed around and connected to harvest areas so that tree voles may recolonize timber stands where vole colonies are taken by timber harvest.

Another tree vole objective is retaining and recruiting complex habitat elements such as decadent and deformed trees providing excellent vole nesting habitat (Section 5.2.2.2).

Green Diamond will use integrated timber harvest planning to maintain an average 50% suitable tree vole habitat across the Plan Area (Sections 5.3.1.2 and 5.3.2). Like NSO and fisher, Sonoma and Red Tree Voles will benefit from Green Diamond retaining and recruiting a network of late seral forests in riparian zones and DCAs distributed throughout the Plan Area (Sections 5.3.1.3 and 5.3.1.4). These measures will result in a dendritic pattern of connected suitable vole habitat across the Plan Area mitigating the effects of intermittent timber harvest on tree voles (Figure 4-19). In addition, suitable vole habitat quality will enhance with retention and recruitment of complex habitat elements like decadent and deformed trees (Section 5.3.2).

7.4.3 No Appreciable Reduction in Likelihood of Red and Sonoma Tree Vole Survival and Recovery

Because they are not currently considered threatened with extinction, Sonoma and red tree voles are not ESA candidates or listed species. The Plan Area tree vole population has persisted through over a century of timber harvest that was more intensive than the management proposed under this FHCP. In addition, the Plan Area is surrounded by millions of acres of public lands with tree vole habitat subject to little or no timber harvest. Under this

FHCP, Green Diamond estimates a maximum of 2% of the Plan Area vole population may be taken by timber harvest each year. Given the large vole population in the Plan Area and its proven capacity to recolonize suitable habitat following timber harvest, the estimated take of 2% of the vole population does not threaten the survival of the tree vole species.

7.5 ASSURANCE OF RESOURCES FOR IMPLEMENTATION OF THIS FHCP

Consistent with ESA requirements, Green Diamond assures the Service it will provide the resources necessary for FHCP implementation. In Section 5.3.7, Green Diamond describes the staffing and other resources it will provide for Plan implementation. To ensure this FHCP integrates harvest planning with conservation measures designed to benefit Covered Species, a Plan Coordinator will work with Green Diamond's wildlife, forestry and timber harvesting staff. The Plan Coordinator will ensure that THP development and implementation is consistent with this FHCP. Green Diamond's significant investment in reliable timber inventory data and a state-of-the-art Timberland Management Information System provides a substantial and reliable resource for planning and implementing timber harvesting and regular reporting to the Service that complies with all FHCP conservation measures. In addition to staffing and management information systems, Green Diamond has a 25-year record of reliable implementation and compliance with three Service-approved habitat conservation plans.

7.6 TAKE IS MINIMIZED AND MITIGATED TO THE MAXIMUM EXTENT PRACTICABLE

ESA Section 10 requires that each habitat conservation plan address the conservation needs of the Covered Species by minimizing and mitigating the impacts of take to the maximum extent practicable. Under the HCP Handbook, this requirement is satisfied if the combination of HCP measures to minimize and mitigate the impacts of take "fully offset" such take. (USFWS 2016b: 9-29). As demonstrated in subsections 7.2 through 7.4, this FHCP contributes substantial positive benefits for survival and recovery of the Covered Species that outweigh the impacts of take. The FHCP not only minimizes take of NSO, fisher, and tree voles, but it mitigates take by managing for enhanced habitat fitness at the landscape level with over 25 percent of the timber stands managed as refugia that are distributed across the landscape, connected and surrounded by edges of young forest that are beneficial for NSO and fisher foraging. The FHCP also retains and recruits habitat structural elements such as down logs and complex trees and snags used for nesting, denning, and resting. The FHCP retains and improves on habitat conditions that already sustain healthy fisher and vole populations. Based on 25 years of research, the FHCP also provides habitat fitness conditions that are conducive to sustaining and growing the NSO population and secures the health of the NSO population by addressing the existential threat of barred owl competition. These mitigate measures fully offset the impacts of incidental take that may occur under the FHCP. (USFWS 2016b: 9-29 to 9-32). As such, the Service need not place a heavy emphasis on the "*maximum extent practicable* criterion because the adequacy of the mitigation provided in this FHCP is not "*a close call*." (USFWS, 1996:7-3).

When an HCP does not fully offset the impacts of take, the ESA also recognizes a practical, technical or economic limit to the conservation measures a permit-holder can provide and the Service can require for approval, called "*the maximum extent practicable".* According to the HCP Handbook, the "*maximum extent practicable"* is a marginal feasibility or economic cost-benefit analysis or cost-effectiveness analysis asking whether more mitigation is reasonably possible or required because additional conservation benefits justify the cost (USFWS, 2016b:9-

33). The Service is not required to apply this test in an instance where the proposed HCP, such as the FHCP, fully offsets the impacts of take. (USFWS, 2016b:9-28). Even so, the operating conservation program proposed in Section 5 of the FHCP also reflects conservation of Covered Species to the maximum extent practicable, after a process of considering alternatives that would require fewer or more conservation measures with varying biological benefits and economic costs.

In Section 8, Green Diamond describes the alternatives to the proposed taking and conservation program that were considered during development of this FHCP. Green Diamond considered a passive approach to ESA compliance (No New Permit and Plan) with no intentional and coordinated conservation program. Green Diamond also considered a conservation program including less timber harvest and more economic sacrifice (Static Reserves and Unevenage Management). Both alternatives posed greater adverse economic impact on Green Diamond, employment and the regional economy with reduced biological benefit. Management alternatives that affect less habitat but do not provide better biological outcomes are evidence of the technical or practical limits of minimizing and mitigating take,

The No New Plan and Permit alternative would have no conservation program direct costs, but it would require a conservative ‘no take’ compliance strategy with reduced timber harvest, reduced timberland productivity, and reduced employment and production in forestry, logging and sawmills. This alone was economically unreasonable, but it also provided less biological benefits than the proposed operating conservation program in Section 5.3. Without a new HCP, Green Diamond and the Service would fail to capture the biological benefits of management beneficial to the NSO based on scientific information gathered during the implementation of the NSO HCP (Green Diamond, 1992). In addition, Green Diamond would take no action to control the barred owl or to conserve other Covered Species.

Green Diamond also considered conservation strategies using habitat management through a reserve system and a change in silviculture. These strategies reduce timber harvest and employment in forestry, logging, and wood products manufacturing and other sectors economically dependent on Green Diamond. Although NSO incidental take through habitat modification could be slightly less than the proposed conservation strategy, NSO survival and recovery remains in doubt without managing for habitat fitness and barred owl removal and invasion experiments proposed in the FHCP. Again, this is evidence of the technical and practical limits of feasible mitigation. Green Diamond could manage the Plan Area to prevent timber harvest in all occupied stands and high quality unoccupied NSO habitat, and the NSO would still be at risk of decline and extinction due to competition and displacement by barred owls. Still larger forest reserves or selection harvest silviculture may provide incidental benefits to fisher and tree voles, but Green Diamond’s managed forests already support healthy populations of these species and alternative with larger forest reserves or selection harvest do not specifically manage and monitor fishers and voles as FHCP Covered Species. In light of the minimal biological benefits that may accrue in return for significant additional economic sacrifice, the economic burden of these strategies is particularly unreasonable and impracticle.

The operating conservation program proposed in Section 5 mitigates take to the maximum extent practicable and fully offsets the impacts of any take of Covered Species. The FHCP no harvest and light harvest areas (DCAs and RMZs) represent a substantial, long-term sacrifice by Green Diamond encumbering approximately 25% of the Plan Area. In addition, Green Diamond incurs the direct cost of integrating FHCP conservation measures, such as no harvest areas and retention of TREE elements into timber harvest planning, permitting and implementation. Green Diamond will also incur the direct cost of barred owl removal and invasion experiments, fisher and vole monitoring, pre-harvest NSO surveys, NSO habitat fitness model validating and FHCP staffing and reporting. Green Diamond sustains these costs by maintaining a viable business continuing to invest in active conservation management.[2] In sum, Green Diamond reasonably demonstrates the proposed operating conservation program fully offsets the impacts of take and provides mitigation to the maximum extent practicable.

7.7 UNCERTAINTY ADDRESSED THROUGH MONITORING, EXPERIMENTATION, AND ADAPTIVE MANAGEMENT

This FHCP conservation strategy is a product of NSO HCP implementation and field data collection and analysis beginning in 1992. A wealth of site-specific data helped Green Diamond craft a Plan that effectively and efficiently conserves the Covered Species and their habitat. Even so, Green Diamond recognizes uncertainty remains and additional scientific information on the Covered Species and their needs remains to be learned. Monitoring the Covered Species and developing experimental data may identify problems or opportunities to adapt the Plan making it even more effective, increasing the conservation efficiency measures through FHCP resource re-allocation. Green Diamond does not anticipate that new data will require major Plan adjustments. However as Green Diamond learns more about the Covered Species and how they respond to management activities and habitat conditions, this FHCP may require subtle changes. With the goal of fine-tuning the conservation measures over time, Green Diamond developed a monitoring and adaptive management component consistent with the Plan's goals and objectives.

For the NSO, this FHCP will monitor the number, location, occupancy and reproductive success of NSO in the Plan Area until Green Diamond validates the habitat fitness model (Sections 5.3.1.1.1; 5.3.1.2; 5.3.3.1; 5.3.5.1). Thereafter, Green Diamond will continue to monitor the occupancy of NSO in the Plan Area and reproductive success of all DCAs plus a minimum of 12 additional NSO sites across the Plan Area (Section 5.3.5.1). Depending on the results of monitoring, adaptive management may lead to adjustments in the management prescriptions for DCAs, the addition of up to one DCA for each OMU, and/or a reduction in NSO incidental take authorized by the Permit (Section 5.3.6.4.1).

For the fisher, Green Diamond will validate this FHCP's fisher occupancy model using non-invasive track plate surveys of fisher presence on at least half of the Plan Area each 5 years. (Section 5.3.5.2). After validating the model, Green Diamond will re-estimate fisher occupancy for at least half the Plan Area every 5 years. If Fisher occupancy declines significantly, Green Diamond will confer with the Service and invest additional resources in more intensive fisher occupancy surveys and in mark-recapture and disease screening studies to determine the cause, magnitude, and potential duration. In addition, Green Diamond will consult and cooperate with the Service to implement recommended remedies (Section 5.3.6.4.2).

Tree vole monitoring and adaptive management will rely on NSO pellet collections establishing a vole occupancy baseline across the Plan Area (Sections 5.3.5.3; 5.3.6.4.3). If there is a statistically significant vole occupancy decline, Green Diamond will confer with the Service and invest additional resources in more intensive tree vole ground-based and tree-climbing surveys

[2] In Recovery Action 16, the NSO Revised Recovery Plan recognizes it is important to maintain local forest management infrastructure, i.e., forest product businesses, with the capacity to engage in active management of forests for NSO benefit (USFWS 2011:III-53). This is especially true for the California Coastal and Klamath NSO Provinces where active forest management produces a mosaic of habitat with a variety of seral stages including young stands where the prey species, dusky-footed woodrat, thrives (USFWS 2011:A-10).

to determine the cause, magnitude and potential duration of decline as well as any remedies that may be recommended by the Service, and implemented with Green Diamond's cooperation. (Section 5.3.6.4.2)

This FHCP manages uncertainty by identifying foreseeable Changed Circumstances and appropriate adaptive management measures (Section 5.4) in addition to monitoring Covered Species and their habitat needs for more information. This uncertainty varies by Covered Species. For the NSO, a listed species and the subject of extensive research and a recovery plan, NSO site occupancy and reproduction is a known recovery-limiting factor requiring specific habitat and take-based adaptive management measures. For fisher and tree voles, however, populations within the Plan Area are healthy and the product of past and present Plan Area habitat conditions. At this time, the quantity and quality of Plan Area habitat is apparently not a threat to their survival. As a result, recommended specific habitat prescriptions possibly triggered by adaptive management are neither possible nor appropriate. Although less likely, a decline in fisher or tree vole occupancy under the FCHP-produced improved habitat fitness could raise questions and uncertainties beyond habitat. Consequently, the adaptive management strategy for these species starts by better understanding the cause and intensity of any observed decline, followed by consulting and cooperating with the Service to implement recommended actions.

7.8 CONCLUSIONS REGARDING MITIGATION OF IMPACTS, PROVISION OF CONSERVATION BENEFITS AND AVOIDANCE OF JEOPARDY

To avoid, minimize or mitigate significant cumulative environmental effects, Green Diamond considered the magnitude and significance of potential cumulative effects, developed alternatives and included specific conservation measures in the Operating Conservation Program to address cumulative effects. Where substantial uncertainties remain, adaptive management provisions accommodate flexible FHCP implementation.

Green Diamond evaluated cause-and-effect relationships among the Covered Activities, potential for Covered Species take and the potential impact of take, including cumulative effects. Specifically, by examining the baseline conditions described in Section 4, Green Diamond analyzed the potential for cumulative effects likely causing take or resulting from incidental take. Green Diamond also evaluated the potential for incremental effects from Covered Activities combining in space and time with existing conditions or adverse and positive effects of third party actions in and around the Eligible Plan Area.

The Plan design focuses on addressing factors with the greatest probability for limiting Covered Species. Green Diamond believes the Plan as designed significantly improves Covered Species habitat at the landscape scale, with the added benefit that specific measures retain and recruit particular habitat elements beneficial to the Covered Species.

Under the Operating Conservation Program outlined in Section 5.3, Green Diamond's activities and management practices will result in significant, long-term improvements in Covered Species habitat conditions. In addition, barred owl removal and invasion experiments will significantly contribute to NSO recovery.

As described above and summarized in Section 6, Green Diamond will minimize and mitigate each of the potential impacts to the maximum extent practicable, including cumulative impacts.

Although particular impact types or potential limiting factors may not be significant alone, this FHCP addresses each potential impact type or potential limiting factor as individually significant and the bottleneck for each Covered Species' local population. In addition, the operating conservation program as a whole addresses potential effects and limiting factors collectively. This ensures Green Diamond's Covered Activities pursuant to the operating conservation program minimize and mitigate all individual and cumulative impacts to the maximum extent practicable and contribute to conservation efforts benefiting the Covered Species.

Furthermore, the Plan includes an extensive monitoring and adaptive management program providing mechanisms to adjust the conservation measures as appropriate. This provides further assurances that this FHCP meets the statutory and regulatory criteria described above. Under these circumstances, incidental take of any Covered Species is not expected to appreciably reduce the likelihood of survival and recovery of any of the Covered Species in the wild.

Finally, Green Diamond expects individual conservation measures and the operating conservation program as a whole to provide significant net benefits to the Covered Species and their habitats over the permit term. These benefits include maintaining and improving habitat fitness with a long-term increase in late seral forest structure distributed throughout the Plan Area. The conservation program will contribute to the recovery of the NSO and to conservation efforts intended to preclude or remove a need to list the unlisted Covered Species in the future.

Section 8. Alternatives Considered

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8.1 INTRODUCTION

This section describes, according to Permit Requirements, the alternatives to taking Covered Species considered by Green Diamond and why they were not selected. Green Diamond identified these alternatives during this FHCP preparation and EIS scoping process. The primary alternatives for the Service's action on the Permit are considered in detail in the EIS, which may address any of the following:

- No New Permit and Plan
- Dynamic Core Management with Barred Owl Management
- Dynamic Core Management without Barred Owl Management
- Dynamic Core Management and Barred Owl Management with Marten Conservation
- Habitat Management using Static Reserves
- Habitat Management through Unevenage Forest Management

8.2 NO NEW PERMIT AND PLAN

Under this alternative, the *no action* EIS alternative, Green Diamond continues to manage its California Timberlands under the NSO HCP expiring in 2022 (Green Diamond, 1992). After 2022, Green Diamond will manage California Timberlands under FPRs requirements and the ESA take prohibition that applies to all Plan Area listed species. Under this alternative Green Diamond:

- Continues to manage California Timberlands under the NSO HCP until its 2022 expiration with no conservation adjustment measures in response to new scientific information on NSO habitat use developed under the NSO HCP
- Maintains NSO HCP set asides established under the NSO HCP until 2022, regardless of whether used by and beneficial to the NSO
- Continues authorized incidental take up to a maximum of 58 pairs of NSO until 2022 (Appendix C.2)
- Modifies its silviculture and harvest regime to avoid NSO take on California Timberlands after 2022, or earlier if Green Diamond exceeds authorized take of 58 pairs
- Implements an NSO no-take harvest regime resulting in selection harvest around NSO activity centers to retain sufficient suitable habitat according to then current FPRs and Service guidelines
- Increases reliance on selection harvest around NSO activity centers gradually converting forest stands to unevenage management, possibly reducing NSO habitat fitness on Green Diamond timberlands by decreasing the quantity and optimal distribution of forest stand edges and young forest reproduction areas used for NSO foraging

This alternative may include some measures benefiting Covered Species in the Plan Area incidental to implementation of the AHCP/CCAA (Green Diamond, 2007) and FPRs. It does not, however, provide coordinated management of habitat for Covered Species and investment in research and adaptive management. Thus, this alternative does not promote and improve conservation as Green Diamond learns more about the Covered Species and their habitat use on its timberlands.

Green Diamond does not support this alternative because it:

- Fails to use scientific information under the NSO HCP to improve and extend conservation measures benefitting the NSO
- Does not implement measures to promote NSO presence and reproduction on California Timberlands after 2022
- Increases reliance on selection harvest around NSO activity centers resulting in more frequent stand entry and disturbance and less efficient use of logging operations and petroleum.
- Does not implement experimental measures that assess NSO and barred owl interaction and prevent barred owls from displacing NSO from habitat on its California Timberlands
- Does not provide conservation measures for the other Covered Species
- Does not offer a long-term solution for reconciling Green Diamond's operations with assurance of compliance with ESA requirements that apply to NSO and the other Covered Species if listed
- Reduces Green Diamond's annual harvest, its long-term forest productivity, and employment and production in forestry, logging and customer's sawmills

8.3 DYNAMIC CORE MANAGEMENT WITH BARRED OWL MANAGEMENT

This alternative is the proposed action supporting Green Diamond's application for a Permit, and it addresses conservation for four Covered Species. Under this alternative, Green Diamond:

- Implements conservation measures for Covered Species
- Manages the Plan Area for NSO habitat fitness and fisher occupancy with a mosaic of nesting and denning stands surrounded by edges and patches of younger timber in various stages of growth that are key habitat for their prey species
- Replaces Set Asides under the NSO HCP with DCAs where NSO have a high probability of nesting and successfully reproducing
- Protects DCAs, the most productive NSO activity centers, while validating NSO habitat fitness modeling and gradually allowing more intensive timber harvest and management in former Set Asides and around DCAs after establishing new, productive NSO sites as DCAs in mature forest growing in riparian corridors and geologically unstable areas
- Implements a barred owl research and experiment plan under a MBTA permit to prevent barred owls from displacing NSO from the Plan Area and from suppressing Plan Area NSO reproduction
- Provides NSO nesting stands, denning and resting areas for fisher, and connected habitat areas for tree voles by developing and maintaining a dendritic pattern of mature forest stands in riparian corridors and areas of unstable geology across the Plan Area combined with DCAs distributed throughout the Plan Area
- Implements TREE measures to provide standing live and dead trees and complex downed woody debris for NSO nesting, fisher denning and resting habitat and tree vole nesting habitat
- Monitors and researches the presence and habitat use of NSO, fisher, and tree voles, and interspecies interaction between NSO and barred owls
- Sustains forest productivity with a mosaic of small patch, evenaged harvest areas, contributing to regional employment and economic productivity

- Receives a Service Permit for NSO and three other Covered Species incidental take, if listed

Under this alternative, Green Diamond manages its operations to provide Plan Area habitat for NSO, fisher and tree voles. It adopts the AHCP (Green Diamond, 2007) riparian measures as enforceable commitments under this FHCP and it implements the TREE to provide additional habitat diversity and structure benefiting Covered Species. Green Diamond also validates the NSO habitat fitness model before fully implementing the NSO Conservation Strategy. The Service would periodically authorize barred owl management throughout all or portions of the Permit and FHCP term.

Green Diamond prefers this alternative because it:

- Enhances and continues Green Diamond's substantial and long-term investment in understanding NSO habitat use and fitness on its California Timberlands, and management of its timberlands to improve NSO habitat fitness
- Implements barred owl experiments and research to prevent NSO displacement that threatens their survival and recovery regardless of Green Diamond's investment in researching and providing NSO habitat fitness
- Enhances and continues Green Diamond's substantial and long-term investment in understanding fisher and vole habitat use on its California Timberlands and manages timberlands for their long-term benefit
- Provides appropriate balance of investment in conservation through foregone timber harvest and active research, monitoring, and management to minimize and mitigate impacts of NSO, fisher, and tree vole take to the maximum extent practicable while preserving Green Diamond's financial viability and contribution to the region's economic health

Section 5 fully describes this alternative in this FHCP Operating Conservation Program.

8.4 DYNAMIC CORE MANAGEMENT WITHOUT BARRED OWL MANAGEMENT

This alternative implements all of the conservation measures included in the Dynamic Core Management alternative described in Section 8.3 above except for barred owl research and management.

Green Diamond considered this alternative during preparation of the Plan and rejected it because the conservation of the NSO on Green Diamond's California Timberlands will be greatly enhanced by barred owl research and management. In fact, The Revised NSO Recovery Plan (USFWS, 2011a) strongly suggests that barred owl control, in addition to habitat conservation, is essential for NSO survival and recovery. Green Diamond has made a substantial and long-term investment in understanding NSO habitat use and fitness on its California Timberlands. Green Diamond is able to manage its timberlands to improve habitat fitness, but the barred owl threatens to displace NSO from Green Diamond's California Timberlands regardless of Green Diamond's efforts to provide NSO with improved habitat. Accordingly, Green Diamond maintains that habitat conservation without barred owl research and management would be ineffective.

8.5 DYNAMIC CORE MANAGEMENT AND BARRED OWL MANAGEMENT WITH MARTEN CONSERVATION

This alternative enhances the Dynamic Core Management and Barred Owl Management Alternative described in 8.2 and adds a conservation strategy for the Humboldt marten. Under this alternative, Green Diamond:

- Implements all conservation measures included in the alternative for Dynamic Core Management with Barred Owl Management
- Establishes a 2,098-acre no-harvest, special management area for marten on Rattlesnake Ridge in Del Norte County
- Participates with other cooperators in a marten capture and assisted dispersal program designed to establish a viable marten population in existing late successional habitat on federal and state park lands, and monitors them to improve understanding of their habitat needs and the success of dispersal to late successional or adjacent managed timberlands
- Expands monitoring and research scope of Covered Species presence and habitat use to include marten, and interspecies interaction between marten and fisher as well as NSO and barred owl
- Evaluates whether maturing timber stands in riparian corridors and unstable geology areas, combined with DCAs distributed throughout the Plan Area, contributes to successful marten dispersal into or across the Plan Area
- Evaluates whether TREE measures providing standing live and dead trees and complex downed woody debris also contributes to successful marten dispersal into or across the Plan Area
- Sustains forest productivity with a mosaic of small patch, evenaged harvest areas, contributing to regional employment and economic productivity
- Receives a Service Permit for NSO incidental take, and three other Covered Species, if listed

Of the species considered as potential Covered Species, the marten is the only species that is not currently found throughout the Plan Area. Green Diamond sought to detect marten on its timberlands for many years and only found marten presence along the fringe of its timberlands northeast of the Klamath River. Under this alternative, Green Diamond will commit to no timber harvest in a designated area that is known to be occupied marten habitat and emphasize the development and enhancement of marten habitat in a special management area where timber harvest will continue together with a program for assisted marten dispersal. Green Diamond will manage most of the Plan Area for fisher conservation because fisher are relatively abundant throughout the Plan Area. Fisher are larger and may prey upon marten or compete with them for prey. Fisher may have an advantage over marten in the Plan Area because they are better suited to habitat created by a mosaic of small timber harvest patches surrounded by mature forest in riparian corridors, unstable geology, and DCAs. Marten are believed to be more sensitive to timberland management activities and fisher presence, and may be better suited to large late-successional forest areas for dispersal, foraging, resting and denning. It is economically impractical for Green Diamond to manage its timberlands to create extensive late-successional forest stands, and even if it were economically feasible, Green Diamond could not manage for late successional forests within the term of this FHCP due to the time (10 to 20 decades) necessary to grow such forest conditions.

Under these circumstances, Green Diamond maintains that the most immediate and appropriate opportunity for marten conservation is assisted dispersal of marten into existing, unoccupied late successional stands only six to eight miles away from currently occupied habitat. There is no immediate conservation benefit in attempting to manage Green Diamond timberlands to establish late successional habitat for marten breeding, denning, resting and foraging. Such an objective is also impractical because marten are absent from nearly all of the Plan Area, fisher are abundant throughout most of the Plan Area, and large areas of old growth cannot be economically or physically created within the Plan Area and Permit term. Green Diamond's proposed marten conservation strategy would rely on a no harvest special management area of 2,098 acres where marten are present on the Plan Area fringe and on capture and assisted dispersal of marten to unoccupied public lands with late successional habitat. Implementation of this marten capture and dispersal strategy requires cooperation of federal and state agencies with jurisdiction over martens and lands for their reintroduction.

Although Green Diamond is willing to implement this alternative, there are several barriers to addressing marten conservation as a Covered Species under this FHCP, including:

- Scientific uncertainty concerning marten habitat requirements
- Scientific uncertainty regarding the status of local marten populations that would be the source for assisted dispersal
- Scientific uncertainty concerning the benefits of assisted dispersal
- Added complexity of a conservation strategy contingent on cooperation and authorization from other state and federal agencies and other property owners

Green Diamond accepts that Covered Species in this FHCP should not include the marten at this time because scientific uncertainties and institutional complexities require further work on a coherent marten conservation strategy.

Because martens are not present throughout most of the California Timberlands, Green Diamond would tolerate a no take approach to ESA compliance if the marten were listed under the ESA. However, it is difficult to predict whether the marten's present range will expand, remain stable or contract over the next 50 years. Green Diamond prefers to provide appropriate marten conservation commitments in exchange for regulatory certainty through long-term federal assurances for Green Diamond if the Service listed the marten. Green Diamond is open to developing an appropriate marten conservation strategy as more scientific information and conservation science become available and interested agencies, land managers, and property owners gain a better understanding of the marten and its conservation needs.

8.6 HABITAT MANAGEMENT USING STATIC RESERVES

The basis for this alternative is a habitat prescription typically applied to federal lands under the Revised Recovery Plan for the NSO (USFWS, 2011a). Consistent with the intent of Recovery Action 10 in the Plan, Green Diamond would protect, enhance and develop habitat in the quantity and distribution thought to be necessary to provide for the long-term recovery of NSO. The habitat management elements of the Recovery Plan call for protection of all occupied and high value NSO habitat, which includes historically occupied NSO sites and older, structurally complex multi-layered conifer forest that can be maintained or restored. Under this alternative Green Diamond:

- Identifies NSO site conservation priorities based on site occupancy, reproductive status and site habitat condition

- Designates several large reserve areas encompassing up to a total of 44 NSO sites that meet NSO site conservation priorities for the California coastal province
- Develops and conducts silvicultural strategies to promote short-term development and long-term retention of late-seral forest structure in Reserves
- Conducts Covered Activities to avoid take of Covered Species in Reserves
- Conducts forest management outside of Reserves using all available silvicultural techniques under the then current FPRs
- Receives a Service Permit for NSO and three other Covered Species incidental take, if listed

Green Diamond does not propose implementing this alternative because:

- Conservation of the NSO, fisher, and tree voles does not require the use of static reserves, which are too costly for Green Diamond and impractical.
- It prevents timber harvest on a large area of Green Diamond timberland regardless of whether the NSO habitat reserves contain productive NSO sites over the term of the Plan
- It is not consistent with Green Diamond's habitat fitness model that describes the habitat needs of NSO based on over twenty years of site-specific research.
- It implements costly and severe sacrifices that threaten the viability of Green Diamond's business without providing long-term and sustainable NSO conservation, as barred owls occupy NSO habitat, suppress NSO productivity, and displace NSO from Green Diamond timberlands regardless of the habitat protection sacrifices made by Green Diamond
- It provides no economic incentive to implement barred owl research and experiments for the protection and enhancement of NSO productivity on Green Diamond timberland when it would only increase and prolong the set aside of Green Diamond timberland as unmanaged NSO habitat
- It provides no incentive for Green Diamond to conduct monitoring and research on the presence and habitat use of NSO, fisher, marten, or tree voles, and on interspecies interaction between fisher and marten or NSO and barred owls
- It provides no incentive for Green Diamond to implement wildlife habitat management measures to provide standing live and dead trees and complex downed woody debris for fisher denning and resting habitat
- The Service Permit for NSO incidental take associated with this alternative provides little benefit to Green Diamond because there is almost no risk of incidental take when all currently occupied, historically occupied, and older, structurally complex multi-layered conifer forest is set aside as NSO habitat that cannot be harvested
- It provides a negative return on Green Diamond's extensive investment in understanding the presence, distribution, use of habitat by and threats to NSO, fisher, marten, and tree voles on its timberlands
- It fails to use the information, expertise and conservation infrastructure Green Diamond invested in to provide cost-effective benefits for Covered Species while also preserving the economic viability of its commercial timberlands
- It is economically impracticable because decreases Green Diamond's harvest volumes and long-term forest productivity dramatically, threatening its financial viability, and seriously compromising its contribution to regional employment and economic productivity despite very unlikely NSO incidental take

Green Diamond prefers the No Action and No Permit alternative over a static reserve alternative because a No Action and No Permit strategy avoids NSO take at a lower cost than static reserves and provides Green Diamond with a more viable strategy for long-term economic survival as the barred owl displaces NSO from Green Diamond timberlands.

Green Diamond also disfavors this alternative because ESA Section 10 does not require an applicant to implement species recovery as a condition for Permit approval. Green Diamond is willing to contribute to Covered Species recovery under the alternative described in Section 8.2, but it has no legal obligation to implement the NSO Recovery Plan on its timberlands in exchange for a Permit and federal assurances.

Green Diamond does not propose to adopt this alternative because it would impose costly and severe sacrifices threatening the viability of its business without providing for long-term and sustainable conservation of NSO and other Covered Species. Without barred owl management, NSO habitat conservation benefits are temporary as barred owls would likely occupy NSO habitat, suppress NSO productivity and displace NSO from Green Diamond timberlands.

Pursuant to Council of Environmental Quality NEPA guidelines, alternatives are to be reasonable, practical, and feasible. Extensive use of timberland reserves similar to management prescriptions for federal lands is economically impractical for Green Diamond (as well as biologically inappropriate for achievement of NSO habitat fitness objectives).

8.7 HABITAT MANAGEMENT THROUGH UNEVENAGED FOREST MANAGEMENT

Single tree and group selection silviculture, otherwise known as “Unevenaged Forest Management,” is designed to accelerate the growth of immature trees and establish new trees in a forest stand. It is not a conservation strategy per se, but rather a forest management decision based on many factors including, but not limited to, landowner objectives, environmental conditions, and growth characteristics of the native tree species. Selection harvest is often chosen where a forest of multiple-aged trees is desired, the regenerating trees are suited to growth in shaded settings and maintenance of larger trees in the overstory is a desired condition. Over time, Green Diamond would transition to Unevenaged Forest Management silviculture as the predominant technique to manage commercial conifer timber stands. This transition would degrade otherwise favorable site specific growing conditions for redwood forests and it would be inconsistent with over 20 years of data collected on Covered Species indicating the benefits of Green Diamond’s version of evenaged management. Other silviculture techniques would continue to be used where conifer stocking levels are inadequate to apply unevenage management. Under this alternative Green Diamond would:

- Transition to unevenaged selection harvesting in commercial timber stands and only use even age management techniques for forest stand improvement
- Decrease its harvest volumes and long-term forest productivity dramatically, threatening its financial viability, and seriously compromising its contribution to regional employment and economic productivity despite very unlikely NSO incidental take
- Increase selection harvest around NSO activity centers reducing Green Diamond’s annual harvest and long-term forest productivity, and decreasing its employment and production in forestry, logging, and sawmills
- Increase selection harvest throughout the landscape producing unevenaged forest stands and likely reducing NSO habitat fitness on Green Diamond timberlands by decreasing the

quantity and optimal distribution of forest stand edges and young forest seral stages used for NSO foraging

- Remove Set Asides and not implement DCA strategy because greater amounts of mature tree retention at the landscape scale provides nesting and denning habitat for Covered Species
- Implement a modified TREE program to provide standing live and dead trees for NSO nesting and fisher denning and resting
- Initiate harvest in all former Set Asides subject to NSO take standards developed for this alternative.
- Likely reduce the amount of NSO take over time because the NSO population declines through time from barred owl effect and lower habitat fitness potential
- Receive a Service Permit for NSO incidental take and other Covered Species if listed, but with little benefit to Green Diamond because over time, the NSO population declines due to the barred owl effect and habitat is retained across the landscape as unevenaged forest stands resulting in less habitat heterogeneity.

Green Diamond does not support this alternative because:

- It fails to implement a barred owl research and experiment plan to prevent barred owls from displacing NSO in the Plan Area and from suppressing Plan Area NSO reproduction
- It fails to monitor and research the presence and habitat use of NSO, fisher, and tree voles, and interspecies interaction between NSO and barred owls
- It fails to implement DCAs designed to prevent disturbance around the most productive NSO activity centers, while validating NSO habitat fitness modeling.
- It fails to implement validation of and management in accordance with NSO habitat fitness model.
- It does not implement experimental measures that assess NSO and barred owl interaction and prevent barred owls from displacing NSO from habitat on its California Timberlands
- It does not achieve maximum sustained productivity MSP on Green Diamond's lands under the MSP Option (a) document (Section 2.4), as mandated by state law.
- Such silvicultural prescriptions would also be inconsistent with Green Diamond's existing harvesting and management framework reflected in documents reviewed and approved pursuant to state statutes.
- Unevenaged management systems require placement and concentration of roads, skid trails corridors, and landings along the mid- and lower-slope reaches within a watershed and more active road use over time and throughout the Plan Area.
- Pervasive use of unevenaged management systems throughout the Plan Area increases frequency of stand entry, miles of active roads constructed and used in road network, and use of ground-based tractor logging, in potential conflict with management for aquatic resources under the AHCP/CCAA (Green Diamond, 2007).
- Pervasive use of unevenaged management is less energy efficient due to more frequent stand entry and it results in increased emissions associated with use of petroleum for logging operations.
- It fails to use scientific information under the NSO HCP to improve and extend conservation measures benefitting the NSO through management in accordance with habitat fitness model. Resulting unevenaged forest stands reduce habitat fitness for NSO with loss of edges and foraging habitat in young forest stands where NSO prey, the woodrat, thrive.
- It reduces Green Diamond's annual harvest, its long-term forest productivity, and employment and production in forestry, logging and customer's sawmills

- Transitioning to another silvicultural regime, such as unevenaged management, within the proposed timeframe of the ITP is impractical, infeasible, and uneconomical because of numerous logistical and operational constraints

Green Diamond does not propose to adopt this alternative because it would impose costly and severe sacrifices threatening the viability of its business without providing for long-term and sustainable NSO conservation. Without barred owl management, NSO habitat conservation benefits are temporary as barred owls would likely occupy NSO habitat, suppress NSO productivity and displace NSO from Green Diamond timberlands.

Pursuant to Council of Environmental Quality NEPA guidelines, alternatives are to be reasonable, practical, and feasible. Transitioning to another silvicultural system, such as unevenaged management, is inconsistent with Green Diamond's management and productivity objectives that are based on the unique growing conditions of the North Coast redwood region. Also, it does not conform to Green Diamond's ownership-wide and watershed-level approach to managing its timberlands. Allowing for the unique growing conditions of the local area and the long-term management approach implemented by Green Diamond, the continued use of evenaged regeneration tools are necessary to support Green Diamond's management and business objectives.

Forest Habitat Conservation Plan

Prepared for:

U.S. Fish and Wildlife Service

Prepared by:

GREEN DIAMOND
Resource Company

FINAL

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FHCP Appendices

GREEN DIAMOND RESOURCE COMPANY (GDRC)

FOREST HABITAT CONSERVATION PLAN (FHCP)

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Appendix A. General Guidelines for Locating and Protecting Bald and Golden Eagle Nests

As described in Section 1.2.3, Green Diamond is not seeking incidental take coverage for bald or golden eagles. The following is a general summary of the training, scoping procedures, survey methods and range of protection measures implemented by Green Diamond for bald and golden eagles. The surveys and protection measures for these species are implemented through the California Forest Practice Rules (Section 1.2.5) and are developed through site-specific consultation with the California Department of Fish and Wildlife (CDFW).

Training and Scoping

- Green Diamond wildlife staff conducts annual training on identification of resident raptor species for Green Diamond employees and contractors implementing Covered Activities
- Observations of eagles and eagle nests are reported to Green Diamond's wildlife staff and those sightings are documented and maintained in a GIS database
- During development of timber harvest plans (THP), registered professional foresters disseminate proposed project area maps with harvest unit boundaries and roads that will be used for access to and from timber harvest units
- A qualified wildlife biologist assesses the proposed THP units, roads and associated biological assessment area (CalWater Planning Watersheds[1]) for potential eagle habitat (trees with structure to support an eagle nest and foraging habitat) using aerial imagery and first surface Light Imaging Detection and Ranging (LIDAR) imagery
- The biologist also conducts a search of the GDRCo GIS, the California Natural Diversity Database (CNDDB) and any other relevant available databases for known nests or eagle detections within the project area footprint and the biological assessment area

Surveys

- Ground-based area surveys to locate potential eagle nests are conducted during the breeding season (generally early January through mid-August) by Green Diamond wildlife staff in response to incidental sightings of the species within project areas in years of planned timber harvest operations.

  - Surveys are conducted each year prior to operations from major vantage points where eagle access to the timber harvest plan and surrounding areas can be clearly viewed
  - Each vantage point is surveyed a minimum of three times during the breeding season
  - Each area survey visit lasts for three consecutive hours during favorable weather conditions
  - If eagles are observed to frequently use (seen in the same area on greater than two survey visits) areas for perching and roosting or exhibit evidence of nesting

[1] CALWATER provides a standard nested watershed delineation scheme using the State Water Resources Control Board numbering scheme. The hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region (HR), Hydrologic Unit (HU), Hydrologic Area (HA), Hydrologic Sub-Area (HSA), Super Planning Watershed (SPWS), and Planning Watershed (PWS). The primary purpose of CalWater is the assignment of a single, unique code to a specific watershed polygon. https://catalog.data.gov/dataset/calwater-2-233fac.

(delivering prey, carrying nest building materials), a ground-based search occurs in the area of suitable nesting habitat to locate potential nest trees
  - Helicopter surveys may also be conducted to locate potential nest trees in addition to the stand search or if on-the-ground conditions prohibit an effective search from the ground
  - A survey report is submitted to CDFW for review prior to harvest operations during the breeding season

- Nest surveys are conducted annually at known nest sites to determine occupancy, and where possible, reproduction.
  - Nest surveys consist of three two-hour observation periods a week apart with at least one survey occurring after April 1
  - Operations do not occur within 0.5 miles of the nest during the breeding season until all surveys have been completed and qualified biologists have determined, with concurrence from CDFW, that the nest is unoccupied or that the nest has failed
  - A survey report is submitted to DFW for review prior to harvest operations during the breeding season
  - A map depicting the location of the operations and appurtenant roads relative to the eagle nests is included in the THP
  - Reconsultation with DFW is conducted if helicopter operations are amended to the THP or any other significant changes are made to the project description
- Helicopter surveys are used to aid in the discovery of new nests and are conducted annually across the ownership in areas where visual searches from the ground are impaired due to limited access and topography.
- Jet Boat Surveys are conducted annually along portions of the Klamath River in order to document new bald eagle nests and aid in surveys for known nest sites.
- Future potential habitat is maintained across Green Diamond's ownership through implementation of the TREE document (Appendix D).

General Nest Site Protection Measures

- Site-specific habitat and disturbance protection measures are developed for nest sites through the consultation process with CDFW. Generally, operations are prohibited within a distance of 0.25 mile to 1.0 mile of an occupied nest during the breeding season. Buffers for road use only activities are typically a minimum distance of 0.25 miles for nests near mainline roads with consistent traffic. Buffers for seasonal roads with little or intermittent use and buffers for timber harvest operations are typically 0.5 to 1.0 mile from occupied nest sites for bald and golden eagles.
- In addition to the nest tree and any documented perch trees, a habitat buffer (minimum 10-acre buffer for bald eagle and 8-acre buffer for golden eagle under the CFPRs) is established around active nests. As stated above, the habitat and disturbance protection buffers are modified through the consultation process with CDFW depending on site-specific factors (the activity proposed, proximity of the nest to the proposed activity, topography, baseline noise disturbance conditions, etc.).

Appendix B. Profile of the Covered Species

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B.1 NORTHERN SPOTTED OWL (STRIX OCCIDENTALIS CAURINA)

B.2 LISTING STATUS

The Service completed a status review for the northern spotted owl (spotted owl) in 1990 (USFWS, 1990a) and officially listed the owl as threatened under the Endangered Species Act (ESA) on June 26, 1990. When listed, the spotted owl was assigned a recovery priority number of 3C, based on a recovery priority scale of 1C (highest) to 18 (lowest; USFWS, 1983a; 1983b), indicating the subspecies had a high degree of threat, high recovery potential, and was in conflict with other economic activities (USFWS, 1990a). A draft recovery plan was completed in 1992, but was never finalized (USFWS, 1992). Following completion of the 1992 draft recovery plan, the Service designated Critical Habitat for the spotted owl in a final ruling dated January 1, 1992, which encompassed 6,887,000 acres of Federal lands in California, Oregon, and Washington (USFWS, 1992). In 2004, the Service completed a 5-year review of the spotted owl's status and concluded that it should remain listed under the ESA as a threatened species (USFWS, 2004). The 5-year review went on to recommended that the spotted owl be given a recovery priority number of 6C, indicating that the subspecies had a high degree of threat, but low recovery potential, and was in conflict with other economic activities (USFWS, 2004). A final recovery plan for the spotted owl was completed and signed on May 13, 2008 (USFWS, 2008a), which was followed by a final ruling for revised Critical Habitat on August 13, 2008 (USFWS, 2008b). The 2008 final recovery plan was challenged in court and in 2010 the Service was ordered to revise the plan. A revised recovery plan was published in June 2011 (USFWS, 2011a) and a new designation of critical habitat for NSO was adopted on December 4, 2012 (USFWS, 2012a). On September 4, 2012, the CFGC received a petition to list the NSO as threatened or endangered pursuant to the CESA (EPIC, 2012). On August 25, 2016, the CFGC listed the NSO as threatened pursuant to CESA.

B.2.1 Range and Distribution

Before modern settlement by Europeans in the mid-1800s, spotted owls are believed to have inhabited most old-growth forests throughout the Pacific Northwest, including northwestern California (USFWS, 1989). The current range of the spotted owl extends from southwest British Columbia through the Cascade Mountains, coastal ranges, and intervening forested lands in Washington, Oregon, and California, as far south as Marin County, California (USFWS, 1990b). Within the US, the range of the spotted owl is partitioned into 12 physiographic Provinces based on recognized landscape subdivisions exhibiting different physical and environmental features (Thomas et al., 1993). These Provinces are distributed across the species' range as follows:

- In Washington: Eastern Washington Cascades, Olympic Peninsula, Western Washington Cascades, Western Washington Lowlands
- In Oregon: Oregon Coast Range, Willamette Valley,
- Western Oregon Cascades, Eastern Oregon Cascades, Oregon Klamath
- In California: California Coast, California Klamath,
- California Cascades

Spotted owls have become rare in certain areas, including British Columbia, southwestern Washington, and the northern coastal ranges of Oregon.

B.2.2 Life History

Spotted owls are territorial and typically monogamous. Home-range sizes vary across the species' range, with a generally increasing trend from south to north (USFWS, 1990b). Estimates of median annual home range size vary from 2,955 acres in the Oregon Cascades (Thomas et al., 1990) to more than 14,000 acres on the Olympic Peninsula (USFWS, 1994). Home range sizes may vary depending on the primary prey available in a given region and it has been demonstrated that spotted owls had larger home ranges where flying squirrels were the predominant prey and smaller home ranges where wood rats are the predominant prey (Zabel et al., 1995). The portion of the home range used during the breeding season is smaller than that used during the remainder of the year (Forsman et al., 1984; Sisco, 1990), and home annual home ranges of adjacent pair generally overlap (Forsman et. al, 1984; Solis and Gutiérrez, 1990), suggesting that territorial owls defend an area that is somewhat smaller than their annual home range.

The spotted owl is relatively long-lived, has a long reproductive life span, and exhibits high adult survivorship relative to other North American owls (Forsman et al., 1984; Gutiérrez et al., 1995). Spotted owls become sexually mature at one year of age, but rarely breed before two years of age (Miller et al., 1985; Franklin 1992; Forsman et al., 2002). Breeding females lay an average clutch size of two eggs (range of 1-4), but do not typically nest every year (Forsman et al., 1984; USFWS, 1990b; Anthony et al., 2006). Due to relatively small clutch size, variability in nesting success, and the delayed onset of breeding, fecundity of spotted owls is relatively low (Gutiérrez, 1996).

Spotted owls generally begin courtship in February or March, with females typically laying eggs in late March or April. The timing of nesting and fledging varies with latitude and elevation (Forsman et al., 1984). After fledging in late May or June, juvenile spotted owls are dependent on their parents until they are able to hunt on their own, with parental care continuing from fledging into September (Forsman et al., 1984; USFWS, 1990b). Adults often roost during the day with their young for the first few weeks post-fledging, but by late summer are rarely found roosting with their young and usually only visit the juveniles to feed them at night (Forsman et al., 1984).

Dispersal of juvenile spotted owls from their natal territories typically begins in September and October, with a few individuals dispersing as late as November and December (Miller et al., 1997; Forsman et al., 2002). Median natal dispersal distances are approximately 10 miles for males and 15.5 miles for females (Forsman et al., 2002). Dispersing juveniles often experience high mortality rates, exceeding 70% in some studies (Miller, 1989; USFWS, 1990b). Causes of mortality during dispersal include starvation, predation, and accidents (Miller, 1989; USFWS, 1990b; Forsman et al., 2002).

Spotted owls are primarily nocturnal, but may forage opportunistically during the day (Forsman et al., 1984; Sovern et al., 1994). The composition of spotted owl diets varies geographically and by forest type, with flying squirrels generally being the predominant prey for spotted owls in Douglas-fir and western hemlock forests in Washington and Oregon (Forsman et al., 1984), while dusky-footed wood comprise a major part of the diet in the Oregon Klamath, California Klamath, and California Coastal Provinces (Forsman et al., 1984, 2001, 2004; Ward et al., 1998; Hamer et al., 2001). Although they generally comprise a small portion of the spotted owl diet, deer mice, tree voles, red-backed voles, gophers, snowshoe hare, bushy-tailed wood rats, birds, and insects may be important prey items in some locations (Forsman et al., 1984, 2004; Ward et al., 1998; Hamer et al., 2001).

B.2.3 Habitat Requirements

Spotted owls have been observed in a variety of forest types, including Douglas-fir, western hemlock, grand fir, white fir, ponderosa pine, Shasta red fir, mixed evergreen, mixed conifer hardwood, and redwood (Forsman et al., 1984). The transition to subalpine forest, which is characterized by relatively simple structure and severe winter weather, generally corresponds to the upper elevation limit for spotted owl occurrence (Forsman, 1975; Forsman et al., 1984).

Spotted owls generally rely on older forest habitats because they contain the structural characteristics necessary for nesting, roosting, foraging, and dispersal (Carroll and Johnson, 2008). Spotted owls nest almost exclusively in trees. Nesting and roosting habitat typically consists of forested habitats that include a Moderate to high canopy closure (60-90%); a Multi-layered, multi-species canopy with large overstory trees (>30 in dbh); a High incidence of large trees with various deformities, e.g., large cavities, broken tops, mistletoe infections, and other evidence of decadence; Large snags; Large accumulations of fallen trees and other woody debris on the ground; and Sufficient open space below the canopy for owls to fly (Thomas et al., 1990). Foraging habitat generally contains attributes similar to those in nesting and roosting habitat, but may not be of high enough quality to support nesting pairs (USFWS, 1992b). At a minimum, dispersal habitat consists of forests with adequate tree size and canopy closure to provide protection from avian predators and at least some foraging opportunities (USFWS, 1992b). Spotted owls may disperse through landscapes of highly fragmented forests (Forsman et al., 2002), but the stand- and landscape-level attributes necessary to facilitate successful dispersal are not well known (Buchanan, 2004). Whereas large non-forested valleys may act as barriers to dispersal, small openings in forested landscapes are not thought to influence dispersal (Forsman et al., 2002).

In the Oregon Coast and California Klamath Provinces, landscape-level analyses have suggested that a mosaic of late-successional habitat interspersed with other seral stages may be more beneficial to spotted owls than large homogeneous tracts of older forests (Meyer et al., 1998; Franklin et al., 2000; Zabel et al., 2003). Younger forests that possess some of the structural characteristics of older forests may also support spotted owls. In coastal northwestern California, younger redwood and mixed conifer-hardwood forests support considerable numbers of spotted owls, particularly in areas where hardwood species and larger residual trees provide for a multi-layered canopy and added structural diversity in younger forest stands (Thomas et al., 1990; Diller and Thome, 1999).

B.3 FISHER (PEKANIA PENNANTI)

B.3.1 Listing Status

On December 5, 2000, the Service received a petition to the list the West Coast distinct population segment (DPS) of the fisher as endangered pursuant to the ESA, and to concurrently designate critical habitat for the DPS. In April 2003, the Service was ordered by the US District Court, Northern California District, to submit a 90-day finding on the 2000 Petition. The Service issued a 90-day finding on July 10, 2003 stating the listing may be warranted and initiated a 12-month status review (USFWS, 2004). In April 2004, the Service published a 12-month status review for the West Coast DPS of fisher and found that listing the DPS was warranted, but precluded by higher priority actions to amend the lists of Endangered and Threatened Wildlife and Plants (USFWS, 2004). The West Coast DPS of fisher was added to the candidate species list at that time and was given a Listing Priority Number of 6, indicating that overall magnitude of threats to West Coast DPS were high, but the overall immediacy of the threats were non-imminent (USFWS, 2004).

In a November 2009 review of candidate species, the Service found that the magnitude of threats remained high for the West Coast DPS of fishers, as they occurred across the range of the West Coast DPS and resulted in a negative impact on fisher distribution and abundance; however, the threats were considered non-imminent as the greatest long-term risks to the DPS was the subsequent ramifications of the isolation of small populations and their interactions with the listed threats which will affect the species over the long-term (USFWS, 2009). In 2011, the Service settled multiple lawsuits by agreeing to either propose the fisher for listing in fiscal year 2014 or issue a notice that listing is not warranted. On March 18, 2013, the Service issued a notice reinitiating a status review of the fisher in anticipation of its decision on a potential listing and critical habitat designation for the Pacific fisher under the ESA. On October 7, 2014, the Service proposed listing of the West Coast fisher as a threatened species. On April 18, 2016, the Service withdrew the proposed listing and determined that the fisher was not threatened with extinction. (USFWS, 2016).

In California, fisher status under state law received much scrutiny in recent years. The California Fish and Game Commission (CFGC) received a petition in January 2008 to list the fisher under the CESA. In August 2008, CFGC voted to reject the petition based on CDFW's recommendation and input from other stakeholders and the public (CDFG, 2008). However, in March 2009, CFGC reversed its decision and voted to accept the petition. CFGC placed the fisher on California's candidate species list, initiating a 1-year status review process in April 2009. Following extensive review, CDFG maintained its recommendation of not listing the fisher and CFGC voted to reject the petition in June 2010. In November 2010, the Center for Biological Diversity filed a lawsuit challenging the CFGC decision not to list the fisher for protection under the CESA. On July 23, 2012, the decision not to list the fisher under the CESA was found invalid and the matter was remanded to CFGC for further review. On June 8, 2015, CDFW completed a new status review for fisher and determined that the Southern Sierra Nevada and Northern California fisher populations are two, distinct evolutionary significant units. The CDFW recommended listing of the Southern Sierra Nevada ESU for protection under the CESA, and, on August 5, 2015, CFGC listed the Southern Sierra Nevada ESU of fisher as a threatened species under the CESA. Fisher in the Plan Area are within the Northern California ESU, which was not listed under the CESA.

B.3.2 Range and Distribution

Fisher occur throughout a large swath of the coniferous and mixed forests of Canada and the northern United States; including areas from Labrador to the southern Yukon Territory in Canada, and from the Appalachian Mountains of the eastern US to central California (Powell, 1993). Overtrapping, predator control, and alterations of forested habitats drastically reduced the fisher's range during the 1800s (Douglas and Strickland, 1987; Powell, 1993; Powell and Zielinski, 1994; Lewis and Stinson, 1998). As a result of trapping closures, changes in forested habitats, and reintroductions, fisher distributions have recovered in some portions of their historic range in the central and eastern US (Brander and Books, 1973; Powell and Zielinski, 1994).

In the western portions of their range, fisher distributions appear to remain restricted relative to their historic range, and Powell and Zielinski (1994) have noted continued population declines for fishers in the west. Fisher may have been extirpated from the lower mainland of British Columbia, but may still occupy the higher elevations of these areas in low densities. In the Pacific States, fishers were historically found most often in low to mid-elevation forests, up to 200 feet (Grinnell et al., 1937; Schempf and White, 1977; Aubry and Houston, 1992). Based upon a scarcity of detections in Washington, Oregon, and the northern Sierra Nevada in recent decades, it is believed that the fisher has been extirpated or reduced to very low numbers in much of this area (Aubry and Houston, 1992; Zielinski et al., 1995; Aubry and Lewis, 2003).

In Washington, the fisher historically occurred both east and west of the Cascade Crest (Scheffer, 1938; Aubry and Houston, 1992) and likely occurred in all wet and mesic forests at low to mid-elevations within the state (Lewis and Stinson, 1998). Based on a lack of recent sightings and trapping reports, it is generally believed that fishers have been extirpated or reduced to a few scattered individuals within the state of Washington (Aubry and Houston, 1992; Lewis and Stinson, 1998). Given that most records of fisher occurrence in Washington came from the western hemlock and Sitka spruce zones (Aubry and Houston, 1992), it is likely that fishers occurred throughout much of northwestern Oregon where these forest zones dominate the landscape (Franklin and Dyrness, 1988). Based on extensive track plate and remote camera surveys, it was concluded that fisher populations had been greatly reduced in Oregon (Lewis and Stinson, 1998). Only two extant fisher populations are believed to occur in Oregon and consist of two disjunct and genetically isolated populations in the southwestern part of the state: one of which occupies the northern Siskiyou Mountains in far southwest Oregon and one in the southern Cascade Range (Aubry and Lewis, 2003). Although isolated from the Cascade Mountain population, the Siskiyou Mountain population is likely contiguous with the northern California population (Aubry and Lewis, 2003). The southern Cascade population is the result of a re-introduction effort of fishers that were translocated to the area from British Columbia and Minnesota (Aubry and Lewis, 2003). The Oregon Cascade population is isolated, with approximately 75 kilometers (47 miles) of mostly unsuitable habitat separating it from the Siskiyou Mountain population and approximately 650 kilometers (404 miles) separating it from the nearest population in southern British Columbia (Aubry and Lewis, 2003).

In the winter of 2007/2008 an effort to establish a self-sustaining population of fishers in the state of Washington began with the translocation of 18 fishers from central British Columbia to Olympic National Park (Lewis et al., 2009). This was the first year of a three year reintroduction effort, with the goal of releasing 100 fishers in Olympic National Park. An additional 31 fishers were translocated during the second year (winter 2008/2009). Based on preliminary analysis of data reported in their 2009 annual progress report, survival of the reintroduced individuals varied over the first two years of releases, with >80% of the first year release surviving their first year, but only 48.1% of the second-year release surviving their first year following release (Lewis et al., 2009).

Fisher were once thought to be distributed throughout most of the Sierra Nevada, Southern Cascade, and northern Coast Ranges in California (Grinnell et al., 1937); however, recent genetic analyses suggest that the southern Sierra Nevada and Northwestern California populations may have been separated for thousands of years, and that the gap in the northern Sierra Nevada may have been present historically (CDFG, 2010). Fisher now occur in two disjunct populations in California: one on the west slope of the southern Sierra Nevada and the other in the Klamath Mountains and Coast Ranges of northwestern California and are separated by approximately 270 miles (430 kilometers; Zielinski et al., 1995). Fisher apparently no longer inhabit much of the Coast Range, including habitats in Marin, Sonoma, and most of Mendocino County, and generally are absent between the Pit River in the northern Sierra Nevada/Cascades to the Merced River in the southern Sierra Nevada (CDFG, 2010). Understanding of the reasons for the gap in the northern Sierra Nevada fisher distribution are confounded by recent preliminary genetic analysis indicating the northern and southern populations may have been separated for thousands of years, suggesting that some portion of this range was not continuously inhabited by fisher (CDFG, 2010). There have only been a handful of reported observations since the 1910-20 period in the northern Sierra Nevada gap and the CDFG concluded that there has not been a substantial change in fisher distribution since the Grinnell period of the 1920s (CDFG, 2010).The range losses that are believed to have occurred are best explained by exploitative trapping in the early decades of the 1900s; with recolonization success hypothesized to be hindered by habitat modification from timber harvesting, other human-caused factors, and limited dispersal capability of fisher (CDFG, 2010).

A reintroduction effort was initiated in 2009 to attempt to relocate fishers from the northwestern California population to areas in the northern Sierra Nevada. Initial plans were to translocate 40 fishers (16 male, 24 female) over a three year period (Powell, 2010). In December 2009 and January 2010, 19 fishers were captured in Siskiyou, Shasta, and Trinity Counties, of which 15 were translocated to a release site located on private timberlands in northeastern Butte County between December 2009 and February 2010 (CDFG, 2010). This introduced population will be intensively monitored by a team led by Dr. Roger Powell, with the objectives of 1) Documenting survival, reproduction and habitat use during the first five years following release; 2) Predicting habitat use by fishers using five models and then evaluating the predictions based on actual use of habitats by fishers; 3) Predicting placement, sizes, and shapes of home ranges using models of optimal home range choice and then test the predictions based on actual use of space by fishers; 4) Predict patterns of breeding by males from home range placement and familiarity with landscapes and to test those predictions using data on paternity of fishers born in the study area; and 5) Conduct a parallel study of fishers in the Klamath mountains, thereby gaining comparative information for a population that has never been extirpated.

B.3.3 Life History

The fisher is a member of the mustelid family, which includes the martens, weasels, mink, and otters. fisher have a slender weasel-like body with relatively short legs and a long well-furred tail. From a distance, fishers appear uniformly black, but are in fact dark brown over most of their bodies, with white or cream patches distributed on their underside (Powell, 1993). The fisher has small rounded ears and forward facing eyes (Powell, 1993). Sexual dimorphism is pronounced, with females weighing between 2.0-2.5 kilograms (4.4-5.5 pounds) and ranging in length from 70-95 centimeters, and males weighing between 3.5-5.5 kilograms (7.7-12.1 pounds) and ranging from 90-120 centimeters long (Powell, 1993).

Although Goldman (1935) recognized three subspecies of fisher in North America, others have indicated that subspeciation was not warranted and all fishers in North America should be considered as one group, *Martes pennanti* (Grinnell et al., 1937; Hagmeier, 1956). Genetic studies have shown evidence of population subdivision in fishers, especially among populations in the western US and Canada (Drew et al., 2003; Aubry and Lewis, 2003; Wisely et al., 2004).

In the west coast population, there is evidence that genetic diversity follows a latitudinal gradient from British Columbia to the southern Sierra Nevada, with genetic diversity decreasing from north to south (Wisely et al., 2004). In California, the northern population of fisher differs strongly in haplotype frequencies from the southern Sierra population (Drew et al., 2003; Schwartz, 2010) and preliminary analyses suggests the two fisher populations in California (northern California and southern Sierra Nevada) have been separated for thousands of years (Schwartz, 2010). Future work on genetics may provide critical information regarding the current distribution of fisher in California.

Although fishers are adept climbers and their arboreal habits are well known, most hunting is believed to takes place on the ground (Douglas and Strickland 1999). Fisher are considered a generalist predator, who feed opportunistically and have a diverse diet that includes mammalian and avian prey, carrion, vegetation, insects, and fungi (Grenfell and Fasenfest, 1979; Powell, 1993; Martin, 1994). Although the diets of fisher in California share some general similarities with fishers across the continental range, fishers in California tend to consume a broader array of foods than described elsewhere in North America (Golightly et al., 2006). Furthermore, coastal regions appeared to have a greatest diversity in diet than interior regions (Martin, 1994; Zielinski et al., 1999; Zielinski and Duncan, 2004; Golightly et al., 2006). Unlike fishers elsewhere in their range, reptiles comprise a regular component of the fisher diet in California (Golightly et al., 2006). Dietary studies from across North America have found that fishers often specialize on porcupine and/or snowshoe hares (Powell, 1993; Martin, 1994; Weir et al., 2005); however, in California, both populations show extremely low occurrences of lagomorphs and porcupine in the diet (Golightly et al., 2006; Zielinski et al., 1999; Zielinski and Duncan, 2004). In northern California, fisher diet appeared to vary with proximity to the coast, with sciurids favored at interior sites and woodrats (*Neotomas* sp*.*) favored at coastal sites (Golightly et al., 2006).

The almost 12-month gestation period of the fisher is distinctive, with a 10-month delayed implantation of the blastocyst (Wright and Coulter, 1967; Powell, 1993) followed by an active pregnancy period of approximately 30-36 days, which typically begins in late February (Powell, 1993; Frost et al., 1997). Parturition typically occurs in late March or early April and is followed by a 7-10 day period during which females are receptive for breeding (Powell, 1993; Mead, 1994; Frost et al., 1997). Average litter size is 2-3 kits (Powell, 1993). Young are born altricial with eyes and ears closed, weighing between 40 and 50 grams (Powell and Zielinski, 1994). The kits' eyes open at 7-8 weeks and they remain dependent on milk until 8-10 weeks of age; however, they mature quickly and are capable of killing their own prey at around four months of age (Powell, 1993; Powell and Zielinski, 1994). Juvenile fishers become sexually mature and begin establishing their own home ranges at about one year of age (Wright and Coulter, 1967; Arthur et al., 1993).

Fisher have low annual reproductive capacity (Heinemeyer and Jones, 1994; Lewis and Stinson, 1998) and due to delayed implantation, females cannot give birth for the first time until reaching at least two years of age. In a meta-analysis of regional fisher studies, Truex et al. (1998) found that reproductive success appeared to vary from year to year, with various studies reporting from 14 to 73% of females lactating during various years. Additionally, a recent study in the Hoopa Valley of northern California reported that 62% (29 of 47) of denning opportunities resulted in the weaning of at least one kit from 2005-2008 (Higley and Mathews, 2009).

B.3.4 Habitat Requirements

The fisher is considered a forest habitat specialist (Buskirk and Zielinski, 2003) and depends on forested habitats to satisfy its needs for successful breeding, resting, and foraging. In California, fisher have been found to select for late successional forest structures for resting and denning, but they may select younger age forest characteristics for foraging (Zielinski et al., 1999). Forest habitats suitable for resting and denning do not have to be late successional forests, but may be younger forests that contain remnant structures, which are suitable for denning or resting (Klug, 1997; Thompson, 2008). Forest cover may provide many benefits to fishers, including protection from predators, reduced energy expenditures due to proximity of foraging and resting sites, favorable microclimates, and increased prey abundance and vulnerability (Buskirk and Powell, 1994; Powell and Zielinski, 1994).

Fisher use a variety of forest types in California, including redwood, Douglas-fir, Douglas-fir – tanoak, white fir, mixed conifer, mixed conifer-hardwood, and ponderosa pine (Klug, 1997; Truex et al., 1998; Zielinski et al., 2004a). Forest structures that provide for successful foraging while still providing resting and denning sites may be of greater importance than actual tree species composition (Buskirk and Powell, 1994). Important forest structures should function to provide for a high diversity of dense prey, lead to increased vulnerability of prey to fishers, and provide for denning and resting sites (Powell and Zielinski, 1994). Forest canopy cover appears to be one of these important structural components, as moderate and dense canopy cover has been an important predictor of fisher occurrence at the landscape scale (Truex et al., 1998; Carroll et al., 1999; Zielinski et al., 2004b; Davis et al., 2007). At the stand and site scale, numerous structural attributes, including a diversity of tree sizes, canopy gaps and under-story vegetation, and decadent structures have been considered beneficial to fishers and (Powell and Zielinski, 1994).

B.3.5 Resting and Denning Habitat

Fisher use two types of dens while raising their offspring, giving birth and early care of young in natal dens and then subsequently raising the young in one or more maternal dens (Lewis and Stinson, 1998). A female fisher will generally use 1-3 dens per litter of kits (Powell et al., 2003). Natal and maternal dens are generally found in tree cavities and tend to be located well above the ground (Buck et al., 1983; Weir, 1995; Truex et al., 1998; Powell et al., 2003; Klug, 1997; Thompson, 2008). Paragi et al. (1996) stressed the importance of cavities as natal dens for fishers and subsequent studies have supported this (Truex et al., 1998; Self and Callas, 2006; Higley and Matthews, 2006; Klug, 1997; Thompson, 2008). The species of tree may be less important to fishers for denning than its structural characteristics (Zielinski et al., 2004b), with a number of tree species having been documented as natal and maternal dens in California, including: California black oak (*Quercus kelloggii*), Canyon live oak (*Quercus chrysolepis*), Oregon white oak (*Quercus garryana*), tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), Golden chinquapin (*Chrysolepis chryosphylla*), Douglas-fir (*Pseudotsuga menziesii*), Big-leaf maple (*Acer macrophyllum*), Incense cedar (*Calocedrus decurrens*), White fir (*Abies concolor*), Port Orford cedar (*Cupressus lawsoniana*), Western red cedar (*Thuja plicata*), Sugar pine (*Pinus lambertiana*), Ponderosa pine (*Pinus ponderosa*), and Coast redwood (Truex et al., 1998; Klug, 1997; Thompson, 2008). fisher use rest sites across their home ranges, and appear to reuse particular structures infrequently (Kilpatrick and Rego, 1994; Seglund, 1995; Zielinski et al., 2004a; Yaeger, 2005; Purcell et al., 2009). Common resting structures in live trees include cavities, large branches, mistletoe clumps, and raptor and squirrel nests. Snags, logs, stumps, rock and brush piles, and holes in the ground are also used (Grinnell et al., 1937; De Vos, 1952; Arthur et al., 1989; Powell, 1993; Kilpatrick and Rego, 1994; Klug, 1997; Thompson, 2008; Zielinski et al., 2004b; Yaeger, 2005). Live trees appear to be used most often for rest sites (Jones, 1991; Seglund, 1995; Truex et al., 1998; Zielinski et al., 2004b; Yaeger, 2005). Rest sites are often located in large trees (Buck et al., 1983; Seglund, 1995; Weir and Harestad, 2003; Zielinski et al., 2004a; Yaeger, 2005), which are more likely than small trees to have large lateral limbs, areas of decay, cavities and other anomalies that provide potential rest sites.

In a study of fisher rest sites in the southern Sierra Nevada, fishers were found to use the largest woody structures for resting sites, but they rarely used the same structures repeatedly, suggesting that fishers do not restrict use of their home range to a few central resting locations, but instead require multiple structures distributed throughout their home ranges (Zielinski et al., 2004a). In another study in the southern Sierra Nevada, Purcell et al. (2009) also noted that infrequent re-use of rest trees suggested a need for numerous quality rest sites within the home range of an individual fisher.

B.3.6 Foraging Habitat

Foraging habitat is not as well understood as resting and denning habitat, and has generally been inferred from estimated locations of active, radio-collared fishers and comparing conditions at camera and track-plate stations where fishers were and were not detected. On the Hoopa Reservation in northwestern California, Higley and Matthews (2009) found that active fishers did not exhibit any habitat selection within their home ranges. Presumably, fisher are foraging when detected with track plates or cameras. In a track plate study in the southern Sierra Nevada, fisher detections were associated with canopy closures of ≥40% (Green et al., 2008); however, placement of track plate devices and cameras may or may not be representative of all habitats available to the fisher. Although foraging habitat requirements are not well understood, high canopy cover may be an important component of foraging habitat.

B.4 MARTEN (*MARTES CAURINA HUMBOLDTENSIS*)

B.4.1 Listing Status

On September 28, 2010, the Service received a petition requesting they consider for listing the (then classified) Humboldt marten (*Martes americana humboldtensis*) or the (now recognized) subspecies Humboldt marten (*Martes caurina humboldtensis*) or the Humboldt marten Distinct Population Segment (DPS) of the Pacific marten (*Martes caurina*) as threatened or endangered under the ESA and designating critical habitat concurrent with the listing (CBD and EPIC, 2010). The Service, in a letter dated October 22, 2010, found that the petition did not indicate that an emergency listing was warranted at the present time (USFWS, 2010). On January 12, 2012, the Service published a 90-day finding that the petition presented substantial information indicating that a listing may be warranted and initiated a status review (77 FR 1900). On June 23, 2014, the Service published a scoping notice that summarized the uncertainty of the current taxonomic classification of marten subspecies and announced its intent to conduct an evaluation of a potential DPS of marten in coastal California and coastal Oregon for the purpose of the 12 month finding (79 FR 35509). On April 7, 2015, the Service published a 12-month finding and concluded that their review of the best available scientific and commercial information indicates that the coastal marten is not in danger of extinction (endangered) nor likely to become endangered within the foreseeable future (threatened), throughout all or a significant portion of its range and that listing the coastal DPS of the Pacific marten as an endangered or threatened species under the Act was not warranted (80 FR 07766). According to the CDFW, the American marten has no special status in California, but the US Forest Service (USFS) lists it as sensitive. However, the CDFW does consider the Humboldt marten a Species of Special Concern (CDFG, 2009). On June 8, 2015 the CA Fish and Game Commission received a petition to list the Humboldt marten as an Endangered Species under the California Endangered Species Act (EPIC and CBD, 2015). On February 16, 2016, CFGC found the petition to be worthy of further consideration, and the Humboldt marten was thereby deemed to be a candidate species subject to protection under the CESA.

B.4.2 Range and Distribution

The marten inhabits forested regions throughout boreal North America, with populations extending southward to the southernmost extent in the Sierra Nevada of California and the southern Rocky Mountains of New Mexico (Gibilisco, 1994). In California, martens are known to occur in the far northwestern Coast Range, east through the Salmon-Trinity Mountains to the Cascades, and south throughout the Sierra Nevada (Zielinski et al., 2001). In the far western US, marten populations also occur in the coastal and interior mountains of Oregon and Washington (Zielinski et al., 2001). Within north coastal California, martens historically occurred in the coast redwood zone from the Oregon border south to Sonoma County. However, since 1995, surveys for martens have been conducted in much of this region and suggest that martens no longer occupy much of their historical range in this portion of California (Zielinski et al., 2001; Slauson, 2003). Currently, martens are known from only one small population in southern Del Norte and northern Humboldt Counties, which comprise <5% of its historical range in this part of the state (Slauson, 2003). Recent marten population monitoring efforts found that the north-coastal California population declined dramatically from 2001 to 2008, with a more pronounced decline in serpentine habitats, suggesting that serpentine areas may be lower quality than late-successional Douglas-fir forest (Slauson et al., 2009).

B.4.3 Life History

Few published papers address life history and habitat requirements specific to martens in northwestern California. The information contained herein is representative of martens in general, with information specific to northwestern California where available.

American martens reach sexual maturity at approximately one year of age, but effective breeding may not occur before three years of age (Powell et al. 2003). Mating generally occurs in July or August (Strickland et al., 1982), with parturition occurring in late March or April the following year, due to delayed implantation of the embryos (Buskirk and Ruggiero, 1994). Kits are helpless and completely dependent at birth, but grow rapidly and are weaned at approximately 6 weeks of age (Buskirk and Ruggiero, 1994). Martens are relatively long lived, but have low reproductive rates (Buskirk and Ruggiero, 1994), producing an average of just under three young per female with one litter per year (Strickland et al., 1982). Females provide all the care for their kits until the time they disperse in late summer or autumn (Strickland et al., 1982).

In Maine, median dispersal distances of 8.9 miles (range= 3 to 21.7 miles) and 7.5 miles (range= 3.4 to 16.8 miles) were recorded for 13 juvenile male and 13 juvenile female martens, respectively (Phillips, 1994). In northeastern Oregon, dispersal distances of three juvenile fishers (2 male, 1 female) averaged 20.7 miles (range=17.4 to 26.8 miles; Bull and Heater, 2001). In Ontario, Canada, most juveniles remained within 3.1 miles of their first capture site, with no significant difference detected for dispersing males and females (Johnson et al., 2009). No information is available for dispersal of juvenile martens in northwestern California.

Martens are opportunistic predators with a diverse diet that includes mammals, birds, carrion, eggs, insects, and vegetation, e.g., fruits, berries, nuts, fungi, lichens, grass, (Buskirk and Ruggiero, 1994; Martin, 1994; Zielinski and Duncan, 2004). Across the range of the marten, voles (*Microtus* spp. and *Clethrionomys* spp.), squirrels (*Tamiasciurus* spp. and *Spermophilus* spp.), and chipmunks (*Tamias* ssp.) are all considered important food items (Martin, 1994). In the Sierra Nevada of California, Zielinski and Duncan (2004) noted 34 distinguishable taxa of plants and animals used as food items, with mammals being the most important, followed by insects and plants. Seasonal variation in diets has been well documented, with the importance of berries (Buskirk and Ruggiero, 1994) and insects, e.g., bees and wasps (Zielinski and Duncan, 2004), peaking in the late summer and fall months.

Based on analysis of 528 scats, Slauson and Zielinski (2017) described the diet of martens in northwestern California. They calculated the proportion of metabolizable energy (PME) that each prey taxon contributed to the diet and found that mammals dominated the diet (72%), followed by birds (22%), with berries, insects, and reptiles contributing <10% PME (Slauson and Zielinski, 2017). Sciurids (*Clethrionomys*) contributed the largest proportion of all prey, representing 42% of overall PME (Slauson and Zielinski, 2017).

Marten home ranges include an array of forest stands that provide for their year-round needs (Slauson et al., 2007). In a review of marten studies, Buskirk and Ruggiero 1994 found marten home ranges to be 3 to 4 times greater than that predicted for a terrestrial carnivore of its size. Buskirk and Ruggiero (1994) also reported a great deal of variation among male marten home range sizes, with the largest home ranges reported in the upper Midwest (3880 acres [15.7 square kilometers) and the smallest in the Montana (200 acres [0.8 square kilometers]). Thompson and Colgan (1987) found that home range size varied as a function of prey abundance. Based on home ranges reported in the literature, it is apparent that male home ranges are significantly larger than those of females, but male home ranges tend to vary significantly among study sites, whereas female home ranges are relatively consistent among different study sites (Buskirk and McDonald, 1989). Martens exhibit intrasexual territoriality allowing for home ranges of males to overlap with those of females (Powell et al., 2003). Male home ranges are usually 2 to 3 times larger than female home ranges (Strickland and Douglas, 1987) that means that the home range of a single male may overlap the home ranges of several females. Little information is available regarding marten home ranges in northwestern California; however, Slauson and Zielinski (2009) estimated 100% MCP seasonal (summer-fall) home ranges for five adult male martens (1,321.7 ac ± 719.6 ac; $\bar{x}$±SE), one adult female (315 ac), and three juvenile females (1,490.8 ac ± 795.7).

B.4.4 Habitat Requirements

American martens are typically associated with closed-canopy, late-successional, coniferous forests that contain a complex physical structure near the ground, which provides for a selection of protective thermal microenvironments as well as protection from predators (Buskirk and Ruggiero, 1994). Near-ground structure may come in the form of large lower branches of living trees, decadent tree boles, coarse woody debris, shrubs, rock piles, and boulder outcroppings (Buskirk and Zielinski, 1997; Slauson et al., 2007). The distribution of mature forest stands at the landscape-scale may be the primary determinant of marten distribution (Kirk and Zielinski, 2009), while marten populations may be limited by lack of late-successional forest characteristics considered important for den sites, e.g., large diameter logs, medium and large diameter snags, and high overhead canopy cover, at smaller scales (Ruggiero et al., 1998).

In the western United States, martens are strongly associated with late-successional coniferous forests, but may occur in younger seral stages that contain remnant structures of late-successional forest, such as large logs and stumps (Baker, 1992). Martens generally avoid non-forested areas including prairies and clearcuts that lack overhead cover (Buskirk and Ruggiero, 1994). Powell et al. (2003) reviewed numerous studies of marten habitat use in Maine, Utah, and Quebec and suggested that martens tolerated an upper limit of 25 to 30% openings within their home range, including clearcuts and natural openings in the forest. Slauson et al. (2007) found that martens in northwestern California often used habitats on serpentine soils that contained large expanses of dense shrub cover, but little forest canopy.

Historical records suggest that martens in northwestern California were closely tied to late-successional coast redwood forests (Slauson and Zielinski, 2003); however, the one remnant population in this region occurs in an area dominated by Douglas-fir and tanoak forest associations (Slauson et al., 2007), with coast redwood associations limited to the western edge of the currently occupied range (Slauson et al., 2007). This population uses two structurally distinct forest types, with one occurring on serpentine soils and one on more productive non-serpentine soils (Slauson, 2003; Slauson et al., 2007). In northwestern California, martens occupy low elevation areas with little or no snowfall and select for forest habitats with some features, e.g., dense, extensive shrub cover, that are distinctly different than those used by martens in the Sierra Nevada (Slauson et al., 2007, 2009). Serpentine habitats occupied by martens have open tree canopies, dense shrub cover, and an abundance of boulder piles, while non-serpentine sites have closed, multi-layered tree canopies and dense shrub cover, and are in the oldest seral stages (Slauson, 2003). Evidence suggested that shrub layers might provide the necessary overhead cover, as some serpentine sites lacked trees (Slauson, 2003). On serpentine sites, boulders and rocky outcrops provide habitat for prey species and may be used for escape cover where trees are sparse (Slauson, 2003; Slauson et al., 2007).

Martens appear to select habitat features at the following four spatial scales; Microhabitat, Stand, Home-range, and Landscape (Bissonette et al., 1997). At each scale, martens select for different habitat features that provide for one or more important life-history requirements, and may vary from selection for specific foraging, resting, or denning opportunities at the microhabitat scale to selection for areas unoccupied by same-sex conspecifics for dispersing juveniles at the landscape scale (Slauson, 2003). Stand level selection may be driven by seasonal needs such as prey populations or available rest structures, while home range selection likely involves selection for an array of stands that provide for year-round needs (Slauson, 2003).

In north coastal California, martens selected for the largest available patches of late-successional forest or serpentine habitats (Slauson et al., 2007). Slauson et al. (2007) found that the minimum patch size of late-successional and serpentine habitats present at locations where martens were detected were similar, suggesting that marten occupancy may be limited by some minimum patch size of suitable habitat. Slauson et al. (2007) also found that the probability of detecting martens increased with increases in the largest contiguous patch of late-successional forest, total amount of late-successional forest, and total area of serpentine habitat (Slauson, 2003). The mean patch size occupied by martens in north coastal California was 447 acres, while the minimum patch size occupied was 205 acres (Slauson et al., 2007).

Dense shrub cover was the most consistent habitat feature at sites selected by martens in both serpentine and non-serpentine stands in north coastal California (Slauson et al., 2007), while martens showed the strongest selection for conifer stands with >80% shrub cover and selected against stands with <60% shrub cover (Slauson and Zielinski, 2007b). Shrub layers were predominately comprised of shade tolerant, long-lived, mast and berry producing ericaceous species (salal [*Gaultheria shallon*], evergreen huckleberry [*Vaccinium ovatu],* Pacific rhododendron [*Rhododendron macrophyllum*]) and shrub oaks (huckleberry oak [*Quercus vaccinifolia*], bush tanoak [*Lithocarpus densiflorus* var. *echinoides*]; Slauson and Zielinski, 2009). Dense stands of mature shrubs provide numerous beneficial functions, including protection from predators, cover for prey, food, e.g., berries and acorns, for prey and martens (Slauson and Zielinski, 2009). Thick shrub layers also provide nesting and foraging opportunities for birds; which may be important based on the high frequency of berries and birds in the diet of the martens in this region.

B.4.4.1 Resting and Denning

Martens select rest sites between bouts of daily activity that provide for thermoregulatory benefits and protection from predators (Slauson and Zielinski, 2009). In general, martens tend to use more ground-based resting locations during colder climatic conditions and more elevated sites during warmer conditions (Wilbert, 1992; Gilbert et al., 1997; Raphael and Jones, 1997; Slauson and Zielinski, 2009). A variety of large snags, stumps, and logs dispersed throughout the home range seem requisite for high quality marten habitat (Spencer, 1987). Of 1,184 resting sites described by Bull and Heater (2001) in their study area in northeastern Oregon, 43% were located in trees with natural platforms, 23% were located in trees with cavities, 23% were subnivean, 7% were located in hollow logs or slash piles, and 3% were underground. In a study in the northern Sierra Nevada, snags used as rest sites by martens were almost exclusively large diameter fir snags, and all were among the largest 15% of available snags (Spencer, 1987).

In north coastal California, Slauson and Zielinski (2009) identified 87% of marten rest sites located during the late summer and fall as being cavities, chambers, and broken snag tops, while the remaining 13% was comprised of branch platforms, ground sites, and basal hollows. Large snags were the most frequently used resting structure, with a mean dbh of 36.6 for conifer snags and 19.7 for hardwood snags (Slauson and Zielinski, 2009). Conifer logs used as resting structures had a mean maximum diameter of >29.6 inches (Slauson and Zielinski, 2009). Whereas woody structures accounted for 95% of all resting structures documented in non-serpentine habitats, they accounted for only 58% in serpentine habitats, while rock and shrub clumps accounted for 42% of the resting structures in serpentine habitats (Slauson and Zielinski, 2009).

Natal dens are those used by mothers for parturition and care of neonatal young, and are typically located in cavities in very large logs, snags, or live trees (Ruggiero et al., 1998). Maternal dens are those dens used by mothers and older, dependent young, and tend to be located in structures more similar to resting sites (Ruggiero et al., 1998). Availability of suitable denning habitat is essential for successful recruitment and persistence of marten populations (Ruggiero et al., 1998). In northeastern Oregon, Bull and Heater (2001) described 30 natal and maternal dens as being tree cavities (40%), hollow logs (37%), underground (17%), and slash piles (6%). In north coastal California, Slauson and Zielinski (2009) documented one adult marten with a single kit at three den structures: a live chinquapin [dbh = 26 inches]; the broken top of a live Douglas-fir [dbh = 44.5 inches], and a Douglas-fir snag [dbh = 45.3 inches].

B.4.4.2 Foraging Habitat

The specific attributes of foraging habitat are not as well understood as resting and denning habitat and are generally inferred from the locations of active, radio-collared martens or from conditions at cameras or track-plate stations where martens have been detected. Numerous studies have documented habitat use by American martens, and although some studies have found that martens did not avoid younger (20-40 years-old) seral stages of forest (Poole et al., 2004), martens are generally believed to select for mature forest habitats (Bull and Heater, 2001; Slauson and Zielinski, 2003; Poole et al., 2004; Slauson et al., 2007). Andruskiw et al. (2008) concluded that in their Canadian study area, martens had a higher frequency of prey encounter, prey attack, and prey kill in old uncut forests than in younger, logged forest due to increased amounts of coarse woody debris in the older forests. Although foraging habitat requirements are not well understood, high canopy cover, patch size, and complex forest structure may be important components of foraging habitat.

B.5 RED AND SONOMA TREE VOLES (ARBORIMUS LONGICAUDUS AND A. POMO)

B.5.1 Listing Status

Neither the red tree vole nor the Sonoma tree vole is protected under the ESA; however, the dusky tree vole (*A. longicaudus silvicola*), a subspecies of the red tree vole, which occurs in the northern coastal region of Oregon, is currently under review for listing as threatened or endangered under the ESA (USFWS, 2008b). Within the range of the species to be covered in this FHCP, the Oregon Department of Fish and Wildlife (ODFW) classifies the red tree vole as Sensitive-Vulnerable (ODFW, 2008) in southern Oregon, while the CDFG classifies the Sonoma tree vole as a Species of Special Concern in northern California (CDFG, 2009). Due to the similar ecological niches of the various tree vole species and the historical variation in taxonomy of the tree voles, they will be discussed together and referred to as tree voles in much of this FHCP. Where appropriate, species specific information may be provided.

B.5.2 Distribution

Voles of the genus *Arborimus* have a limited geographical distribution, occurring from the Columbia River in northern Oregon south to Sonoma County, California (Taylor, 1915; Maser et al., 1981). The red tree vole occurs throughout western Oregon, from the Columbia River south to the California border, then continuing into northwestern California to approximately the Klamath River (Bellinger et al., 2005; Johnson and George, 1991). Until recently, it was believed that red tree voles only occurred west of the Cascade Crest; however, Forsman et al. (2009) have now documented red tree voles in the headwaters of the Lake Branch of the Hood River, on the eastern slope of the Cascade Range. The Sonoma tree vole occupies the region immediately south of the red tree vole in California, stretching south along the Coast Range to Sonoma County, California (Bellinger et al., 2005; Johnson and George, 1991).

B.5.3 Life History

The tree voles are characterized by long, soft pelages that vary in color from a rich brown to bright reddish orange, with underbodies of generally a light gray. They have small eyes, a long well-haired tail, and pale almost hairless ears (Howell, 1926). They range in size from approximately 158 to 206 millimeters (6.2 to 8.1 inches) total length, and generally weigh between 25 and 47 grams (0.88 to 1.65 ounces) (Maser et al., 1981).

The tree voles are rarely seen by people due their nocturnal nature and arboreal habits, and may be considered to be the most highly specialized vole in the world (Maser et al., 1981). Tree voles primarily build nests in Douglas-fir trees, but may also use a variety of other tree species (Maser et al., 1981; Thompson and Diller, 2002), and may occasionally build nests on the ground (Thompson and Diller, 2002). Active tree vole nests are generally located within the live canopy of the nest tree, typically situated against the bole of the tree on a whorl of branches in younger trees and away from the bole on larger branches in older trees (Maser, 1966; Thompson and Diller, 2002). Although most nests are constructed by the vole itself from small twigs it cuts in the nest tree, voles will also occupy nests abandoned by birds, squirrels, and woodrats (Maser, 1966). The inner chamber of a nest is lined with the resin ducts that remain after the vole consumes the non-resinous portions of the conifer needles, which make up its diet (Maser, 1966).

Tree voles have a very specialized diet, with Douglas-fir needles comprising the vast majority of it. In addition to Douglas-fir needles, tree voles will also consume the needles of other conifers, and will eat the tender bark and sometimes the pithy center of fresh twigs (Forsman et al., 2009; Maser, 1966). Recent studies indicate that tree voles may spend very little time actually foraging away from their nest, with most twigs harvested during short foraging bouts and promptly delivered to the nest for later consumption (Forsman et al., 2009). Tree voles cut fresh conifer twigs at night, and although they may feed some while away from the nest, most twigs are promptly brought back to the nest and stockpiled (Maser et al., 1981; Forsman et al., 2009). When feeding, tree voles bite individual needles off at their bases, then one at a time strip the resin ducts from each side of the needle before consuming the remainder of the needle (Benson and Borell, 1931; Maser et al., 1981). The resin ducts are discarded and left to accumulate on the nest or are used to line the nest's inner chambers. Due to the diet of the tree voles, they probably obtain most of their required moisture from their food, but may also lick moisture off foliage when available (Taylor, 1915; Maser, 1966).

Tree voles typically spend their time alone, with one adult vole occupying each nest, except when females are receptive (Howell, 1926; Maser, 1966; Forsman et al., 2009). Tree voles typically breed within 24 hours of giving birth, which may occur anytime throughout the year (Benson and Borell, 1931; Maser et al., 1981; Forsman et al., 2009). Litter sizes vary from one to four young, with two or three being the norm (Maser et al., 1981). Young are altricial and develop slower than ground-dwelling voles, remaining in their nursery nests until they disperse at 1-2 months of age (Hamilton, 1962; Maser et al., 1981; Swingle, 2005; Forsman et al., 2009).

B.5.4 Habitat Requirements

Detailed studies of tree vole habitat requirements are generally lacking; however, general habitat requirements can be gleaned from numerous studies focused on other aspects of tree vole ecology and occurrence. Tree voles are almost exclusively arboreal and generally associated with coniferous forest habitats, including both mature and immature forests (Taylor, 1915; Howell, 1926; Benson and Borrel, 1931; Maser, 1966; Thompson and Diller, 2002; Forsman et al., 2009). Although tree voles do occur and nest in younger forests, they are generally believed to be more abundant in older forests (Corn and Bury, 1986, 1991; Aubry et al., 1991; Thompson and Diller, 2002). Although they may be found in a variety of forest types (Douglas-fir, redwood, Sitka spruce), Douglas-fir trees are typically present in the immediate vicinity of nests (Maser, 1966; Thompson and Diller, 2002), as Douglas-fir needles are generally considered to be the preferred food for the species, although they will consume needles of other conifers.

Trees that contain tree vole nests tend to be larger than the surrounding trees, which do not contain nests, both in girth (diameter at breast height [dbh]) and height (Gillesberg and Carey, 1991; Meiselman and Doyle, 1996; Thompson and Diller, 2002). Although tree voles have been captured and documented on the ground (Corn and Bury, 1986, 1991; Raphael, 1988; Gilbert and Allwine, 1991; Swingle and Forsman, 2009), data suggest that they do not spend extensive amounts of time on the ground, but generally move quickly from tree to tree when interconnecting branches are not available (Swingle and Forsman, 2009). Howell (1926) suggested that considerable expanses of land without suitable trees could be a barrier to tree vole movements, however, more recent data of occurrences in early successional forest stands (Corn and Bury, 1986; Verts and Carraway, 1998), and observations of animals on the ground (Swingle, 2005) suggests that small gaps in the forest may not necessarily impede tree vole movements.

B.6 SENSITIVITY OF THE COVERED SPECIES TO IMPACTS

B.6.1 Northern spotted owl

In 1990, the northern spotted owl was listed as a threatened species throughout its range “due to loss and adverse modification of suitable habitat as a result of timber harvesting and exacerbated by catastrophic events such as fire, volcanic eruption, and wind storms” (USFWS, 1990b). Included in the list of significant threats to spotted owl populations were: low populations, declining populations, limited habitat, declining habitat, distribution of habitat or populations, isolation of provinces, predation and competition, lack of coordinated conservation measures, and vulnerability to natural disturbance (USFWS, 1992a). When listed, three primary threats, including declining amounts of habitat, isolation of populations, and declining populations were thought to represent the greatest concern range-wide to the conservation of the spotted owl (USFWS, 1990b, 1992a). In the Service 5-Year Status Review (2004), the threats related to past habitat loss and continued habitat loss due to timber harvest were considered to be reduced since the 1990 listing of the owl, primarily due to the recovery of habitats from historical losses and to implementation of the Northwest Forest Plan. However, the threat posed by declining populations and population isolation were still considered to be significant threats to the sub-species, particularly in the northern portions of the range (USFWS, 2004). Several new threats were identified during the 5-year review, in particular was competition from barred owls, which was deemed to be a primary and imminent threat (USFWS, 2004). The threat of habitat loss due to catastrophic wildfire was also considered to have increased since 1990 (USFWS, 2004). In 2006 and 2007, a panel of seven experts assessed what they believed to be the most significant threats facing the northern spotted owl, and ultimately agreed unanimously that the three most significant threats were competition from barred owls, past habitat loss, and current habitat loss, i.e., timber harvest and wildfire, even though timber harvest on federal lands has been greatly reduced in recent years (USFWS, 2010). West Nile Virus is also considered a significant threat, although more of a future than current threat (Courtney et al., 2004; USFWS, 2010). Inbreeding and other genetic problems related to small population sizes were not considered imminent threats to the spotted owl when listed (USFWS, 1990b) and recent studies have shown no indication of reduced genetic variation in Washington, Oregon, or California (Barrowclough et al., 1999; Haig et al., 2004).

B.6.1.1 Threat from Barred Owls

Since the listing of the spotted owl in 1990, new information suggests that spotted-barred owl hybridization owl is less of a threat than previously thought (Kelly and Forsman, 2004), but competition with barred owls has become a greater threat (Courtney et al., 2004) than previously thought. As of 2006, the barred owl had expanded its range south to Marin County, California in the coastal mountain ranges (Courtney et al., 2004) and to the southern Sierra Nevada Mountains in the more interior mountains (Steger et al., 2006). The range of the barred owl now completely overlaps that of the northern spotted owl (Livezey, 2009a). Competition with barred owls apparently occurs through a variety of mechanisms, including overlaps in prey (Hamer et al., 2001) and habitat (Hamer et al., 1989; Dunbar et al., 1991; Herter and Hicks, 2000; Pearson and Livezey, 2003), as well as through agonistic encounters (Leskiw and Gutiérrez, 1998; Pearson and Livezey, 2003).

Although barred owls were initially thought to be more closely associated with early successional forests than spotted owls (Hamer, 1988; Iverson, 1993), more recent studies indicate that barred owls use a broader range of habitat types than spotted owls (Courtney et al., 2004; Livezey, 2007) with recent studies in the Pacific Northwest indicating that barred owls use, and may sometimes prefer older/old-growth forests (Herter and Hicks, 2000; Pearson and Livezey, 2003; Gremel, 2005; Hamer et al., 2007 ; Singleton et al., 2010). Hamer et al. (2001) found that spotted owl and barred owl diets in the Pacific Northwest overlapped greatly (> 75 %); however, barred owl diets were more diverse than spotted owl diets (Hamer et al., 2001; Livezey, 2007; Livezey et al., 2008), which may be the primary reason for barred owls having much smaller home ranges than spotted owls (Hamer et. al., 2007).

Evidence of the potentially negative impacts of barred owls on spotted owls is largely indirect and based primarily on retrospective examination of long-term data collected on spotted owls (USFWS, 2010). Correlations between local spotted owl declines and barred owl increases have been noted in many areas throughout the range of the northern spotted owl, form the northern Washington Cascades (Herter and Hicks, 2000; Pearson and Livezey, 2003) and Olympic peninsula (Wiedemeier and Horton, 2000; Gremel, 2005), to the southern Oregon Cascades (Johnston, 2002) and coastal redwood zone in California (Schmidt, 2003).

Barred owls have been reported to negatively impact spotted owl detectability, site occupancy, reproduction, and survival (USFWS, 2010). Olson et al. (2005) found that the detectability of spotted owls was significantly decreased in the presence of barred owls and that the magnitude of the effect did not vary among years. Kelly et al. (2003) found that when barred owls were detected with 0.8 kilometers of a spotted owl territory center, occupancy of the territory by spotted owls was significantly lower. Research by Pearson and Livezey (2003) support the theory of decreased occupancy as they found that significantly more barred owl site-centers were located in unoccupied Spotted Owl circles with radii of 0.8 kilometers, 1.6 kilometers, and 2.9 kilometers than in occupied circles. Furthermore, Gremel (2005) found a significant decrease in spotted owl pair occupancy at sites with barred owls, while Olson et al. (2005)

found declines in the probability of site occupancy when comparing territories with and without barred owls. Presence of barred owls has also been found to have a negative effect on reproduction in spotted owls (Olson et al., 2004). Anthony et al. (2006) found evidence for negative effects of barred owls on apparent survival on two study areas in Washington and one in Oregon.

Although uncertainties related to methodologies, analyses, and possible confounding factors justify caution when interpreting data related to the interactions of barred and spotted owls, the preponderance of evidence gathered to date is consistent with the hypothesis that barred owls are playing a significant role in the decline of northern spotted owl populations, particularly in Washington, parts of Oregon, and north coastal California (Courtney et al., 2004; Olson et al., 2005).

B.6.1.2 Threats from Habitat Loss

When listed, the USFWS (1990b) estimated that spotted owl habitat had declined 60 to 88% since the early 1800s. The majority of habitat loss during this time period was attributed to timber harvest and land conversion activities at lower elevations of the Cascade and in the Coast Ranges (USFWS, 1990a). Although historical habitat loss was considered a major threat to spotted owls when listed (USFWS, 1990b), during the 5-year status review it was concluded that past habitat loss was likely having a reduced effect compared to 1990, but was still a current threat due to potential lag effects and synergistic interactions with other factors (USFWS, 2004). It was also concluded that this effect would continue to decline over time (USFWS, 2004).

Up through the time of listing, timber harvest activities on national forests was removing spotted owl habitat at an annual rate of approximately 1% per year in California and 1.5% per year in Oregon and Washington (USFWS, 1990b). At that time, it was projected that future rates of habitat removal on BLM lands in Oregon would eliminate all suitable habitat on non-protected BLM lands (except the Medford District) within the next 26 years (USFWS, 1990b). Since 1990, few efforts have produced indices or direct estimates of trends or change in the amount of suitable habitat for spotted owls. Recent studies have reported on landscape-level changes in forest cover using Landsat Imagery and dramatic decreases in harvest rates were documented between the late 1980s and early 1990s on state, federal, and private forest lands (Cohen et al., 2002; Bigley and Franklin, 2004). Because not all forested land that is harvested is necessarily suitable habitat for spotted owls, estimates of harvest rates do not translate directly to the amount of spotted owl habitat lost; however, they do provide insight into harvest trends since 1980 (Bigley and Franklin, 2004), which likely correlates to decreased rates of spotted owl habitat loss due to timber harvest. Bigley and Franklin (2004) indicated a decrease of approximately 2.11% in the amount of suitable habitat on Federal lands resulting from range-wide management activities predicted in the Northwest Forest Plan from 1994 to 2003. More than 75% of the management-related habitat loss during this period was in Oregon (USFWS, 2010).

Raphael (2006) estimated that approximately 7.5 million acres of spotted owl habitat existed on non-Federal lands within California, Oregon, and Washington in 1994. Harvest rates on private timberlands were reported by Cohen et al. (2002) for the period of the early 1970s through the mid-1990s, as being consistently about twice the average rate of harvest on public land, with an estimated harvest rate on private industrial timberlands of 2.4% per year during the late 1980s and early 1990s. Harvest rates on non-industrial private forestlands increased from 0.2% in the

1970s to rates similar to those of private industrial timberlands in the early 1990s (Bigley and Franklin, 2004).

Raphael (2006) estimated that losses of spotted owl habitat since 1994 from non-federal timber harvest far outpaced losses from Federal lands. It was estimated that <1% of the over 10 million acres of higher-suitability spotted owl nesting habitat believed to have existed in 1994 (Raphael, 2006; USFWS, 2010).

Habitat is not only lost through timber harvest, but also as a result of natural events. Habitat loss due to natural causes was 3.03% or 224,041 acres from 1994 to 2003 (USFWS, 2004), with 75% caused by wildfires and the rest by insects and disease. Wildfire is considered to be the primary natural threat to spotted owl habitat, with its effects varying by location, fire severity, and habitat function (USFWS, 2010). Spotted owl response to wildfire has been assessed to some degree by several researchers (Bond et al., 2002; Gaines et al., 1997; Anthony and Andrews, 2004), and spotted owls have been documented using a variety of habitat types within burned areas, including areas which experienced moderate burning (Gaines et al., 1997; Clark, 2007; King et al., 1997; Anthony and Andrews, 2004). In some cases areas of low to moderate severity burns may still function as nesting habitat (Gaines et al., 1997; Clark, 2007; Bond et al., 2009), but it is unknown if there is a threshold of high severity fire within a nesting core area that would preclude nesting (USFWS, 2010). Roosting has been documented in stands experiencing the full range of fire severity, but more commonly in low to moderate fire severity areas which maintained a high canopy closure and a large tree component (Clark, 2007; Bond et al., 2009). Spotted owls have also been observed foraging in all levels of burn severity, and may even be attracted to habitat edges where burned areas meet unburned areas (Clark, 2007; Bond et al., 2009). Wildfire not only impacts habitats, but may also cause direct mortality to spotted owls (Gaines et al., 1997).

B.6.1.3 West Nile Virus

Although considered a threat to spotted owls (USFWS, 2010), the ultimate effect of West Nile Virus (WNV) on spotted owl populations is not well understood. WNV has killed millions of wild birds since it arrived in North America in 1999 (McLean et al., 2001; Caffrey, 2003; Marra et al., 2004); however, there is a great deal of variation in the susceptibility to infection and mortality rates of infected individuals among bird species (Courtney et al., 2004). Although, health officials expect WNV to eventually spread throughout the range of the spotted owl (Courtney et al., 2004), it is unknown how WNV will ultimately affect spotted owl populations. Mosquitoes are the primary vectors of the virus. Mammalian prey may also play a role in spreading WNV among predators, like spotted owls (USFWS, 2010). Predators, including owls, which prey on small mammals, can contract the disease by eating infected prey (Garmendia et al., 2000; Komar et al., 2001).

Courtney et al. (2004) offer two scenarios for the likely outcome of spotted owl populations being infected by WNV: One is that because spotted owl populations are widely distributed and number in the thousands, they can tolerate severe, short-term population reductions due to WNV, while the other is that WNV will cause unsustainable mortality, resulting in long-term population declines and extirpation from parts of the spotted owl's current range. Although one captive spotted is known to have contracted WNV and died (Gancz, 2004), no documented cases have been identified in wild spotted owls (USFWS, 2010). The threat of WNV on spotted owl populations remains more of a future threat than a current threat (Courtney et al., 2004; USFWS, 2010).

B.6.2 Fisher

There are numerous potential threats, which could impact populations of fisher in California; however, three primary threats are considered to be the most significant currently (CDFG, 2010). The three primary threats facing fisher populations in California are loss of habitat due to timber harvest activities and catastrophic fire, and small population size (CDFG, 2010). Of the three primary threats, loss of habitat due to timber harvest is more prominent in the range of the northern California population, while the southern Sierra Nevada population is more likely to be threatened by small population size and catastrophic fire (CDFG, 2010).

B.6.2.1 Threats from Habitat Loss (Timber Harvest and Wildfire)

The reduction in late-seral forest habitat in California due to timber harvest has been well documented, with Laudenslayer (1985) reporting that late-seral forests on National Forest lands had declined by 50% in California, from an estimated 4 million acres in 1900 to 2 million acres in 1985. Beardsley et al. (1999) conducted a comparative study of late-seral forests in the Sierra Nevada, and reported that only 11% of the timber in the Sierra Nevada was currently identified as late seral, most of which occurred at high elevations. The CDFG considers the harvest of late-seral forest, and especially the removal of key late-seral habitat elements, to be a potential threat to fisher (CDFG, 2010). Although many younger seral stage forests with high canopy cover may provide suitable foraging habitat, they are not likely to provide for denning and resting unless they also provide the late seral habitat elements necessary to sustain those activities, i.e., large trees and snags with cavities (CDFG, 2010). Two studies of fisher in northwestern California indicated that timber harvest resulting in habitat modification lead to reductions in fisher density and survival (Buck et al., 1994, Truex et al., 1998; however, fishers have documented to occur and reproduce at relatively high densities in heavily managed landscapes with long histories of timber harvest in coastal northwestern California (Klug, 1997; Thompson, 2008; Higley and Matthews, 2009). While timber harvesting can negatively affect various aspects of fisher habitat at various scales, the extent to which studies have demonstrated that harvesting has negatively affected fisher populations or created large, e.g., size of fisher home range, areas of unsuitable habitat in northern California is unknown (CDFG, 2010).

While timber harvest practices cause anthropogenic alteration or loss of habitat, natural phenomenon also impact habitats. Catastrophic wildfire is considered a primary threat to fisher habitat, especially in the southern Sierra Nevada (CDFG, 2010). While low intensity fires may have a beneficial effect on habitat and prey populations, high intensity stand-replacing fires often burn and destroy large tracts of existing forest (CDFG, 2010). Removal of canopy cover by intense fires, which may be replaced by heavy shrub and regenerative forest cover in a decade or two, may be considered a relatively short-lived impact relative to the loss of late-seral elements (large trees and snags with cavities) required for resting and denning, which may take hundreds of years to be replaced.

Fire suppression has changed the forest structure in the Sierra Nevada by causing an increase in fire return interval (FRI); whereas historical (pre-1860s) FRIs in the Sierra mixed conifer zone were consistently <25 years and characterized by low intensity burns (Skinner and Chang, 1996), current FRIs in the Sierra mixed conifer zone are between 185-644 years (Skinner and Chang, 1996; McKelvey and Busse, 1996; McKelvey et al., 1996). Along with the dramatic increase in FRI, have come increased severity, intensity, and spatial coverage of forest fires in the late 20th century (Skinner and Chang, 1996; Lutz et al., 2009).

Catastrophic wildfire could impact fisher populations in a variety of ways, including direct mortality, destruction of habitat, impacting prey species, and isolation and fragmentation of suitable fisher habitat (Green et al., 2008). Destruction and isolation of fisher habitat in the southern Sierra Nevada is expected to synergistically interact with low population size and low genetic variability to increase the risk to the southern Sierra Nevada fisher population (Spencer et al., 2008). With the possible exception of the coastal redwood zone, wildfire may also pose a threat to fisher in northwestern California (CDFG) in a similar manner that it does for spotted owls in the interior region of Northwestern California (Courtney et al., 2004). Recent compilations of fire data for the North Coast Ranges (Stuart and Stephens, 2006), Klamath Mountains (Skinner et al., 2006), and Southern Cascades (Skinner and Taylor, 2006) suggest increased fuel loads and increasing areas of high intensity fires have resulted from decades of fire suppression in these areas. Extensive timber management has created forests more prone to high severity fires in these regions (Frost and Sweeney, 2000; Stuart and Stephens, 2006). Together, increased fuel loads (Stuart and Stephens, 2006; Skinner et al., 2006; Skinner and Taylor, 2006) and extensive timber management that has created forests more prone to high intensity burns may suggest that some risk to fisher populations in northern California exists from catastrophic wildfire (CDFG, 2010).

The CDFG considers wildfire a potential threat to both fisher and their habitat in the southern Sierra Nevada more so than in northern California, and believes ameliorating the risk of catastrophic fire deserves the significant management consideration being given to it by the US Forest Service (CDFG, 2010).

B.6.2.2 Small Population Size

The Southern Sierra Nevada fisher population is separated from the northern California population, and from fisher populations in British Columbia and other parts of North America (Zielinksi et al., 1995). This isolation precludes genetic interchange, increasing the vulnerability of both California populations. Aubry and Lewis (2003) considered the inability of isolated fisher populations to support one another demographically or to colonize currently unoccupied areas within their historical range to be significant conservation concerns. Although genetic isolation may promote adaptations to local conditions, Drew et al. (2003) concluded that continued isolation was a greater risk than the potential benefits of local adaptation. Wisely et al. (2004) documented high levels of genetic diversity in coastal fisher populations, but found a north to south decreasing trend in genetic diversity within west coast populations. Heterozygosity and allelic richness decreased from British Columbia to California and Wisely et al. (2004) found that although heterozygosity was relatively low in the California populations, it was somewhat higher in the northern California populations than in southern Sierra Nevada populations. Wisely et al. (2004) also mentioned inbreeding depression, reduced ability to adapt to changing environments, increased vulnerability to stochastic events and environmental changes as potentially adverse ramifications of population isolation and reduced gene flow and suggested that immediate conservation action might be warranted for west coast fisher populations.

Although southern Sierra populations exhibit low genetic diversity and high genetic structure which suggested that they may be vulnerable to extinction (Wisely et al., 2004), northern California populations have slightly higher genetic diversity and less genetic structure, which in combination with larger population sizes, suggest that the potential threat to northern populations are likely not as acute as those faced by the southern Sierra population (CDFG, 2010). Because genetic diversity is lower than that found within British Columbia populations, continued study and monitoring of the northern California population is warranted (CDFG, 2010).

Powell and Zielinski (2005) evaluated the population using the population matrix modeling software VORTEX to investigate the potential effects of removing animals from that population. The authors cautioned the model's output is an index of population viability for the purpose of investigating possible effects of translocation projects, not a dependable estimate of the probability of extinction of the population. Assuming an initial population size of 1000 fishers in northwestern California and a carrying capacity of 2000 (±250) animals, the authors modeled a 5% probability of extinction over the 100 year modeling period. Halving the initial population size increased the probability of extinction by 1%. The authors also estimated that the removal of 20 fishers per year (five fishers from each of four different subpopulations) for 8 years would increase the probability of extinction <5% and would not jeopardize the population.

The model used by Powell and Zielinski (2005) rests on various assumptions about the population and environmental conditions, and the authors expressed concern about their assumptions regarding the effects of timber harvest, the rate of timber harvest, fisher vital rates, and the sex ratio of adult fishers. In particular, they stated the difficulty of building multi-year effects of timber harvesting activities on fisher subpopulations into the model "may lead to somewhat optimistic forecasts on the viability of the northwestern California population." This caveat is important, because to the best of our knowledge, there are no published studies on the effects of timber harvest, and its rate, on fisher vital rates. Additionally, the analysis was conducted without considering information that suggested that fisher, particularly females, may be declining on Hoopa Tribal lands. Powell and Zielinski (2005) noted the model would have to be revised, by varying the adult sex ratio to account for such a potential scenario. As noted earlier, the population size of fishers in the southern Sierra Nevada is considered low. Because the population is isolated, it is more at risk of extirpation by a variety of stochastic influences (Spencer et al., 2008). Examples of stochastic events include successive years of drought that deplete prey populations for fisher, and/or one or more catastrophic fires in a short time frame. There is also the potential for the accumulation of deleterious mutations to negatively affect population growth, and mutation accumulation and extinction time are highly sensitive to habitat fragmentation. There is a critical level of habitat connectivity that must be maintained for efficient selection against deleterious mutations. Because the interaction between mutation accumulation and metapopulation demography is synergistic, an assessment of metapopulation viability based only on demographic forces is especially likely to underestimate the risk of extinction (Higgins and Lynch, 2001).

B.6.3 Marten

Loss, modification, and fragmentation of habitat are considered significant ongoing threats to the remaining population of martens in northwestern California (Hamlin et al., 2010). The marten has been extirpated from as much as 99% of its historical distribution in northwestern California (Hamlin et al., 2010). Past timber harvest activities have eliminated much of the late-seral forests in coastal northern California, and due to the specialized habitat requirements of martens, such as large diameter live trees, snags, and logs, it will likely take decades for habitat with the necessary structural characteristics to support martens to regenerate (Hamlin et al., 2010). With approximately 38% of the occupied range in northwestern California located on lands currently available for timber harvest, it is unlikely that these lands will support a viable marten population without a management strategy to maintain key habitat elements (Hamlin et al., 2010). Wildfire that removes structural components such as overstory canopy, large logs or dense understory shrubs may greatly alter habitat essential to martens (Hamlin et al., 2010). Roads may fragment suitable habitats and provide corridors for movement of potential predators, e.g., bobcats and coyotes (Hamlin et al., 2010). Trapping of martens remains legal in coastal Oregon, while trapping of martens has been illegal in California for several decades. In California, incidental capture of martens while targeting other species may still create a risk to the species, and should be monitored to assess that risk (Hamlin et al., 2010). Management activities that encourage growth of other mesocarnivore populations may also be considered a threat to marten populations, as some of these species, e.g., fisher and bobcat, may opportunistically kill martens when encountered (Hamlin et al., 2010).

B.6.3.1 Habitat Loss

Habitat loss due to loss, degradation, and fragmentation of suitable forest habitats due to timber harvest, wildfire, fuels reduction projects, and roads, are threats to the marten in northwestern California (Hamlin et al., 2010).

Timber harvest has eliminated most late-successional forests on private lands in coastal northern California. Approximately 2.6% of the original late-successional coast redwood forest currently remains in north coastal California, occurring primarily in reserves on State and Federal land where it is protected from timber harvest (Hamlin et al., 2010). The majority of coast redwood forests have been logged one or more times, primarily using even-aged silvicultural methods. Privately owned industrial timber lands are often managed under relatively short rotations (50-years), which preclude development of late-successional forest characteristics that are important to martens, such as large diameter logs, snags, and trees (Hamlin et al., 2010). In north coastal California, marten populations currently occur only in coastal forest habitats with a dense, spatially-extensive, shade tolerant shrub layer (Slauson and Zielinski, 2007b), where little timber harvest has occurred. Maintenance of this shrub layer may be critical to the restoration of this subspecies (Slauson and Zielinski, 2007b). Coastal forests managed on short rotations have reduced complexity of the shrub and herb layers (Slauson and Zielinski, 2007b) and Zielinski et al. (2001) believe past and current timber harvest in the coast redwood region is the most plausible reason for the absence of martens throughout most of their historical range in north coastal California.

Martens are most often found resting in structural elements that require more than a century to develop (Slauson and Zielinski, 2009). Loss of these elements can reduce the suitability of forested areas for martens (Slauson and Zielinski, 2004). Slauson (2003) found that the detection probability for marten increased with increasing maximum patch size of late-successional forest and the minimum patch size necessary to identify potential marten home range areas was 445 acres of late-successional forest with dense shrub cover. Several factors may have significant influence on the future occupancy of regenerated habitat by martens, including the proximity to currently occupied sites, population size, and connecting corridors (Hamlin et al., 2010). Along with the reduction of late-successional forest, the continued simplification of forest structure and forest fragmentation is also of concern (Cooperrider et al., 2000).

Wildfire is also considered a threat to marten populations in northwestern California (Hamlin et al., 2010). The frequency and intensity of fires increase with distance from the ocean and elevation (Sawyer et al., 2000). In the Douglas-fir and tanoak region of the Six Rivers National Forest, where the remnant population of martens is located, fire continues to be an important disturbance factor (Jimerson et al., 1996). The effects of fire vary, with high-severity fires tending to eliminate late-successional forest (Hamlin et al., 2010).

While fire poses a low risk in coastal redwood communities, the extant marten population primarily utilizes Douglas fir-tanoak communities and may be more vulnerable to lightning-ignited fires (Hamlin et al., 2010). The frequency of these types of fires has increased in recent years and there is a potential that climate change issues may further exacerbate this threat (Hamlin et al., 2010). In the past 12 years, approximately one-third of the occupied range of martens in northwestern California has burned due to the wildfires (Hamlin et al., 2010). In 2008, a complex of lightening fires burned approximately 20% of the marten occupied range (Slauson et al., 2009b).

The 2008 fires may have contributed to the 42% decline in occupancy detected in the northwestern California marten population between 2000-2001 and 2008 (Hamlin et al., 2010). Due to its small population size and limited range, martens in northwestern California may be significantly threatened by future wildfires, a threat which is expected to continue and potentially increase in the future (Hamlin et al., 2010).

Fuels management projects designed to lower fire risks may be critical in reducing the potential for catastrophic wildfire impacts on martens (Hamlin et al. 2010); however, if not done properly, these same practices may have potential negative effects on martens and their habitat (Hamlin et al., 2010). Prescribed burning may impact natal dens and displace martens if done during the breeding season (Hamlin et al., 2010) and significant loss of the shrub layer may reduce habitat suitability, due to reduction in prey abundance or improved access by competitors (Slauson and Zielinski, 2004). There are potential long-term benefits from carefully designed fuels management projects as they minimize the loss of late-successional stands due to wildfires (Hamlin et al., 2010). The effects of fuels reduction projects will depend on amount and type of fuel removed and the location of treatments relative to suitable and/or occupied habitat (Hamlin et al., 2010). Other forest management activities, e.g., salvage and hazard tree removal, also have the potential to degrade habitat by reducing the number of large trees, snags, and logs.

Roads may impact martens through direct habitat removal, habitat fragmentation, road kill mortality, and disturbance from noise and human activities (Hamlin et al., 2010). U.S. Highway 101 likely represents a significant barrier separating the known population of martens from the late-successional coast redwood forests in Redwood National and State Park (RNSP; Slauson and Zielinski, 2003). Roads may also modify habitat by creating linear openings, which facilitate increases in the presence and abundance of generalist forest predators, e.g., cougar, gray fox, and bobcat, in forest interiors, which may lead to increased risk of predation for martens (Slauson and Zielinski, 2010).

B.6.3.2 Trapping

American martens were highly valued in the fur trade and virtually unregulated trapping before the 1920s severely reduced populations by the early 1900s (Strickland, 1994). Excessive harvest may reduce to a point where it takes years to recover, and may result in long-term loss of genetic variation (Strickland, 1994). Grinnell et al. (1937) found records of individual trappers taking 35 and 50 martens within a few miles of the coast, e.g., east of Big Lagoon and Loleta, in one winter. The California Fish and Game Commission closed the trapping season in all or parts of Del Norte, Humboldt, Siskiyou, and Trinity counties in 1946 due to declining harvests (Twining and Hensley, 1947). Although the effects of trapping and/or poisoning likely contributed to the decline and extirpation of historical marten populations in northwestern California (Slauson and Zielinski, 2007c), decades of protection from trapping has not resulted in the recovery of marten populations in the region (Slauson and Zielinski, 2004). Although targeted trapping of martens is illegal in California, it is currently legal to trap other fur-bearing mammals that may occur in marten habitat, including bobcat and gray fox. Trapping is still legal in southern coastal Oregon. Although data does not exists to assess incidental trapping-related injury or mortality, the required use of non-body gripping traps, i.e., box traps, suggests that if trapped, martens should be released unharmed (Hamlin et al., 2010). Due to the remote location of the occupied habitat and the aforementioned trapping restrictions, it is assumed that mortalities and injuries from legal incidental capture of martens are infrequent (Hamlin et al., 2010).

B.6.3.3 Disease

Mortality from disease or predation may be a significant threat to martens in northwestern California, primarily due to the small size of the extant population (Hamlin et al., 2010). Species with small populations are subject to rapid declines in the number of individuals as a result of environmental fluctuations, such as a disease outbreak or increased predation (Primack, 1993).

Gabriel et al. (2008) investigated the prevalence of several pathogens within the mesocarnivore community on the Hoopa Valley Indian Reservation in northeastern Humboldt County and found a combined total of 63 gray foxes, ringtails (*Bassariscus astutus*), raccoons (*Procyon lotor*), and skunks (*Spilogale putorius* and *Mephitis mephitis*) showed prior exposure to canine distemper virus (2% of individuals), canine parvovirus (30%), canine adenovirus (9%), West Nile virus (6%), *Anaplasma phagocytophilum* (50%), and *Toxoplasma gondii* (40%). Of 20 animals tested for active infections, 15% were found to be infected by *A. phagocytophilum* and 19% were found to be actively shedding canine parvovirus (Gabriel, 2008). Although disease has the potential to be a threat due to the extremely small population size (<100 individuals), the Service stated that they were not aware of any evidence suggesting that martens were currently threatened by disease (Hamlin et al., 2010).

B.6.3.4 Predation

Mortality from predation could be another significant threat for the marten because of its small population size (Hamlin et al., 2010). Strickland et al. (1982) summarized reports of martens being preyed upon by coyotes, fishers, red foxes (*Vulpes vulpes*), cougars, eagles (*Aquila chrysaetos*, *Haliaeetus leucocephalus*), and great horned owls (*Bubo virginianus*). Bull and Heater (2001) documented 18 martens killed by predators in their northeastern Oregon study area: 44% by bobcats, 22% by raptors, 22% by other martens, and 11% by coyotes.

The distribution of mesocarnivores in coast redwood forests has changed over the last 80 years (Slauson and Zielinski, 2007b); with the distribution of martens dramatically declining in coastal forests, while fisher and gray fox, have maintained their interior distributions and appear to have expanded their distributions in coastal forests (Slauson and Zielinski, 2007b). Slauson and Zielinski (2007b) found fishers and gray foxes typically occupied forest types with shrub densities that were naturally lower and rarely detected them in coastal forest with extensive shrub cover. Dense, spatially extensive shrub layers may provide the smaller-bodied martens an advantage over larger-bodied carnivores (Slauson et al., 2007).

Slauson and Zielinski (2010) showed that bobcats and gray foxes tend to frequent roads in the coast redwood region and suggested that roads may be facilitating the presence and abundance of these species in dense-shrub landscapes. This increase in bobcats and gray foxes may lead to increased risk of predation for martens if encounters with the larger-bodied carnivores occur on roads, where martens are more vulnerable than in forest interiors (Slauson and Zielinski, 2010). Slauson and Zielinski (2010) hypothesized that the most significant threats likely responsible for the marten decline included disease and intraguild predation (Slauson and Zielinski, 2010).

B.6.4 Tree voles

The ecology and habitat requirements of tree voles are not well understood. As such, threats to the species have not been well documented. Two primary threats to the persistence of tree vole populations are loss of habitat and habitat fragmentation.

B.6.4.1 Loss of Habitat

Loss of habitat within the range of the tree vole is primarily caused by timber harvest, as wildfire threats in the coastal mountains are generally not as great as in more interior forests. Because tree voles are often patchily distributed, timber harvest has the potential to remove entire colonies. Additionally, timber harvest may reduce habitat quality through removal of structural components important to tree voles, e.g., deformed trees, large live trees and snags. As occupied habitat is removed or degraded due to timber harvest, local tree vole populations are put at risk due to increased risks of predation and their poor ability to disperse to other suitable habitats.

B.6.4.2 Fragmentation

Forest fragmentation may threaten the persistence of tree voles as they are not know to disperse long distances (Dunk et al. 2009). As landscapes become highly fragmented due to timber harvest or other disturbances, e.g., wildfire, windthrow, the colonization of new sites by dispersing voles may become difficult. It is unknown if the time required for colonization of new sites is due to the delayed development of suitable stand structure necessary to support vole populations or if it is related to the time necessary for voles to disperse from adjacent stands. Thompson and Diller (2002) reported anecdotal observations of vole nests in stands 10 to 16 years-old, and suggested that the source distance of colonizing voles may increase the time for colonization beyond the age when stands are structurally suitable for occupation. Fragmentation of suitable habitats may limit dispersal and colonization of suitable habitats by tree voles, leaving the long-term viability of tree voles in some regions dependent on the long-term survival of vole colonies in occupied stands.

B.7 LITERATURE CITED

Andruskiw, M., J.M. Fryxell, I.D. Thompson, and J.A. Baker. 2008. Habitat-mediated variation in predation risk by the American marten. Ecology 89:2273–2280.

Anthony, R.G. and L.S. Andrews. 2004. Summary Report: Winter habitat use by spotted owls on USDI Bureau of Land Management Medford District Lands within the boundaries of the Timbered Rock Fire. Unpublished report, Oregon Cooperative Wildlife Research Unit, Corvallis.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehring, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutiérrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2006. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monograph No. 163.

Aubry, K.B., M.J. Crites, and S.D. West. 1991. Regional patterns of small mammal abundance and community composition in Oregon and Washington. In: Ruggiero, L.F., K.B. Aubry, A.B. Carey, and M.G. Huff (Tech. Coords.), Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTRPNW- 285.

Aubry, K.B. and D.B. Houston. 1992. Distribution and status of the fisher (*Martes pennanti*) in Washington. Northwest Naturalist 73:69-79.

Aubry, K.B. and J.C. Lewis. 2003. Extirpation and reintroduction of fishers (*Martes pennanti*) in Oregon: implications for their conservation in the Pacific states. Biological Conservation. 114: 79-90.

Arthur, S.M., W.B. Krohn, and J.R. Gilbert. 1989. Habitat use and diet of fishers. Journal of Wildlife Management 53:680-688.

Arthur, S.M., T.F. Paragi, and W.B. Krohn. 1993. Dispersal of juvenile fishers in Maine. Journal of Wildlife Management 57:868-874.

Baker, J.M. 1992. Habitat use and spatial organization of pine marten on southern Vancouver Island, British Columbia. Thesis, Simon-Fraser University, Burnaby, British Columbia, Canada.

Barrowclough, G. F., R.J. Gutierrez, and J.G. Groth. 1999. Phylogeography or spotted owl (*Strix occidentalis*) populations based on mitochondrial DNA sequences: gene flow, genetic structure, and a novel biogeographic pattern. Evolution 53:919-931.

Beardsley, D., C. Bolsinger, and R. Warbington. 1999. Old-growth forests in the Sierra Nevada: by type in 1945 and 1993 and ownership in 1993 (Research Paper PNW-RP-516). Portland, OR: USDA Forest Service Pacific Northwest Research Station.

Bellinger, M.R., Haig, S.M., Forsman, E.D., Mullins, T.D., 2005. Taxonomic relationships among Phenacomys voles as inferred by cytochrome b. Journal of Mammalogy 86: 201–210.

Benson, S.B., and A.E. Borell. 1931. Notes on the life history of the red tree mouse *Phenacomys longicaudus*. Journal of Mammalogy 12:226-233.

Bigley, R.E. and J.F. Franklin. 2004. Habitat trends. Pages 1-35 in S. Courtney et al., editors. Scientific evaluation of the status of northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Bissonette, J.A., D.J. Harrison, C.D. Hargis, and T.G. Chapin. 1997. The influence of spatial scale and scale-sensitive properties on habitat selection by American marten. Pages 368–385 *in* Bissonette J.A., ed. Wildlife and landscape ecology effects of pattern and scale. Springer, New York.

Bond, M.L., R.J. Gutiérrez, A.B. Franklin, W.S. LaHaye, C.A. May, and M.E. Seamans. 2002. Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022–1028.

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management 73:1116-1124.

Brander, R.B., and D.J. Books. 1973. Return of the fisher. Natural History 82:52-57.

Buchanan, J.B. 2004. Managing habitat for dispersing northern spotted owls – are the current management strategies adequate? Wildlife Society Bulletin 32:1333–1345.

Buck, S.G., C. Mullis, and A. Mossman. 1983. Corral- Bottom/Hayfork Bally fisher study. Unpublished Final Report USDA Forest Service and Humboldt State University, Arcata, California.

Buck, S.G., C. Mullis, A. S. Mossman, I. Show, and C Coolahan. 1994. Habitat use by fishers in adjoining heavily and lightly harvested forest. Pages 368-376 *in* S. W. Buskirk, A. S. Harestad, M.G. Raphael, R.A. Powell, editors. Martens, Sabels, and Fishers: Biology and Conservation. Cornell University Press, Ithica, N.Y., USA.

Bull, E.L. and T.W. Heater. 2001. Survival, causes of mortality, and reproduction in the American marten in northeastern Oregon. Northwest Naturalist 82:1–6.

Buskirk, S.W. and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283-296 in S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. Martens, sables and fishers: biology and conservation. Cornell University Press, Ithaca, NY.

Buskirk, S.W. and L.L. McDonald. 1989. Analysis of variability in home-range size of the American marten. Journal of Wildlife Management. 53:997–1004.

Buskirk, S. W., and L. F. Ruggiero. 1994. Marten. Pages 7-37 in L. F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski, eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. General Technical Report RM-254.

Buskirk, S.W. and W.J. Zielinski. 1997. American marten (*Martes americana*) ecology and conservation. Pages 17–22 *in* J.E. Harris and C.V. Ogan, eds. Mesocarnivores of northern California biology, management, and survey techniques. August 12–15, Humboldt State University. The Wildlife Society California North Coast Chapter, Arcata, California.

Buskirk, S.W., and W.J. Zielinski. 2003. Small and mid-sized carnivores**.** In: Zabel, C.J.; Anthony, R.G., editors. Mammalian community dynamics: Management and conservation in the coniferous forests of western North America. Cambridge, UK: Cambridge University Press: 207-249.

Caffrey, C. 2003. Determining impacts of West Nile Virus on crows and other birds. American Birds 57:12-13.

Carroll, C., W.J. Zielinski, and R.F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath Region, U.S.A. Conservation Biology 13: 1344-1359.

Carroll, C. and D.S. Johnson. 2008. The importance of being spatial (and reserved): assessing northern spotted owl habitat relationships with hierarchical Bayesian models. Conservation Biology 22: 1026-1036.

CBD (Center for Biological Diversity), and EPIC (Environmental Protection Information Center). 2010. Petition to list the Humboldt marten (*Martes americana humboldtensis*) as threatened or endangered under the Endangered Species Act. 28 March 2010. 47 pp.

CDFG (California Department of Fish and Game). 2008. Evaluation of petition: Request of the Center for Biological Diversity to list the Pacific Fisher (*Martes pennanti*) as threatened or endangered. California Department of Fish and Game, Wildlife Branch, Sacramento, CA.

CDFG (California Department of Fish and Game). 2010. A status review of the fisher (*Martes pennanti*) in California. Report to the California Department of Fish and Game Commission. California Department of Fish and Game 183 pp.

Clark, D.A. 2007. Demography and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon.

Cohen, W.B., T.A. Spies, R.J. Alig, D.R. Oetter, T.K. Maiersperger, and M. Fiorella. 2002. Characterizing 23 years (1972-95) of stand replacement disturbance in Western Oregon Forests with Landsat Imagery. Ecosystems 5:122-137.

Cooperrider, A., R.F. Noss, H.H. Welsh, Jr., C. Carroll, W.J. Zielinski, D. Olson, S.K. Nelson, and B.G. Marcot. 2000. Terrestrial fauna of redwood forests. Pages 119–163 *in* Noss, R.F, ed. The redwood forest: history, ecology, and conservation of the coast redwoods. Island Press, Covelo, California.

Corn, P.S., Bury, R.B., 1986. Habitat use and terrestrial activity by red tree voles (*Arborimous longicaudus*) in Oregon. Journal of Mammalogy 67: 404–406.

Corn, P.S., Bury, R.B., 1991. Small mammal communities in the Oregon Coast Range. In: Ruggiero, L.F., Aubrey, K.B., Carey, A.B., Huff, M.G. (Tech Coords.), wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTRPNW- 285.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleisher, A.B. Franklin, J.F. Franklin, R. J. Gutiérrez, J.M. Marzluff, L. Sztukowski. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Davis, F.W., C. Seo, and W.J. Zielinski. 2007. Regional variation in home-range-scale habitat models for fisher (*Martes pennanti*) in California. Ecological Applications 17(8):2195-2213.

De Vos, A. 1952. Ecology and management of fisher and marten in Ontario. Ontario Department of Lands and Forests; Technical Bulletin, Wildlife Service 1.

Douglas, C.W. and M.A. Strickland. 1987. Fisher. Pages 511-529 in Novak et al., technical editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto, Ontario.

Douglas, C.W. and M.A. Strickland. 1999. Fisher *in* Wild Furbearer Management and Conservation in North America. Section IV. Species Biology, Management, and Conservation.

Diller, L.V. and D.M. Thome. 1999. Population density of northern spotted owls in managed young-growth forests in coastal northern California. Journal of Raptor Research 33: 275–286.

Drew, R.E., J.G. Hallett, K.B. Aubry, K.W. Cullings, S.M. Koepfs, and W.J. Zielinski. 2003. Conservation genetics of the fisher (*Martes pennanti*) based on mitochondrial DNA sequencing. Molecular Ecology 12:51-62.

Dunbar, D.L., B.P. Booth, E.D. Forsman, A.E. Hetherington, and D.J. Wilson. 1991. Status of the spotted owl, *Strix occidentalis*, and barred owl, *Strix varia*, in southwestern British Columbia. Canadian Field-Naturalist 105:464-468.

Dunk, J.R., and J.J. Hawely. 2009. Red tree vole habitat suitability modeling: implications for conservation and management. Forest Ecology and Management 258:626-634.

EPIC (Environmental Protection Information Center), and CBD (Center for Biological Diversity). 2015. Petition to list the Humboldt marten (*Martes caurina humboldtensis*) as an endangered species under the California Endangered Species Act. 01 June 2015. 39 pp.

Forsman, E.D. 1975. A preliminary investigation of the spotted owl in Oregon. Thesis, Oregon State University, Corvallis.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87:1–64

Forsman, E.D., R.G. Anthony, E.C. Meslow, and C.J. Zabel. 2004. Diets and foraging behavior of northern spotted owls in Oregon. Journal of Raptor Research 38:214–230.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149:1–35.

Forsman E.D., J.K. Swingle, and N.R. Hatch. 2009. Behavior of red tree voles (*Arborimus longicaudus*) based on continuous video monitoring of nests. Northwest Science 83:262–272.

Franklin, A.B. 1992. Population regulation in northern spotted owls: theoretical implications for management. Pages 815–827 *in* D.R. McCullough and R.H. Barrett, editors. Wildlife 2001: populations. Elsevier Applied Sciences, London, England.

Franklin, J.F., and C.T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Corvallis, OR: Oregon State University Press.

Franklin, A.B., D.R. Anderson, R.J. Gutiérrez, and K.P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70:539–590.

Frost, H.C., W.B. Krohn and C.R. Wallace. 1997. Age-specific reproductive characteristics in fishers. Journal of Mammalogy 78(2): 598-612.

Frost, E. J. and R. Sweeney. 2000. Fire regimes, fire history and forest conditions in the Klamath-Siskiyou region: an overview and synthesis of knowledge. World Wildlife Fund, Klamath-Siskiyou Ecoregion Program, Ashland, OR.

Gabriel, M. W., G. M. Wengert, J. E. Foley, J. M. Higley, S. M. Matthews, and R. N. Brown. 2008. Pathogens associated with fishers (*Martes pennanti*) and sympatric mesocarnivores in California. Final report to the U.S. Fish and Wildlife Service, Yreka, California, USA, 53 p.

Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Effects of the Hatchery Complex Fires on northern spotted owls in the eastern Washington Cascades. Pages 123–129 *in* J.M. Greenlee, editor. Proceedings of the First Conference on Fire Effects on Rare and Endangered Species and Habitats. International Association of Wildland Fire, Coeur d'Alene, Idaho.

Gancz, A., I.K. Barker, R. Lindsay, A. Dibernardo, K. McKeever, and B. Hunter. 2004. West Nile Virus outbreaks in North American owls, Ontario, 2002. Emerging Infectious Diseases 10:2135-2142.

Garmendia, A.E., H.J. Van Kruiningen, R.A. French, J.F. Anderson, T.G. Andreadis, A. Kumar, and A.B. West. 2000. Recovery and identification of West Nile Virus from a hawk in winter. Journal of Clinical Microbiology 38:3110-3111.

Gibilisco, C.J. 1994. Distributional dynamics of modern *Martes* in North America. Pages 59–70 *in* S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, eds. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York, USA. 484 pp.

Gilbert, F.F., and R. Allwine. 1991. Small mammal communities in the Oregon Cascade Range. In: Ruggiero LF, Aubry KB, Carey AB, Huff MH, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. Portland, OR: USDA Forest Service. General Technical Report PNW-GTR-285.

Gilbert, J.H., J.L. Wright, D.J. Lauten, and J.R. Probst. 1997. Den and rest-site characteristics of American marten and fisher in Northern Wisconsin. *In* G. Proulx, H.N. Bryant, and P.M. Woodard (editors), *Martes*: taxonomy, ecology, techniques, and management, Provincial Museum of Alberta, Edmonton, Canada.

Gillesberg, A., and A.B. Carey. 1991. Arboreal nests of *Phenacomys longicaudus* in Oregon. Journal of Mammalogy 72: 784–787.

Goldman, E.A. 1935. New American mustelids of the genera Martes, Gulo, and Lutra. Proceedings of the Biological Society of Washington 48:175-186.

Golightly, R.T., T.F. Penland, W.J. Zielinski and J.M. Higley. 2006 Fisher diet in the Klamath/North Coast Bioregion. Final Report to U.S. Fish and Wildlife Service and Scotia Pacific. Humboldt State Sponsored Programs Foundation, Arcata, California.

Green, G.A., L.A. Campbell, and D.C. MacFarlane. 2008. A conservation assessment for fishers (*Martes pennanti*) in the Sierra Nevada of California. USDA Forest Service, Pacific Southwest Region, Vallejo, California.

Gremel, S. A. 2005. Factors controlling distribution and demography of Northern Spotted Owls in a reserved landscape. M.S. Thesis, University of Washington, Seattle, WA. 56 p.

Grenfell, W.E., and M. Fasenfest. 1979. Winter food habits of fishers, *Martes pennanti*, in northwestern California. California Fish and Game 65:186-189.

Grinnell, J., J.S. Dixon, and J.M. Linsdale. 1937. Fur-bearing mammals of California. University of California Press. Berkeley, California.

Gutiérrez, R.J. 1996. Biology and distribution of the northern spotted owl. Studies in Avian Biology 17:2–5.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted owl (*Strix occidentalis*) *in* A. Poole and F. Gill, editors. The birds of North America, No. 179. The Academy of Natural Sciences and The American Ornithologists' Union, Washington, D.C.

Hagmeier, E. M. 1956. Distribution of marten and fisher in North America. Canadian Field-Naturalist 70:149-168.

Haig, S.M., T.D. Mullins, and E. D. Forsman. 2004. Subspecific relationships and genetic structure in the spotted owl. Conservation Genetics 5:683-705.

Hamer, T.E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. M.S. thesis, Western Washington University, Bellingham, WA.

Hamer, T.E., D.L. Hays, C.M. Senger, and E.D. Forsman. 2001. Diets of northern barred owls and northern spotted owls in an area of sympatry. Journal of Raptor Research 35:221–227.

Hamer, T.E., E.D. Forsman, and E.M. Glenn. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. The Condor 109:750-768.

Hamilton, W.J., III. 1962. Reproductive adaptations of the red tree mouse. Journal of Mammalogy 43:486-504.

Hamlin, R., L. Roberts, G. Schmidt, K. Brubaker and R. Bosch 2010. Species assessment for the Humboldt marten (*Martes americana humboldtensis*). U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Heinemeyer, K.S. and J.L. Jones. 1994. Fisher biology and management in the western United States: a literature review and adaptive management strategy. Version 1.1. USDA Forest Service Northern Region and Interagency Forest Carnivore Working Group.

Herter, J.E. and L.L. Hicks. 2000. Barred owl and spotted owl populations and habitat in the central Cascade Range of Washington. Journal of Raptor Research 34:279-286.

Higgins, K. and M. Lynch. 2001. Metapopulation extinction caused by mutation accumulation. Proceedings of the National Academy of Sciences, USA 98:2928-2933.

Higley, J.M. and S.M. Matthews. 2006. Demographic rates and denning ecology of female Pacific fishers (*Martes pennanti*) in northwestern California. Preliminary report October 2004 – July 2006. Submitted to U.S. Fish and Wildlife Service Yreka Office, Yreka, CA.

Higley, J.M. and S. Matthews. 2009. Fisher habitat use and population monitoring on the Hoopa Valley Reservation, California. Final Report USFWS TWG U-12-NA-1. Hoopa Valley Tribe. Hoopa, CA.

Howell, A.B., 1926. Life history of the red tree mouse *Phenacomys longicaudus* True. North American Fauna 48: 39–64.

Iverson, W.F. 1993. Is the barred owl displacing the spotted owl in western Washington? M.S. thesis, Western Washington University, Bellingham, WA.

Jimerson, T.M, E.A. McGee, D.W. Jones, R.J. Svilich, E. Hotalen, G. DeNitto, T. Laurent, J.D. Tenpas, M.E. Smith, K. Hefner-McClelland, J. Mattison. 1996. A field guide to the tanoak and the Douglas-fir plant associations in northwestern California. R5-ECOl-TP-009. USDA Forest Service, Pacific Southwest Region.

Johnson, M.L., and S.B. George. 1991. Species limits within the *Arborimus longicaudus* species-complex (Mammalia: Rodentia) with a description of a new species from California. Contributions in Science 429: 1–16.

Johnson, C.A., J.M. Fryxell, I.D. Tompson, and J.A. Baker. 2009. Mortality risk increases with natal dispersal distance in American martens. Proceedings of the Royal B. Society 276:3361–3367.

Johnston, A. 2002. Northern spotted owl survey and monitor report. U.S. Department of Interior, National Park Service, Crater Lake National Park, Crater Lake, Oregon.

Jones, J.L. 1991. Habitat use of fishers in north-central Idaho. Thesis, University of Idaho, Moscow.

Kelly, E.G., E.D. Forsman, and R.G. Anthony. 2003. Are barred owls displacing spotted owls? Condor 105:45-53.

Kelly, E.G., and E.D. Forsman. 2004. Recent records of hybridization between barred owls and northern spotted owls. Auk 121:806-810.

Kilpatrick, H.J. and P.W. Rego. 1994. Influence of season, sex and site availability on fisher (*Martes pennanti*) rest-site selection in the central hardwood forest. Canadian Journal of Zoology 72:1416-1419.

Kirk, T.A., and W.J. Zielinski. 2009. Developing and testing a landscape habitat suitability model for the American marten (*Martes americana*) in the Cascades mountains of California. Landscape Ecology 24:759-773.

Klug, R.R. 1997. Occurrence of Pacific fisher in the Redwood Zone of northern California and the habitat attributes associated with their detections. Thesis, Humboldt State University, Arcata, California.

Komar, N., N.A. Panella, J.E. Burns, S.W. Dusza, T. M. Mascarenhas, and T.O. Talbot. 2002. Serologic evidence for West Nile Virus infection in birds in the New York City vicinity during an outbreak in 1999. Emerging Infectious Diseases 7:621-625.

Laudenslayer, W.F., Jr. 1985. Candidate old-growth on National Forest System administered lands in California. USDA Forest Service Pacific Southwest Region Report, San Francisco 17 p.

Lewis, J.C. and D.W. Stinson. 1998. Washington State status report for the fisher. Washington Dept. Fish and Wildlife, Olympia, WA. 64 pages.

Lewis, J.C., P.J. Happe, K.J. Jenkins, and D.J. Manson. 2009. Olympic fisher reintroduction project: 2009 progress report. Unpublished report: Washington Department of Fish and Wildlife, Olympic National Park, and US Geological Survey. Olympia Washington.

Leskiw, T. and R.J. Gutierrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29:225-226.

Livezey, K.B. 2005. Iverson (2004) on spotted owls and barred owls: comments on methods and conclusion. Journal of Raptor Research 39:102–103.

Livezey, K.B. 2007. Barred Owl habitat and prey: a review and synthesis of the literature. Journal of Raptor Research 41:177–201.

Livezey, K.B. 2009a. Range expansion of Barred Owls, part I: chronology and distribution. American Midland Naturalist 161:49–56.

Livezey, K.B. 2009b. Range expansion of Barred Owls, part II: facilitating ecological changes. American Midland Naturalist 161:323–349.

Livezey, K.B. 2010. Killing barred owls to help spotted owls I: a global perspective. Northwestern Naturalist 91:107-133.

Livezey, K.B. and T.L. Fleming. 2007. Effects of barred owls on spotted owls: the need for more than incidental detections and correlational analyses. Journal of Raptor Research 41:319–325.

Livezey, K.B., M.F. Elderkin, P.A. Cott, J. Hobbs, and J.P. Hudson. 2008. Barred owls eating worms and slugs: the advantage in not being picky eaters. Northwestern Naturalist. 89:185-190.

Lutz, J.A., J.W. van Wagtendonk, A.E. Thode, J.D. Miller, and J.F. Franklin. 2009. Climate, lightning ignitions, and fire severity in Yosemite National Park, California, USA. International Journal of Wildland Fire 18:765-774.

Marra, P.P., S. Griffing, C. Caffrey, A.M. Kilpatrick, R. McLean, C. Brand, E. Saito, A.P. Dupuis, L. Kramer, and R. Novak. 2004. West Nile Virus and wildlife. BioScience 54:393-402.

Martin, S.K. 1994. Feeding ecology of American martens and fishers, *in* S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell (Eds.) Martens, sables and fishers: biology and conservation. Ithaca, N.Y. Cornell University Press.

Maser, C.O. 1966. Life histories and ecology of *Phenacomys albipes, Phenacomys longicaudus, Phenacomys silvicola*. Thesis, Oregon State University, Corvallis.

Maser, C., Mate, B.R., Franklin, J.F., Dyrness, C.T., 1981. Natural History of Oregon Coast Mammals. USDA Forest Service, PNW-GTR-133.

McLean, R.G., S.R. Ubico, S.E. Docherty, W.R. Hansen, L. Sileo, and T.S. McNamara. 2001. West Nile Virus and transmission and ecology in birds. Annals of the New York Academy of Sciences 951:54-57.

Mead, R.A. 1994. Reproduction in *Martes*, *in* S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell (Eds.) Martens, sables and fishers: biology and conservation. Ithaca, N.Y. Cornell University Press.

Meiselman, N., and A.T. Doyle. 1996. Habitat and microhabitat use by the red tree vole (*Phenacomys longicaudus*). American Midland Naturalist 135: 33–42.

Meyer, J.S., L.L. Irwin, and M.S. Boyce. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. Wildlife Monographs 139:1–51.

Miller, G.S. 1989. Dispersal of juvenile spotted owls in western Oregon. Thesis, Oregon State University, Corvallis.

Miller, G.S., S.K. Nelson, and W.C. Wright. 1985. Two-year-old female spotted owl breeds successfully. Western Birds 16:69–73.

Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. Journal of Wildlife Management 61:140–150.

Olson, G.S., E. M. Glenn, R. G. Anthony, E.D. Forsman, J.A. Reid, P.J. Loschl, and W.J. Ripple. 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039-1053.

Olson, G.S., R.G. Anthony, E.D. Forsman, S.H. Ackers, P.J. Loschl, J.A. Reid, K.M. Dugger, E.M. Glenn, and W.J. Ripple. 2005. Modeling of site occupancy dynamics for northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918-932.

Paragi, T.F., S.M. Arthur, and W.B. Krohn. 1996. Importance of tree cavities as natal dens for fishers. Northern Journal of Applied Forestry 13:79-83.

Pearson, R.R., and K.B. Livezey. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265-275.

Phillips, D.M. 1994. Social and spatial characteristics and dispersal of marten in a forest preserve and industrial forest. Thesis, University of Maine, Orono.

Poole, K.G, A.D. Porter, A. de Vries, C. Maundrell, S.D. Grindal, and C.C. St. Clair. 2004. Suitability of a young deciduous-dominated forest for American marten and the effects of forest removal. Canadian Journal of Zoology 82:423-435.

Powell, R.A. 1993. The fisher: life history, ecology and behavior. Second edition. University of Minnesota Press, Minneapolis, Minnesota, USA.

Powell, R.A. and W.J. Zielinksi. 1994. Fisher. Pages 38-73 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski, eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, wolverine in the western United States. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. General Technical Report RM-254.

Powell, R.A., S.W. Buskirk, and W.J. Zielinski. 2003. Fisher and marten. Pages 635-649 in G. A. Feldhamer, B. Thompson, and J. A. Chapman, editors. Wild mammals of North America. Second edition. Johns Hopkins University Press, Baltimore, Maryland.

Powell, R.A., and W.J. Zielinski. 2005. Evaluating the demographic factors that affect the success of reintroducing fishers (*Martes pennant*) and the effects of removals on a source population. Final Report to the U.S. Fish and Wildlife Service. 20 p.

Powell, R.A. 2010. Ecological Studies of Fishers (*Martes pennanti*) on Managed Landscapes in Northern California: working draft document located online at http://ucce-plumas-sierra.ucdavis.edu/files/63883.rtf.

Primack, R.B. 1993. Essentials of Conservation Biology. Sinauer Associates Inc., Sunderland, Massachusetts.

Purcell, K.L., A.K. Mazzoni, S.R. Mori, and B.B. Boroski. 2009. Resting structures and resting habitat of fishers in the southern Sierra Nevada, California. Forest Ecology and Management 258:2696-2706.

Raphael, M.G., 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in Douglas-fir forests of northwestern California. In: Szaro, R.C., K.E. Severson, and D.R. Patton (Eds.), Management of amphibians, reptiles, and small mammals in North America. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, RM-GTR-166.

Raphael, M.G. and L.C. Jones. 1997. Characteristics of resting and denning sites of American martens in Central Oregon and Western Washington. In: Proulx, G., H.N. Bryant, and P.M. Woodard (eds). *Martes*: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmington, Alberta, Canada.

Raphael, M. G. 2006. Conservation of listed species: Northern spotted owl and marbled murrelet. Pages 117-143 in R.W. Haynes, B.T. Borman, D.C. Lee, and J.R. Martin, editors. Northwest Forest Plan – The First 10 Years (1994-2003): Synthesis of Monitoring and Research Results. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Ruggiero, L.F., D.E. Pearson, S.E. Henry. 1998. Characteristics of American marten den sites in Wyoming. Journal of Wildlife Management 62:663–673.

Sawyer, J.O., S.C. Silett, W.J. Libby, T.E. Dawson, J.H. Popenoe, D.L. Largent, R. Van Pelt, S.D. Veirs Jr., R.F. Noss, D.A. Thornburgh, and P.D. Tredici. 2000. Redwood trees, communities, and ecosystems: a closer look. Pages 81–118 *in* Noss, R.F, ed. The redwood forest: history, ecology, and conservation of the coast redwoods. Island Press, Covelo, California.

Scheffer, V.B. 1938. Notes on wolverine and fisher in the state of Washington. Murrelet 19:8-10.

Schempf, P.F. and M. White. 1977. Status of six furbearer populations in the mountains of Northern California. Berkeley (CA): USDA Forest Service, Pacific Southwest Region.

Schmidt, K. 2003. Northern spotted owl monitoring and inventory, Redwood National and State Parks, 2002 annual report. Redwood National and State Parks, Orick, California.

Schwartz, M.K. 2010. Letter in Appendix C of a status review of the fisher *(Martes pennant)* in California. California Department of Fish and Game. February 2010

Seglund, A.E. 1995. The use of resting sites by the Pacific fisher. Thesis, Humboldt State University, Arcata, California.

Self, S. and R. Callas. 2006. Pacific Fisher Natal and Maternal Den Study: Progress Report No. 1. Redding: Sierra Pacific Industries and California Department of Fish and Game.

Singleton, P.J., J.F. Lehnkuhl, W.L. Gaines, and S.A. Graham. 2010. Barred owl space use and habitat selection in the eastern Cascades, Washington. Journal of Wildlife Management 74:285-294.

Sisco, C.L. 1990. Seasonal home range and habitat ecology of spotted owls in northwestern California. Thesis, Humboldt State University, Arcata, California.

Skinner, C.N. and C. Chang. 1996. Fire regimes, past and present. In: Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II. Assessments and scientific basis for management options. Water Resources Center Report No. 37. Davis, CA: Centers for Water and Wildland Resources, University of California: 1041-1069.

Skinner, C.N., and A.H. Taylor. 2006. Southern Cascade bioregion. Pages 195-224 *in* N. S. Sugihar, J. W. van Wagtendonk, K. E. Shaffer, J. Fites-Kaufman, and A. E. Thode, editors. Fire in California's ecosystems, University of California Press: Berkeley, CA.

Skinner, C.N., A.H. Taylor, and J.K. Agee. 2006. Klamath Mountains Bioregion. Pages 170-194 *in* N.G. Sugihara, J.W. van Wagtendonk, J. Fites-Kaugmann, K.E. Shaffer, and A.E. Thode, editors. Fire in California's ecosystems, University of California Press, Berkeley, CA.

Slauson, K.M. 2003. Habitat selection by a remnant population of American martens in coastal Northwestern California. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Slauson, K.M. and W.J. Zielinski. 2003. Distribution and habitat association of the Humboldt marten (*Martes americana humboldtensis*), and Pacific fisher (*Martes pennanti pacifica*) in Redwood National and State Parks. Final Report. Unpublished report dated March 18, 2003. USDAFS, PSW, Redwood Sciences Laboratory, Arcata, California.

Slauson, K.M. and W.J. Zielinski. 2004. Conservation status of American martens and fishers in the Klamath-Siskiyou bioregion. Pages 60–70 *in* Merganther K, J. Williams, and E. Jules, 31 eds. Proceedings of the 2nd conference on Klamath-Siskiyou ecology, Cave Junction, Oregon.

Slauson, K.M. and W.J. Zielinski. 2006. Characteristics of summer/fall home ranges of American martens in coastal northwestern California. Page 65 *in* The Western Section of The Wildlife Society, Annual conference program and abstracts, Plenary Theme: Monitoring wildlife populations: state of the science. February 8–10, Sacramento, California.

Slauson, K.M. and W.J. Zielinski. 2007a. The relationship between the understory shrub component of coastal forests and the conservation of forest carnivores. Pages 241–244 in R.B. Standiford, G.A. Giusti, Y. Valachovic, W.J. Zielinski, M.J. Furniss, eds. Proceedings of the redwood region forest science symposium: what does the future hold? Gen Tech Rep PSW-GTR-194, Pacific Southwest Research Station, Forest Service, USDA, Albany, California.

Slauson, K.M. and W.J. Zielinski. 2007b. The relationship between the understory shrub component of coastal forests and the conservation of forest carnivores. Pages 241–244 *in* R.B. Standiford, G.A. Giusti, Y. Valachovic, W.J. Zielinski, M.J. Furniss, eds. Proceedings of the redwood region forest science symposium: what does the future hold? Gen Tech Rep PSW-GTR-194, Pacific Southwest Research Station, Forest Service, USDA, Albany, California.

Slauson, K.M. and W.J. Zielinski. 2007c. Strategic surveys for *Martes* populations in northwestern California: Mendocino National Forest, Final Report. Unpublished report dated February 2007. USDA FS, PSW, Redwood Sciences Laboratory, Arcata, California.

Slauson, K. M., W. J. Zielinski, and J. P. Hayes. 2007. Habitat selection by American martens in coastal California. The Journal of Wildlife Management 71:458-468.

Slauson, K.M. and W.J. Zielinski. 2009. Characteristics of summer and fall diurnal resting habitat used by American martens in coastal northwestern California. Northwest Science 83(1):35–45.

Slauson, K.M., J.A. Baldwin, W.J. Zielinski, and T.A. Kirk. 2009. Status and estimated size of the only remnant population of the Humboldt subspecies of the American marten (*Martes americana humboldtensis*) in northwestern California, Final report. Unpublished report dated November 25, 2009. USDA FS, PSW, Redwood Sciences Laboratory, Arcata, California.

Slauson, K.M. and W.J. Zielinski. 2010. Carnivore use of forest roads in the redwood region of northwestern California. Pages 77–78 *in* The Western Section of The Wildlife Society, Annual conference program and abstracts, Fostering resilient wildlife populations. January 26–29, Visalia, California.

Slauson, K.M. and W.J. Zielinski. 2017. Seasonal specialization in diet of the Humboldt marten (*Martes caurina humboldtensis*) in California and the importance of prey size. Journal of Mammalogy 98:1697-1708.

Solis, D.M., and R.J. Gutiérrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92:739–748.

Sovern, S.G., E.D. Forsman, B.L. Biswell, D.N. Rolph and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200–202.

Spencer, W.D. 1987. Seasonal rest-site preferences of pine martens in the northern Sierra Nevada. Journal of Wildlife Management 51(3):616–621.

Spencer, W.D., H.L. Rustigian, R.M. Scheller, A. Syphard, J. Strittholt, and B. Ward. 2008. Baseline evaluation of fisher habitat and population status, and effects of fires and fuels management on fishers in the southern Sierra Nevada. Unpublished report prepared for USDA Forest Service, Pacific Southwest Region, 133 pp.

Steger, G.N., L.R. Werner, and T.E. Munton. 2006. First documented record of the barred owl in the southern Sierra Nevada. Western Birds 37:106-109.

Strickland, M.A. 1994. Harvest management of fishers and martens. Pages 149–164 *in* Buskirk, S.W., A.S. Harestad, M.G. Raphael, eds. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York. 484 pp.

Strickland, M.A., C.W. Douglas, M. Novak, and N.P. Hunziger. 1982. Marten. Pages 599–612 *in* Chapman, J.A. and G.A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. Johns Hopkins University Press, Baltimore, Maryland.

Strickland, M.A. and C.W. Douglas. 1987. Marten. Pages 530–546 *in* Novak, M., J.A. Baker, and M.E. Obbard, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario.

Stuart, J.D., and S.L. Stephens. 2006. North Coast Bioregion. Pages 147-169 *in* N.G. Sugihara, J.W. van Wagtendonk, J. Fites-Kaugmann, K. E. Shaffer, and A. E. Thode, editors. Fire in California's ecosystems, University of California Press, Berkeley, CA.

Swingle, J.K. 2005. Daily activity patterns, survival, and movements of red tree voles (*Arborimus longicaudus*) in western Oregon. Thesis, Oregon State University, Corvallis.

Swingle, J.K., and E.D. Forsman. 2009. Home range areas and activity patterns of red tree voles (*Arborimus longicaudus*). Northwest Science 83:273-286.

Taylor, W.P., 1915. Description of a new subgenus (*Arborimus*) of *Phenacomys*, with a contribution to knowledge of the habits and distribution of *Phenacomys longicaudus*. Proceedings of the California Academy of Sciences 5: 111–161.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. National Park Service, Portland, Oregon.

Thomas, J.W., M.G. Raphael, R.G. Anthony, E.D. Forsman, A.G. Gunderson, R.S. Holthausen, B.G. Marcot, G.H. Reeves, J.R. Sedell, and D.M. Solis. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. U.S. Forest Service, Portland, Oregon.

Thompson, I.D. and P.W. Colgan. 1987. Numerical responses of martens to a food shortage in north central Ontario. Journal of Wildlife Management 51:824-835.

Thompson, J.L. 2008. Density of fisher on managed timberlands in north coastal California. Thesis, Humboldt State University, Arcata, California.

Thompson, J.L., and L.V. Diller. 2002. Relative abundance, nest site characteristics, and nest dynamics of Sonoma tree voles on managed timberlands in coastal northwest California. Northwestern Naturalist 83:91-100.

Truex, R.L., W.J. Zielinski, R.T. Golightly, R.H. Barrett, and S.M. Wisely. 1998. A metaanalysis of regional variation in fisher morphology, demography, and habitat ecology in California. Draft report submitted to California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section.

Twining, H. and A. Hensley. 1947. The status of pine martens in California. California Fish and Game 33(3):133–137.

USFWS (U.S. Fish and Wildlife Service). 1983*a*. Endangered and threatened species listing and recovery priority guidelines. Federal Register 48:43098–43105.

USFWS (U.S. Fish and Wildlife Service). 1983*b*. Endangered and threatened species listing and recovery priority guidelines: correction. Federal Register 48:51985.

USFWS (U.S. Fish and Wildlife Service). 1989. The northern spotted owl; a status review supplement. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1990*a*. The 1990 status review: northern spotted owl: *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. 95 pp.

USFWS (U.S. Fish and Wildlife Service). 1990b. Endangered and threatened wildlife and plants: determination of threatened status for the northern spotted owl. Federal Register 55:26114–26194

USFWS (U.S. Fish and Wildlife Service). 1992a. Draft final recovery plan for the northern spotted owl. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1992b. Final rule for the designation of critical habitat for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. 43 pp.

USFWS (U.S. Fish and Wildlife Service). 1994. Letter from D.C. Frederick (USFWS) to J. Belcher (Washington Department of Natural Resources) dated February 1, 1994, regarding correction to spotted owl home-range data for the Olympic Peninsula. U.S. Fish and Wildlife Service, Olympia, Washington.

USFWS (U.S. Fish and Wildlife Service). 2004. Northern spotted owl: Five Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2008a. Final Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*). Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2008b. Endangered and threatened wildlife and plants; 90-day finding on a petition to list the dusky tree vole (*Arborimus longicaudus silvicola*) as threatened or endangered. Federal Register 73: 63919-63926.

USFWS (U.S. Fish and Wildlife Service). 2010. Draft revised recovery plan for the northern spotted owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2016. Endangered and threatened wildlife and plants; withdrawal of the proposed rule to list the West Coast Distinct Population Segment of fisher. Federal Register 81:22710-22808.

Verts, B.J. and L.N. Carraway. 1998. Land mammals of Oregon. University of California Press. Berkeley, California.

Ward, J.W. Jr., R.J. Gutiérrez, and B.R. Noon. 1998. Habitat selection by northern spotted owls: the consequences of prey selection and distribution. Condor 100:79–92.

Weidemeier, D.J. and S.P. Horton. 2000. Trends in spotted owl and barred owl detections in the Olympic Experimental State Forest from 1991 to 1999. Northwestern Naturalist 81:93.

Weir, R.D. 1995. Diet, spatial organization, and habitat relationships of fishers in south-central British Columbia. Thesis, Simon Fraser University, Burnaby, British Columbia.

Weir, R.D. and A.S. Harestad. 2003. Scale-dependent habitat selectivity by fishers in south-central British Columbia. Journal of Wildlife Management 67: 73-82.

Weir, R.D., A.S. Harestad, and R. C. Wright. 2005. Winter diet of fishers in British Columbia. Northwestern Naturalist 86:12-19.

Wilbert, C.J. 1992. Spatial scale and seasonality of habitat selection by martens in southeastern Wyoming. Thesis, University of Wyoming, Laramie.

Wisely, S.M., S.W. Buskirk, G.A. Russell, K.B. Aubry, and W.J. Zielinski. 2004. Genetic diversity and structure of the fisher (*Martes pennanti*) in a peninsular and peripheral metapopulation. Journal of Mammalogy 85(4): 640-648.

Wright, P.L. and M.W. Coulter. 1967. Reproduction and growth in Maine fishers. Journal of Wildlife Management 31(1):70-87.

Yaeger, J. S. 2005. Habitat at fisher resting sites in the Klamath Province of northern California. Thesis, Humboldt State University, Arcata, California.

Zabel, C.J., K.M. McKelvey, and J.P. Ward, Jr. 1995. Influence of primary prey on home-range size and habitat-use patterns of northern spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433–439.

Zabel, C.J., J.R. Dunk, H.B. Stauffer, L.M. Roberts, B.S. Mulder, and A. Wright. 2003. Northern spotted owl habitat models for research and management application in California (USA). Ecological Applications 13:1027–1040.

Zielinski, W.J., K.M. Slauson, C.R. Carroll, C.J. Kent, and D.G. Kudrna. 2001. Status of American martens in coastal forests of the Pacific States. Journal of Mammalogy 82(2):478–490.

Zielinski, W.J. and N.P. Duncan. 2004. Diets of sympatric populations of American martens (*Martes americana*) and fishers (*Martes pennanti*) in California. J. Mammalogy 85:470-477.

Zielinski, W.J., N.P. Duncan, E.C. Farmer, R.L. Truex, A. P. Clevenger, and R.H. Barrett. 1999. Diet of fishers (*Martes pennanti*) at the southernmost extent of their range. Journal of Mammalogy 80:961-971.

Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004a. Resting habitat selection by fishers in California. Journal of Wildlife Management. 68(3):475-492.

Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004b. Home range characteristics of fishers in California. Journal of Mammalogy, 85(4):649–657.

Zielinski, W.J., G.A. Schmidt, and K.N. Schmidt. 1995. Six rivers National Forest fisher study: progress report II. U.S. Forest Service, Pacific Southwest Research Station, Albany, California.

Appendix C. Studies, Surveys, and Assessments of Covered Species and Their Habitats Conducted in the Current Plan Area

Table of Contents

C.1 INTRODUCTION

Appendix C is a compilation of published and unpublished reports resulting from numerous surveys, studies and monitoring that Green Diamond undertook for the Plan Area Covered Species. The earliest of these studies started in 1989 with the initial Northern Spotted Owl (NSO) surveys of Green Diamond's (formerly Simpson Timber Company's) ownership. The NSO surveys and studies continue to the present, but Green Diamond collected the data summarized here from 1990-2006. Green Diamond initiated work on fisher with a graduate thesis in 1994 and continued with various other studies through 2006. Although Green Diamond collected incidental information on tree voles from 1990 to the present, the formalized studies were primarily restricted to 1994-1996. The results of all of these investigations, along with continuing scientific progress in assessing habitat and populations of the Covered Species inhabiting Green Diamond's properties prompted development of the conservation strategy described in Section 5.

C.2 NSO STUDIES AND MONITORING

The complete compilation, analyses, summaries and conclusions of all NSO surveys and monitoring from 1990-2006 are in the Northern Spotted Owl Habitat Conservation Plan (HCP), Ten-Year Review Report (Ten-Year Review), completed and submitted to the US Fish and Wildlife Service (USFWS) in 2010 (Section C.2). This review of the original NSO HCP was mandated to evaluate the overall workings of the HCP and the fundamental biological premise on which the conservation strategy was based. The Ten-Year Review evaluated the take amount and impact, provided new definitions of foraging and nesting habitat, reviewed previous research about NSO biology and its primary prey and provided an assessment of the long-term viability of Plan Area NSO. This report represents possibly the most comprehensive review ever conducted of any NSO population, based on the single largest NSO dataset in existence. The Ten-Year Review provided the fundamental premise for the NSO conservation program in Section 5 of the FHCP and included future projections of NSO habitat that will be the basis for determining the success of the FHCP. The following is a complete copy of the 232-page Ten-Year Review followed by an 11-page Addendum A of future habitat projections for NSO and fisher.

Green Diamond Resource Company

Northern Spotted Owl Habitat Conservation Plan

Ten-Year Review Report

April 7, 2010

The data analysis and writing that went into the development of this report were the compilation of the efforts of Green Diamond's biological staff, US Fish and Wildlife Service, Arcata Field Office staff and several private consultants. Listed below are the primary contributors to this report.

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The following report is based on a review of Green Diamond Resource (formerly Simpson Timber) Company's Northern Spotted Owl Habitat Conservation Plan (HCP) that was approved in September 1992. This review was done to satisfy a requirement in the original HCP, which specified "that a comprehensive review of the HCP and permit conditions be conducted at the end of the first 10 years." The following five objectives listed in the 1992 HCP were designed to guide the Ten-Year Review:

- *A comparison of actual and estimated levels of owl displacement;*
- *A comparison of actual and estimated distribution of owl habitat;*
- *A reevaluation of the biological basis for the conservation strategy based on the data collected through the research program and other sources;*
- *A detailed analysis of efficacy of and continued need for the set-asides and of the long-term viability of the owl population on Simpson's property; and*
- *An estimate of annual owl displacement for the remainder of the permit period.*

Although some of these objectives were not very specific, the intent of this Ten-Year Review was to evaluate the overall workings of the HCP and the fundamental biological premise on which the conservation strategy was based. At the time when the 1992 HCP was approved, the prevailing biological opinion was that a system of strategically placed late seral/old growth reserves was the most appropriate conservation strategy for spotted owls (Thomas et al. 1990, USFWS 1992 and 2008 and USDA 1994). In contrast, this HCP was based on the fundamental premise that spotted owl habitat could be regenerated at a rate equal to or greater than it was lost due to timber harvest. Given the rather dramatic departure from the preponderance of scientific knowledge on Northern Spotted Owls at the time, the US Fish and Wildlife Service (FWS) approved the plan contingent on a major review of the plan after 10 years. In September 2002, Green Diamond (GD) and the FWS initiated a series of meetings to develop a strategy for completing this review. Due to the amount of data that had been collected by GD and the advancement of the science on spotted owls since the HCP was signed, these meetings laid out a very ambitious set of highly complex and sophisticated analyses. Given the time that was required to complete some of these analyses, much of the data summarized in this report were collected from 1990-2006 by Green Diamond's biological staff and a variety of university directed graduate studies.

Executive Summary of the Major Findings

Chapter 1:

Green Diamond's (GD) incidental take permit allowed for a maximum of 50 Northern Spotted Owl pairs to be "displaced" (a "take" based on habitat modification that resulted in abandonment of their site or disruption of the owl's normal behavior) in the first 10 years of the HCP. Timber harvest triggered reporting of 63 displacements from1992-2002, but 20 of the displacements met the criteria to be "returned" (based on continued occupancy or normal nesting behavior) by 2002. For the entire time since implementation of the HCP (1992-2008), timber harvest triggered reporting of 75 displacements with 45 being judged to have resulted in an actual take. Displacements triggered by harvesting within 152.4 m of the core of an owl site (nest or primary activity center) tended to cause fewer actual takes (34.5%) than displacements caused by harvesting outside the core (52.9%). In particular, harvesting near or within the nest stand appeared to have less impact on spotted owls compared to the cumulative effect of harvesting in the areas outside the nest center that might be the primary areas for foraging

Timber harvesting that triggered displacements primarily resulted in the take of spotted owls by causing site abandonment. However, other factors also contributed to site abandonment since review of the occupancy data indicated that 33 of 50 sites abandoned (66%) had no timber harvest within 0.5 miles. To better understand this phenomenon, we investigated the primary proximate factors that were associated with spotted owl site abandonment. The results of the top model from this abandonment analysis indicated that abandonment was lowest when a 405 ha (1000 acre) buffer around spotted owl sites was composed of small patches and approximately 50% of the stands were in the 41-60 year old age class. This 41-60 year old age class was the primary older age class in which timber harvesting occurred on GD's ownership, so apparently abandonment was lowest when timber harvesting had created small patches of approximately equal amounts of younger and older forests.

Chapter 2:

A major premise of GD's HCP was that habitat suitable for spotted owls would increase throughout the 30-year period of the plan. The original HCP defined suitable habitat as forest stands of a specific age (>30 years old = foraging habitat and >45 years = roosting and nesting habitat), but data were not available to develop the spatial patterns of forest stands in the landscape used by spotted owls. Based on the original habitat definition, owl habitat increased 38% from 1992 to 2002, but this was based on a simplistic definition of spotted owl habitat that needed to be revised. Determining what habitat spotted owls used during their period of nocturnal activity was the first step in developing a more comprehensive and sophisticated model of owl habitat. To gather data on what habitat spotted owls used at night, we conducted a radio telemetry study from 1998-2000 that included 28 total owls that were followed all or a portion of that time. The resulting data was used to construct 95% kernel distributions based on what owls used versus a random selection of available points within the same area. These data were used to develop a resource selection function for spotted owl nighttime activity. The top model indicated that owls tended to be found low on the slope in areas composed of approximately 70% age class 41+ years with a high percentage of hardwood. Furthermore, selection was highest if the nearest stand to the owl's location was either 6-20 or 21-40 years, and lower if the nearest stand was either 0-5 or 41+ years. In other words, at night spotted owls on GD's ownership were most likely to be found in older more complex forest stands that were in close proximity to younger stands (i.e., stands with more potential prey). Using projections of future habitat created by in-growth and harvesting patterns, the "best" nocturnal habitat was projected to increase from 20% in 1992 to 44% of GD's ownership by 2022.

To further refine spotted owl habitat, we conduct a study of the habitat selected for nesting by spotted owls on GD's managed timberlands. Based on the locations of 182 successful nests (fledged at least one young) from 1990-2003, we estimated a resource selection function to characterize the habitat of an "average" successfully nesting spotted owl. The top model for managed timberlands indicated that the relative probability of locating a successful nest increased with age of the stand and open edge density within 600 m of the nest. In addition, selection was greatest in stands with approximately 55% basal area of residual older trees, 30% hardwood basal area and a large amount of good nighttime activity habitat within 400 m. This indicated that for nesting, spotted owls were selecting older more complex stands that were in fairly close proximity to potential foraging areas. Using projections of future habitat created by in-growth and harvesting patterns, the "best" nesting habitat was projected to increase from 20% in 1992 to 54% of GD's ownership by 2022. The "drivers" of these future increases in high quality spotted owl nesting habitat on GD's ownership is primarily related to decreases in clearcut size and large riparian reserves as part of GD's aquatic HCP that will greatly increase habitat heterogeneity in future managed landscapes.

Chapter 3:

This chapter provided an overview of all known studies conducted within GD's ownership or other studies within the range of the Northern Spotted Owl that were relevant to the HCP. In GD's study area, spotted owl diet consisted of a variety of small mammals, birds, reptiles and insects. However, the dusky-footed woodrat dominated the diet comprising approximately 45% of the frequency and 74% of the biomass, but tree voles and flying squirrels were also important in overall composition of the diet. Woodrat studies on GD's ownership in both redwood and Douglas-fir zones indicated that woodrats were in greatest abundance in young stands <40 yrs of age. Use of uneven-aged silviculture techniques such as commercial thinning or selection is not likely to enhance woodrat abundance, because these practices generally encourage the proliferation of unpalatable understory vegetation. Silviculture practices that promote a dense and diverse shrub layer of palatable heliophilic species should promote woodrat abundance. Because woodrats are the primary prey species of spotted owls in northern California, forest management practices that influence woodrat abundance are likely to have the greatest potential to positively influence spotted owl populations relative to any other management practice on commercial timberlands.

Of the numerous studies that have attempted to characterize the habitat associations of Northern Spotted Owls, the seminal study relative to GD's owl population was a study done on the "Willow Creek Study Area" (US Forest Service land) immediately to the east of GD's ownership. Franklin et al. (2000) was the first to model temporal and spatial variation in reproduction and survival of spotted owls with respect to habitat configuration and weather at the landscape scale. Based on the estimated influence of habitat on survival and fecundity, they estimated habitat fitness potential of spotted owl sites. Survival was positively associated with the amount of interior older forest, while reproductive output was negatively associated with the amount of interior older forest and was positively associated with the amount of edge between older forest and other vegetation types. There appeared to be a trade-off between the benefits to survival conferred by interior older forest and benefits to reproduction conferred by less interior older forest and more convoluted edge between the two habitat categories. Thus, the highest habitat fitness potential for owl sites was conferred by having approximately an equal mixture of older and other forest types (i.e., high habitat heterogeneity). In addition, owls in territories of higher habitat quality had greater survival during inclement weather than those in poorer quality habitat." Two other studies Olson et al. 2004, and Dugger et al. 2005) generally followed the methods of Franklin et al. (2000) for Northern Spotted Owls in the Oregon Coast Range and Oregon Cascades (respectively). In general terms, Olson et al. (2004) obtained results consistent with Franklin et al. (2000) (i.e., habitat heterogeneity had a positive influence), while Dugger et al. (2005) did not (i.e., survival and reproduction were positively associated with the amount of old growth forest within the owl's home range core).

An in-house study on GD's ownership was conducted in 1999 to investigate the key specific habitat elements utilized at night by spotted owls in a managed landscape. The unique aspect of this study was that it involved direct observations of spotted owls while they were active at night. We obtained visual observations for 18 of the 22 spotted owl fitted with radio transmitters, which demonstrated that the owls were a sit-and-wait predator that foraged by flying from perch-to-perch in search of prey. Mean perch time for both sexes while foraging was approximately 16 minutes, but males tended to spend less time per foraging perch than females. Our data indicated that spotted owls captured prey at few (11%) of their hunting perches and that few (14%) of their attempts to capture prey were successful. Mean perch height was approximately 5 m, which suggested that spotted owls in our study area were foraging primarily on the ground and understory. The observation was consistent with preying on dusky-footed woodrats, which primarily nest on the ground. Despite the biases associated with determining an owl's location by either visual observations or triangulation, it was apparent that spotted owls tended to spend the greatest time in older stands (>40 yrs) during their period of activity at night. Stands 10-20 yrs also received high use, and although not a high proportion (7.7% triangulation and 16.9% visual) of all the locations, spotted owls used recent clearcuts (0-4 yrs) more than we anticipated based on other studies. In addition, the foraging in recent clearcuts was not an aberrant behavior of just a few of the birds being monitored since 13 of 22 birds were recorded in these open areas on at least one occasion.

Relative to the regional environment in 1992 when GD's HCP was approved, a new major threat to the spotted owl has emerged. Barred owls, a congener to the spotted owl, invaded from the east coast and initially colonized more northerly areas in the Northwest. Barred owls have rapidly expanded southward and in the last decade their numbers have begun to increase on GD's ownership. Barred owls have been detected incidental to spotted owl surveys, so even though the absolute number of barred owl sites was suspect, it is apparent that the number of sites has increased in recent years.

Chapter 4:

Mark-recapture studies were initiated throughout GD's ownership in 1990 to estimate key demographic parameters and trends in the population. Along with other range-wide demographic studies of Northern Spotted Owls, GD participated in three previous meta-analyses in 1998, 2004 and 2009. Results from the most recent meta-analysis that analyzed GD data from 1990-2008 indicated that mean apparent survival probabilities of adult spotted owls on GD land were 0.851 and 0.853 for males and females, respectively. These estimates were similar to adult survival estimates from the nearby Willow Creek and Hoopa study areas and there was evidence that all three areas showed a decline in survival. Estimated mean annual fecundity for adult spotted owls on GD land was 0.305, which was similar to the estimate from Willow Creek and higher than the estimate from Hoopa. However, there was evidence for a declining trend in fecundity for GD and Willow Creek, but Hoopa showed a stable trend. Estimated rate of spotted owl population change (λ_{RJS}) on GD land was 0.972, similar but slightly lower than the two nearby study areas. There was evidence of a statistically significant decline for GD and Willow Creek, but not for Hoopa. The trend in estimates of the realized population change indicated that the population of spotted owls on the GD study area was apparently stable or increasing until 2000 when the population began an apparent downward trend. The barred owl covariate entered the top model for both survival and fecundity, which suggested that barred owls were the most likely cause for the recent decline of spotted owls on GD's study area. Potentially, this downward trend has been reversed during the 2009 field season, when pilot work doing limited barred owl removal, modifications of the survey protocol to increase spotted owl detection rates and newly colonized owl sites led to a 26.6% increase in the number of occupied owl sites on GD's study area.

To investigate the effects of take on survival, we did a post hoc analysis in which we constructed a "take" covariate (owls at a take site at some time during the study versus those not taken) from the capture histories we used in the 2009 meta-analysis and fitted it into the top survival model resulting from analysis conducted as part of the meta-analysis. The results indicate that take did not have a statistically significant effect on survival and the effect of take was estimated to change survival of adults by only 0.11%. We conducted a similar analysis by fitting the take covariate into the top fecundity analysis for the meta-analysis. Inclusion of take lowered fecundity of adult females associated with take sites by 15.2%. Finally, lambda was estimated using survival and fecundity values both with and without take. When take was included, lambda decreased by 1.4% and this drop was almost entirely attributable to the reduction in fecundity of birds associated with a take. We interpret this reduction to mean that lambda would have been approximately 1.4% higher if take sites had not been present.

An identical type of post hoc analysis was conducted with a "set-aside" covariate (owls in or associated with a set-aside versus those away from set-asides). The effect of the set-aside covariate was slightly negative (survival of birds associated with set-asides was slightly lower than that of other birds), but it was not statistically significant. Both the fecundity and lambda analyses showed no difference between set-aside versus non-set-aside owls. From this particular analysis, there was no evidence that demographic parameters were influenced by an owl being associated with a set-aside.

GD's long term demographic study within the context of an approved HCP that allowed take provided a unique opportunity to assess the impacts of timber harvesting on spotted owls. Furthermore, the combination of geographically referenced and relatively detailed forest stand information on all parts of GD's ownership made it possible for us to directly relate habitat characteristics with survival and fecundity to estimate habitat fitness for spotted owls. We utilized capture-resight data from 1990-2003 to estimate survival, while fecundity was estimated from nesting information over the same time frame. Finally, we estimated habitat fitness as a function of average survival and fecundity at a location through a site-specific projection matrix.

The top survival model estimated negative effects on survival for increased days of precipitation during the early nesting and for locations > ½ mile from a designated set-aside (relative to locations inside a set-aside). Positive effects on survival were associated with increased temperatures during early nesting, increased nest site selection values and for locations near (< ½ mile) to a set-aside (relative to locations inside a set-aside). The top fecundity model estimated negative effects on fecundity for locations inside a set-aside, sites where take had occurred and for increased precipitation in the early nesting season. Positive effects were estimated for locations < ½ mile from a set-aside (relative to locations outside a set-aside), even number years, adult females relative to S2 females, natural log of the percent of 41-60 old stands in a 600 m radius buffer, natural log of the percent of 21-40 year old stands in a 600-921 m annulus, average nighttime activity selection values in a 600 m radius buffer and average open edge density in a 600 m buffer.

From the average survival and fecundity at a specific location, the growth rate or largest Eigenvalue of the Leslie projection matrix was computed and defined to be the habitat fitness of the site. Relative to other categorical variables, habitat fitness was most sensitive to the location of the nest site/activity center relative to a set-aside. Habitat fitness values were highest in the ½ mile buffer surrounding a set-aside with all other covariates being realistically equal. While considerably lower relative to the magnitude of the effect, sites that went from non-take to take were the second most important categorical variable relative to habitat fitness. Relative to continuous variables, habitat fitness was most sensitive to changes in precipitation during the early nesting period such that increases in the total number of days of measurable precipitation within the early nesting period caused habitat fitness to decline. The second most important continuous variable was open edge density, where increases in this variable resulted in higher values of habitat fitness. Relative to latent variables, habitat fitness was most sensitive to changes in survival followed by changes in fecundity and nesting habitat.

Following modeling of survival, fecundity, and habitat fitness potential on GD's current study area, we investigated the trend in future habitat with the landscape in 1992 (year the HCP was approved) as the baseline. Using projections of future landscapes that will result from timber harvest and re-growth of harvested stands, we predicted the proportion of GD's future ownership that will fall within various habitat categories. The total area in the best survival, fecundity and habitat fitness potential class, which were all set at 20% in 1992, increased to 37, 57 and 45%, respectively, of GD's study area by 2022. Since non-habitat variables (e.g., weather and take) and set-asides were set at constant median values throughout the future projections, they did not contribute to the changes. Based on the sensitivity analysis, the habitat variable that likely contributed the most to the trend was open edge density. The proportion of older stands (41-60 yrs) adjacent to younger stands (6-20 and 21-40 yrs) would have also contributed to the trend. Riparian and geologic reserves mandated by GD's aquatic HCP will create a future landscape in which an estimated 20% or more of the landscape will be in some type of protected reserve. Along with smaller clearcuts, the net affect will be much greater overall open edge density and a higher overall level of habitat heterogeneity, which appears to be highly beneficial to spotted owls in GD's ownership.

Chapter 5:
During preparation of the 10-year review in 2002, the FWS and GD agreed that additional data collection would enhance the scientific quality of the comprehensive review. In addition, the permitted level of take (50 pairs) was less than anticipated for the first ten years of plan implementation. The FWS extended the time for the comprehensive review and the time frame for the original 50 permitted takes. In 2006, GD submitted phase one of the comprehensive review, and as a result of that analysis and review, GD proposed amendments to the HCP and ITP. In 2007, the FWS approved the first amendment to the HCP permitting take of up to 58 pairs of owls until 2012 when the updated Comprehensive Review would occur. The additional takes through 2012 would allow the company to continue its sustained yield harvest activities, implement initial research on northern spotted owl and barred owl interactions and report the results to the FWS as part of the Comprehensive Review update in plan year twenty.

Conclusions:

The level of take permitted by the HCP apparently did not have a detrimental effect on GD's population of spotted owls for the first approximately eight years of the Plan, but in recent years it may have exacerbated a region-wide spotted owl decline. The only hypothesis for the decline with any analytical support was the increase in barred owls on GD's ownership. The positive response of spotted owls to set-asides suggested that some type of a stable core area was important to spotted owls. All measures of spotted owl habitat were projected to show a substantial increase in the future, which appears to be driven primarily by increases in habitat heterogeneity. However, increases in habitat will likely not have any positive influence on the spotted owl population in the absence of some form of barred owl management.

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CHAPTER 1 – SPOTTED OWL DISPLACEMENT

This chapter is based on the requirement for "a comparison of actual and estimated levels of owl displacement."

1. A. COMPARISON OF ACTUAL AND ESTIMATED LEVELS OF SPOTTED OWL DISPLACEMENT

Green Diamond's (GD) incidental take permit covers all take of spotted owls incidental to timber harvest operations. However, the primary form of incidental take anticipated in the HCP was the displacement of owls due to modification of owl habitat. The quantification of owl habitat modification was done within a 0.5 mile radius centered on an "owl site." The HCP described owl sites as "areas with nest sites and primary activity centers." The definition of an owl site was further refined in GD's annual report to the FWS as "the area within a five hundred-foot radius of the activity center for a single owl or activity center/nest site of a pair of owls. Temporary roosts of floater owls do not constitute owl sites." Therefore, we use the term "owl site" to represent an area at the core of a spotted owl's territory and home range where the resident owls commonly roost and/or nest. However, an "owl site" is also used as a point to center a 0.5 mile radius circle when quantifying habitat relative to potential take. The most recent nest tree, or lacking a nest tree, the most commonly used roost tree was the point around which habitat was quantified.

It was recognized that such displacement could impair essential behavioral patterns and result in actual death or injury to owls. Rather than examining the circumstances of each case to determine whether a take (as defined under the Endangered Species Act) had in fact resulted from GD's habitat modification, the implementation agreement calls for reporting as a "displacement" any instance in which an owl site is harvested or habitat around an owl site is reduced below thresholds established in the HCP. This approach provides for an ongoing evaluation of the suitability of owl habitat at sites where displacements are reported as a result of timber harvesting.

The total number of displacements reported under this system is significant because: 1) it provides guidance on GD's compliance with the formal permit limit on incidental taking (an estimated 50 owl pairs during the first ten-years of the permit's 30-year term) and, 2) it would have triggered a five-year plan review if more than 33 displacements had been reported within the first five years of the permit period.

During the 1995 reporting period, GD and the US Fish and Wildlife Service (FWS) agreed upon a system for displacement accounting. With this system, owl sites in which harvesting occurred were 1) reported and added to the displacement total when timber harvest triggered the criteria for direct or indirect displacement, 2) evaluated subsequently to the harvest that triggered the report of displacement, and, 3) removed from the displacement total if the site met specified post-harvest criteria for owl occupancy and reproduction. The proposed criteria for removing sites from the displacement tally were presented to the FWS in the 1996 annual report and are described below (see "Removal of displacements"). The level of take was estimated to occur during the first 10 years of operations under the 30-year term. Because take has occurred at a lower rate than estimated, the Service extended the take period to September 16th, 2008 or 16 years.

Definitions

GD and the FWS agreed upon the following definitions to use when determining displacement:

Owl site: the area within a 152.4 m (500 ft) radius (= 7.3 ha or 18 acres) of the activity center of a single owl or activity center/nest site of a pair of owls. Temporary roosts of floater owls do not constitute owl sites. Pair status is determined by 1992 USFWS guidelines, except that single status must be determined from at least three site visits.

Perennial owl site: an owl site established for at least two consecutive field seasons.

Newly colonized owl site: a new owl site found in an area that was surveyed in a previous field season and unoccupied by spotted owls.

Newly discovered owl site: a new owl site found in an area not surveyed for owls in a previous field season.

Nest site: a tree in which a pair of spotted owls has nested.

Activity center: When a nest site is not known, the activity center is the location (point on the landscape) most frequently used as a daytime roost during the breeding season. A minimum of three daytime observations is usually needed to establish an activity center. Establishing the central location of an activity center is primarily a biologist's judgment call based on evidence found and evaluated in the field. It may be a primary roost site identified by the consistent presence of owls or whitewash and pellets, or the geometric center of several roosts where owls or owl sign have been detected. In the latter case, the activity center must be located in suitable habitat. Activity centers may be established based on nighttime responses if they are consistently heard in the same area.

Owl home range: areas predominantly used by territorial owls. Home ranges will be determined using the known locations of individual owls, the spatial distribution of all owls in the area of concern, and major topographic features.

Floater owl(s): an owl found sporadically in an area, but not showing sufficient site fidelity to establish an activity center according to the criteria described below (see "designation of activity centers for new responses").

Direct displacement: timber harvesting within an owl site (within a 152 m radius of the site center). Such harvesting is assumed to cause a displacement of spotted owls and therefore triggers a report, whether or not the location of spotted owls in the site actually changes. In most cases, a direct displacement of a single owl occupying a site is considered to be the same as a direct displacement of an owl pair. The accounting of direct displacement for sites perennially occupied by single spotted owls is addressed by including site occupancy (by a single or pair of owls) in the criteria for removal of displacements (see below).

Indirect displacement: timber harvesting that reduces spotted owl habitat within the 203 ha (502 acre) circle around an owl activity center below the following thresholds: :

- 36 ha (89 acres) of stands ≥ 46 years old , and
- 94 ha (233) acres of stands ≥31 years old.

Such harvesting is assumed to cause a displacement of spotted owls and therefore triggers a report, whether or not the location of spotted owls in the site actually changes. In most cases, a direct displacement of a single owl occupying a site is considered to be the same as a direct displacement of an owl pair.

Permanence of owl sites: Only the most current owl site within a home range is considered for evaluation of displacement. The current owl site shall be defined based upon the most recent nest site found in the last three years. If spotted owls have not nested in an established home range in the past three years, the most recent activity center shall be used to define the current owl site.

If no owls are detected in a home range after conducting HCP surveys in a given year the following scenarios apply:

- If in the previous year the owl site was either
  newly colonized by a pair that nested,
  perennial, or
  newly discovered,
  the owl site shall be maintained for three subsequent breeding seasons. If after three breeding seasons no occupied sites are found within a home range, past owl sites within that home range will no longer be considered for potential displacement.

- If in the previous year the owl site was established as a newly colonized site in which owls did not nest, the owl site shall be maintained for one breeding season. If the site is found to be unoccupied by owls in the following breeding season, then the site will no longer be considered for potential displacement.

Designation of activity centers for new responses: For owl responses detected during the breeding season in areas where an owl site has not been previously designated, an activity center will be designated if either an owl pair is detected at least two times in the same area for at least one month, a single owl is detected in the same area for at least two months, or an owl detection was not followed-up adequately using the standards described below.

Owl detections will not lead to the designation of an activity center if three adequate, HCP-protocol site visits, at least five days apart, all result in no owls being found within 30 (pair) or 60 (single owl) days of the initial response. If the initial response occurs in March, then at least one of the three site visits shall be completed in April.

Late breeding season detections: Owls initially detected in August will not be used to designate an owl site in areas where no owls were detected earlier in the breeding season of the same year, when the required number or survey visits and follow-ups can not be completed. In addition, the area will not be cleared for timber harvest until after surveys are conducted in the subsequent breeding season. If the required number of night surveys and follow-up visits are conducted before the end of the breeding season and no owls are detected, the area will be cleared for harvest.

Special displacement circumstances: A direct displacement will not be reported if owls establish an owl site during the breeding season within 152 m of an area where timber falling has already been completed. If owls establish an activity center during the breeding season within 152 m of an active timber harvest unit where timber falling has not been completed, timber harvest will be suspended until the appropriate HCP measures (Sections III.A.1.(a) (3) and III.A.1.(a) (4) of the Implementation Agreement) have been taken to determine reproductive status and protect nesting owls. If harvesting is not suspended until appropriate HCP measures occur, a direct displacement will be reported.

If GD resumes timber harvesting after complying with the HCP measures, the following shall apply:

- if less than 4 ha (10 acres) remain to be felled, a direct displacement will not be reported
- if more than 4 ha remain, GD will consult with the Service to determine whether a displacement will be reported.

Indirect displacements are assessed and reported based on the location of all known owl sites at the time that falling is initiated. Any subsequent movements of owl sites during the falling and harvesting period are not assessed for potential indirect displacement. If any other situation arises in which the determination of whether to report a displacement is questionable, the Service will be consulted to resolve the determination.

Removal of displacements

Each direct and indirect displacement is originally reported on the basis of harvest activity in relation to an owl site within a particular home range. Displacement associated with a particular owl site in a home range can occur only once, but individual owls can be displaced more than once if they occupy successive owl sites in different home ranges where harvesting triggers a report of displacement.

Removing previously reported displacements from the cumulative total will be based on the post-harvest performance of owls within the home range in which harvesting triggered the original report of displacement. The proposed performance criteria are based upon occupancy and/or reproduction of any owls at a site; i.e., different owls occupying a site will be judged as if the same individual owls continuously occupied and reproduced at the site. Including occupancy in the criteria allows sites perennially occupied by single owls to be evaluated for removal from the displacement total. Owl performance within a home range where a displacement has been reported may be evaluated in a subsequent annual report to determine whether the displacement will be removed. This evaluation can occur beginning at the third and ending at the fifth breeding season following a displacement. The criteria for removing displacements from the total are as follows.

Displacement is removed in the third breeding season following the triggering of displacement if
owls nest in at least 2 years, or
owls nest in one year, with 3 years occupancy (including occupancy by single owls).

Displacement is removed in the fourth breeding season following the triggering of displacement if
owls nest in at least 2 years, or
owl(s) occupy the site for four years

Displacement is removed in the fifth breeding season following the triggering of displacement if
owl(s) occupy the site four out of five years.

If cumulative harvest occurs in a home range, the displacement removal assessment will occur between the third and fifth breeding seasons after the last harvest under a Timber Harvest Plan (THP) within the home range that triggered the report of displacement. If the owl site shifts to a new location where harvest occurs within 805 m (0.5 mile) but does not cause displacement, the last year in which harvesting triggered a report of displacement will be the starting point for evaluation of displacement removal within the five-year period. If five breeding seasons have passed since the displacement was triggered and the owls still have not met the displacement removal criteria, the original displacement will not be removed from the total.

Implementation

If a timber harvest plan was determined to require a report of direct or indirect displacement, the report was triggered when the plan was initiated, i.e. when the first tree in a THP unit was felled. This pertained to THPs that were contiguous as well as those comprised of units spaced closely together. If a THP was comprised of several units spaced widely apart, harvest progress was monitored to determine when the displacement would be reported. As indicated in the 1994 annual report, the Service agreed that timber harvest activities could continue in THPs triggering displacement during the owl breeding season as long as no spotted owl nest was found. If a nest was found, the site was protected by measures described in HCP Section II.A.1

To determine the owl(s)' response to the harvest, we monitored all owls occupying sites in which timber harvesting triggered a report of direct displacement. Harvest contractors were informed that spotted owls were in the area, and any owl behavior observed during falling operations was noted. We also conducted post harvest owl surveys as conditions allowed. If possible, the owls associated with direct displacement THPs were located before slash burning was conducted.

Each THP initiated within the reporting period that had an owl site within 805 m of the plan was evaluated for indirect displacement by using the process described in HCP Section IV.B.2. This involved estimating the amount of habitat within the 805 m radius circle around each owl site using GD's GIS and aerial photographs. If the entire 203 ha circle was not on GD land, aerial photographs were used to determine the age class or habitat category of areas outside of the ownership, because GD's GIS does not include data from other ownerships.

Results

GD's incidental take permit allowed for a maximum of 50 owl pairs to be displaced in the first 10 years of the HCP. During those first 10 years (1992-2002), timber harvest triggered reporting of 63 displacements (39 direct and 24 indirect) of spotted owls. Twenty displacements met the criteria to be "returned" by 2002, yielding 43 net displacements during the first 10 years of the Habitat Conservation Plan (Table 1.1). For the entire time since implementation of the Habitat Conservation Plan (1992-2008), timber harvest triggered reporting of 75 displacements (48 direct and 27 indirect). Thirty displacements met the criteria to be "returned" through 2008, yielding 45 net displacements (Table 1.1).

Although displacements initially were characterized by triggering the criteria for a direct or indirect displacement, subsequent harvesting in the area sometimes resulted in both types of displacements being triggered. A higher proportion (65.5%) of the direct displacements met the criteria to be "returned" than either indirect or combined direct and indirect (both) displacements (Table 1.2). However, a Chi-square analysis of the number of displacements, excluding those not yet meeting the criteria for completing the assessment of displacement (i.e. more time required), was not significant (Chi-square = 4.188, d.f. = 2, P = 0.123). The thirty displacements that were returned had an average of 236.5 acres of habitat within 0.5 miles post-harvest.

Table 1.1. Spotted owls displaced through timber harvest on Green Diamond lands, by territory, since implementation of the Habitat Conservation Plan. Bold (blue) font indicates direct displacement and standard (red) font indicates indirect displacement. Underscoring indicates territories that met the criteria for displacement returns and territories followed by an asterisk have not met the criteria (i.e. more time required) for completing the assessment of displacement. Displacements were tallied from 1 September of the previous year through 1 September of the indicated year.

Reporting Year	Spotted Owl Sites											Cumulative Displacements	Cumulative Returns	Net Displacements
1993	**Pelletreau**	5700	Dolf Cr*	**Liscom Hill**	H510*	**Buzzard Cr**	**H300***					7		
1994	**Boundary Cr**	C2300*	**B140***	**P200***	**Tectah Mouth**	W100						13		
1995	**R200**	Quarry Cr	W400*	Johnson Cr								17		
1996	**B-10**	**H110***	**Miñon Cr***	D100*								21	2	19
1997	**Omagar Cr***	**Cappell Cr**	**S-12***	**Morek Cr**	Dolly Varden	Lower Dry Cr	**Lake Mtn**	**4230 #1**	**Powerline North**	**NF 1300**	**Ayres Cabin***	32	4	28
1998	**R1400**	T300*	**Salmon Cr #2**	Old 299 #2	Fielder Cr*							37	6	31
1999	A400*	**6400**	**Klamath Mill**	**Salmon Cr East**	Upper S.F. #2*							42	8	34
2000	**Bear Gulch***	Boundary Cr*	**Cuddeback South.**	Little River #1	Upper Little R.	Upper S. F. #1	**Walsh**					49	13	36
2001	**G400**	Henderson Gulch	**Lower Dolf Cr**	**Lower S.F. #1***	**NF1300**	Ryan Cr						55	17	38
2002	R13*	**M-Line Cr**	Little River #2	**HWY 101**	**Jackson Hill**	**Lower S.F. #2**	**Mule Cr**	**Quarry Cr**				63	20	43
2003	R-8-1											64	20	44
2004	**Upper Beach Cr**	**Salmon Cr East**	**Klamath Mill**									67	23	44
2005	**Upper Stevens**	**M1150**										69	25	44
2006	**R15**											70	26	44
2007	**Mynot School**	**Middle Salmon Creek**										72	28	44
2008	Puter Creek	**Panther Creek**	HWY 101									75	30	45

Table 1.2. Summary of displacements based on the criteria that triggered the displacement and the subsequent follow-up assessment.

Take Type	Follow-up Assessment					
	Displacements returned (%)	Acres of Habitat $\bar{x}$ (SE)	Not Returned (%)	Acres of Habitat $\bar{x}$ (SE)	Incomplete assessment*	Total
Direct	19(65.5)	264.6(24.3)	10 (34.5)	182.2(37.5)	5	34
Indirect	8 (47.1)	204.5(18.1)	9 (52.9)	153.2(13.9)	7	24
Both	3 (30.0)	205.8(26.6)	7 (70.0)	139.7(36.4)	7	17
Total	30 (53.6)	236.5(15.2)	26 (46.4)	158.5(16.1)	19	75

* There has been insufficient time to fully assess these sites for occupancy and reproduction following the criteria that was established in the 1996 annual report.

Discussion

A five-year review of the HCP was not invoked, because the number of displacements did not exceed the threshold (33 displacements) specified in the HCP and Implementation agreement. In addition, there were no known instances of direct harm or injury to spotted owls as a result of timber harvest operations. The number of displacements projected in the HCP over a 10-year period was three sites per year via direct modification of the nest or roost area and two sites per year via indirect displacement where habitat within the 203 ha circle was reduced below threshold levels. The actual number of displacements (43) over the 10 year period was lower than the estimated number of displacements based on harvesting model forecasts and known owl sites in 1992. Since take authorization continued for the seven "unused displacements" (50-43 = 7), timber harvesting has continued to trigger displacements with a total of 45 displacements recorded as of 2008.

The criteria for establishing whether or not a displacement actually occurred were based on a combination of occupancy (or its inverse, abandonment) and reproductive performance. Timber harvesting that exceeded the HCP threshold for direct displacements resulted in reduced occupancy or fecundity in 34.5% (10 of 29) of the cases observed. In contrast, 59.3% (16 of 27) of the cases where timber harvesting exceeded the HCP threshold for indirect take (or both thresholds at the same time) resulted in reduced occupancy or fecundity. While not statistically significant probably because of the small sample size, this suggested that there was a potential biological difference in how spotted owls responded to different forms of habitat disturbance. In particular, the pattern reported here suggested that harvesting near or within the nest stand had less impact on the owls compared to the cumulative effect of harvesting in the areas outside the nest center that might be the primary areas for foraging. However, combined, these results also indicated that the majority of spotted owls assessed (30 of 56, or 53.6%) did not show a negative response in occupancy or fecundity to adjacent timber harvest. The amount of post-harvest habitat at returned sites (236.5 acres) was very close to the threshold initially developed in the HCP for indirect displacements (233 acres). The factors influencing abandonment and reproduction (fecundity) are further explored in Sections 1.B and 4.B.2 below.

1. B. FACTORS INFLUENCING ABANDONMENT OF NORTHERN SPOTTED OWL SITES

As described above, "direct take" of an owl was defined as timber harvest within 500 feet of the nest location, and "indirect take" occurred when harvest within half a mile of the nest or activity center reduced forest habitat below a set of predetermined threshold acreages listed in the section above. As defined under the federal Endangered Species Act, "take" was presumed to occur when habitat fell below predetermined thresholds, which would result in displacement of an owl from its nest site or activity center. However, it was recognized that owls may abandon sites, either temporarily or permanently, due to harvest effects that were not quantified by the legal definition of "take", or for reasons that were totally unrelated to timber harvest near their nests. Conversely, owls were known to persist and reproduce at sites that exceeded the thresholds where "take" was expected to occur.

This chapter investigates the factors influencing owl site abandonment to better understand the primary proximate factors that led to abandonment. Using logistic regression analysis, we related probability of nest site or activity center abandonment to a suite of habitat characteristics at different spatial scales including those directly related to timber harvest.

Methods

1.1 Field Methods

The study area for analysis of site abandonment was a subset of all GD lands consisting of approximately 87,000 ha (216,000 acres) (see Fig 2.1 in Section 2.B.1). All areas with relatively similar physiographic characteristics and management history were included in the study, while areas with fundamentally different habitats (e.g., higher elevation, different forest type, or less precipitation) or management histories were excluded.

Each year from 1990-2005, we attempted to locate all individual territorial spotted owls within the study area. Surveys were initiated each year beginning 1 March using protocols initially adapted from Forsman (1983) and further modified to support GD's approved spotted owl habitat conservation plan (GD, unpublished report). Owls were initially located primarily at night using vocal imitations or recordings of their calls. Daytime surveys were used primarily to locate roosts and determine the status of owls at sites where they had been previously located or where nighttime responses had been heard. Once an owl was located, it was typically offered live mice to determine its identity (if previously captured and marked), paired and reproductive status (Forsman 1983). Most nests were initially located by following the male back to the nest where the male would commonly attempt to deliver the mouse to the female. Once a nest was located, it was revisited one or more times after the typical period for fledging (late May through early June) to determine the status of the nesting attempt. A nesting attempt was considered successful if at least one fledgling was determined to have left the nest and the immediate vicinity of the structure supporting the nest.

1.2 Analytical Methods

The data available for analysis included annual evaluations of known owl site status for the period 1990 – 2005, inclusive. Each year, all surveyed owl sites were classified as either *occupied* (represented by a 1 in the data), *unoccupied* (0), or *inadequately investigated* (-1) if it had not been visited the required number of times to determine occupancy status. From these annual data, we constructed a site history matrix comprised of 1's, 0's and -1's to represent the occupancy status of every owl site.

For analysis, an owl site was designated as *perennial* if it was continuously occupied or was unoccupied for no more than two consecutive years. An owl site was defined to be *abandoned* if it was *unoccupied* for three or more successive years (e.g., a site history such as [1 1 1 0 0 0 1 1]. The annual status both preceding and following the occurrence of [1 0 0 0] were immaterial to this analysis and the classification. Note that the '1' in this history fragment represents the last year pre-abandonment. If there were two or more such fragments in the entire history, the earliest occurrence was chosen as the year of abandonment.

To obtain meaningful habitat covariates for an owl site, we designated a year of abandonment for all *abandoned* owl sites and a focus year for *perennial* sites. The habitat covariates for *abandoned* owl sites were based on the last year pre-abandonment. This year was thought to represent conditions most likely to have contributed to abandonment. No corresponding single point in time was considered more representative than others for contributing to perpetuation of *perennial* owl sites. Consequently, *perennial* owl sites were assigned a focus year selected at random from those years when the annual status was *occupied*. Because owl site locations routinely moved a few hundred meters between years, a single representative location was obtained by calculating a median location for both *abandoned* and *perennial* owl sites. Median locations (i.e., the medians of the *x*- and *y*-coordinates calculated separately) were calculated using the locations during the year of abandonment or in the focus year, and the two preceding years. Because annual status in either or both of the two preceding years could have been *inadequately investigated*, anywhere from one to three actual locations could have contributed to the median location.

1.2.1 Covariates

A list of all habitat variables used in the analysis appears in Table 1.3. Habitat covariates for each owl site were obtained from an annually updated GIS maintained by GD and included sixteen "fragmentation" statistics measured on each of 6 circular buffers centered on median locations. "Fragmentation" statistics such as mean patch size, edge density, age of neighboring patch, etc. were calculated to reflect the complex mosaic of habitats created by timber harvest. For example, as timber harvest is first initiated in an area, we would expect, among other things, opening edge density to increase, distance to the nearest edge to decrease and the percentage of a buffer in the 0-5 year old age class to increase. The circular buffer sizes we considered, 200, 300, 400, 500, 750, and 1000 acres, were selected *a priori* to bracket the buffers assumed to be biologically meaningful in previous studies on GD's ownership (Folliard 1993 and Thome 1997). Corresponding radii of these buffers were 0.31 mile (507 m), 0.39 mile (622 m), 0.45 mile (718 m), 0.5 mile (802 m), 0.61 mile (983 m), and 0.7 mile (1135 m). Non-fragmentation statistics were computed from information associated with a stand containing the site's median location. Certain variables were coded as 0-1 indicators (Table 1.3). Since we did not have habitat information off GD property, and because we required accurate habitat covariates in the analysis, we discarded a location if 75% of any buffer was not contained on GD lands.

1.2.2 Estimation and Model Development

Owl site status (either *abandoned* or *perennial*) was related to covariates using logistic regression (Hosmer and Lemeshow 2000). Models were developed in a four stage process using SAS software. First, a set of models with up to five main effects was identified using the best subsets procedure. The second stage entailed modifying the models identified in the first stage, because the best subsets procedure implemented in SAS does not permit categorical variables nor does it provide a convenient mechanism for forcing inclusion of all indicators representing a categorical variable. At this second stage, we modified the list of best subsets model as follows. If any indicator variable quantifying a categorical variable appeared in a model, we added the remaining indicators that quantified the remaining levels of the categorical variable. If any variable was represented on more than one buffer size in a single model, that model was discarded. After these two modification steps, any duplicate models created by the addition of appropriate indicators were discarded.

In the third stage of model development, we fit all models identified in the second stage and ranked those models using Akaike's information criterion corrected for small sample size (AICc). Models were sorted from lowest to highest based on AICc, with the lowest AICc model being considered "best". Finally, in the fourth stage, quadratic effects of continuous variables were added to the top 30 models. This created a set of models that included the 30 main effects models and all possible quadratic effects versions of those models. All models (quadratic and not) were then ranked by AICc.

Results

Of 350 owl sites considered initially, 109 were classified as *unknown* (i.e., owl site status not determined either because the field survey results were ambiguous or there were too few surveys conducted to meet the occupancy protocol), leaving 241 classified as either *abandoned* or *perennial*. Of these unambiguous sites, 114 were eliminated from further consideration because the owl site did not meet the minimum criterion for GD ownership (i.e., one or more buffers had less than 75% of the area within the ownership). Twelve other owl sites were eliminated for various reasons: 5 sites had missing values for several vegetation covariates (e.g., *%_RW*); and, 7 sites were within 250 meters of the property edge, which led to edge effects from the FRAGSTATS moving window process. In the final dataset, 50 owl sites were classified as *abandoned* and 65 owl sites were classified as *perennial*.

The best subsets procedure identified 541 models containing up to 5 main effects at the end of stage 1 of model selection. Following modification at stage 2 and addition of quadratic effects to the top 30 main effects models during stage 4, a set of 316 candidate models for final evaluation was identified. Of these 316, the top 21 models (those with $\Delta AICc \leq 2$) are shown in Table 1.4.

All models within 2 AICc units of the top model contained some form of *mean_patch_size*, either within 750 or 1000 acre buffers. Also, all top models contained some form of the percentage of the stand with trees of either age class *41-60_yrs* or age class *6-20_yrs* or both. The top 4 models contained main effects of *mean_patch_size* and percentage of the stand in age class *41-60_yrs*, plus one or both corresponding quadratic effects. Among the remaining models (ranked 5 – 21), all contain the effect of age class of nearest stand (*nearest_0-5_yrs* to *nearest_>=81_yrs*) and all but one include the effect of distance to nearest road.

The fitted equation for the top model was:

$$\text{logit}(p) = -0.169 + 0.0238(\textit{mean\_patch\_size\_1000}) - 0.0823(\textit{\%\_41-60\_yrs\_1000}) + 0.000766(\textit{\%\_41-60\_yrs\_1000})^2$$

where p is the probability of site abandonment. From this model, p was estimated to increase with *mean_patch_size* (Figs. 1.1 and 1.3) and has a quadratic relationship with *%_41-60_yrs* (Figs. 1.2 – 1.3).

Discussion

It was noted above (Section 1.A) that there may have been a biological difference in how spotted owls responded to different forms of habitat disturbance created by timber harvest. In particular, harvesting near or within the nest stand appeared to have less impact on spotted owls compared to the cumulative effect of harvesting in the areas outside the nest center that might be the primary areas for foraging.. In addition, the data on displacements indicated that the majority of spotted owls assessed (26 of 47, or 55.3%) did not show a negative response in occupancy or fecundity due to adjacent timber harvest. In contrast, review of the data that was used for this abandonment analysis indicated that 33 of 50 sites (66%) were abandoned that had no timber harvest within 0.5 miles. Conversely, 41 of 65 perennial sites (63%) had some level of timber harvest within 0.5 miles. Clearly, there were other factors besides timber harvest that were responsible for site abandonment.

The results of the top model from this abandonment analysis indicated that abandonment was lowest when a 1000 acre buffer around spotted owl sites was composed of small patches and approximately 50% of the stands were in the 41-60 year old age class. This 41-60 year old age class was the primary older age class in which timber harvesting occurred on GD's ownership, so apparently abandonment was lowest when timber harvesting had created small patches of approximately equal amounts of younger and older forests. Franklin et al. (2000) in northern California as well as Olson et al. (2004) in the central coast range of Oregon reported that increasing habitat heterogeneity resulted in increased habitat fitness for spotted owls. (But see Dugger et al. (2005) where habitat heterogeneity was not shown to increase habitat fitness of spotted owls in the south Cascades of Oregon). Although these studies estimated habitat fitness from survival and fecundity and did not specifically address abandonment, it seems likely that in areas where habitat fitness was high, abandonment should have been relatively low. Therefore, we believe our abandonment results provide additional support for the conclusion that increasing habitat heterogeneity provides more favorable habitat conditions for spotted owls in at least some portions of its range.

Table 1.3. Habitat variables (covariates) considered for inclusion in the abandonment logistic regression. Column "Frag" if fragmentation statistic derived from Fragstats. Column "Ind" if the variable was a 0-1 indicator. Column "Buffer" the variable was defined on each of 6 circular buffers (200, 300, 400, 500, 750, and 1000 acres). All non-fragmentation statistics were derived from the stand containing the site's median location.

Covariate	Frag	Ind	Buffer	Description
0-5_yrs	Yes	Yes		age class of stand = 0 to 5 years
6-20_yrs	Yes	Yes		age class of stand = 6 to 20 years
21-40_yrs	Yes	Yes		age class of stand = 21 to 40 years
41-60_yrs	Yes	Yes		age class of stand = 41 to 60 years
61-80_yrs	Yes	Yes		age class of stand = 61 to 80 years
nearest_0-5_yrs	Yes	Yes		age class of nearest stand = 0 to 5 years
nearest_6-20_yrs	Yes	Yes		age class of nearest stand = 6 to 20 years
nearest_21-40_yrs	Yes	Yes		age class of nearest stand = 21 to 40 years
nearest_41-60_yrs	Yes	Yes		age class of nearest stand = 41 to 60 years
nearest_61-80_yrs	Yes	Yes		age class of nearest stand = 61 to 80 years
nearest_>80_yrs	Yes	Yes		age class of nearest stand >= 81 years
%_0-5_yrs	Yes		Yes	percentage aged 0 to 5 years
%_6-20_yrs	Yes		Yes	percentage aged 6 to 20 years
%_21-40_yrs	Yes		Yes	percentage aged 21 to 40 years
%_41-60_yrs	Yes		Yes	percentage aged 41 to 60 years
%_61-80_yrs	Yes		Yes	percentage aged 61 to 80 years
%_>80_yrs	Yes		Yes	percentage aged >= 81 years
%_non-forest	Yes		Yes	percentage in 'Non-Forest'
edge_density	Yes		Yes	edge density (ft/acre) (edge: change in age class)
NTA_HSI	Yes		Yes	average night time activity hsi
interior_hab	Yes		Yes	amount of habitat within a uniform age class (acres)
mean_patch_size	Yes		Yes	mean patch size (acre) (patch: uniform age class)
number_patches	Yes		Yes	number of patches
open_edge_density	Yes		Yes	opening edge density (ft/acre) (open: age < 6 or non-forest)
patch_density	Yes		Yes	patch density (n/100acres)
CV_patch	Yes		Yes	patch size CV (%)
total_edge	Yes		Yes	total edge in circular buffer
dist_to_edge	Yes			distance to nearest edge (ft)
age				age (yrs)
dist_to_road				distance to mainline road (ft)
tree_height				height of trees (ft)
%_HW				% hardwood
%_residual				% residual
%_RW				% redwood
%_WW				% whitewood (e.g., Douglas-fir, grand fir and etc.)
%_WW_RW				% whitewood + % redwood
slope_position				slope position (%); bottom = 0, top of ridge = 1
RW_dominant		Yes		dominant species = redwood (> 50%)
WW_dominant		Yes		dominant species = whitewood (> 50%)

Table 1.4. Top 21 models as ranked by AICc at the end of stage 4 of model selection, out of 316 candidate models. Models not listed had ΔAICc > 2.

Rank	AICc	Model
1	146.890	*mean_patch_size* _1000; *%_41-60_yrs* _1000; *%_41-60_yrs* _1000**%_41-60_yrs _yrs* _1000
2	147.080	*mean_patch_size* _750; *%_41-60_yrs* _1000; *%_41-60_yrs* _1000**%_41-60_yrs* _1000
3	147.402	*mean_patch_size* _1000; *%_41-60_yrs* _1000; *mean_patch_size* _1000* *mean_patch_size* _1000; *%_41-60_yrs* _1000**%_41-60_yrs* _1000
4	148.066	*mean_patch_size* _750; *%_41-60_yrs* _1000; *mean_patch_size* _750* *mean_patch_size* _750; *%_41-60_yrs* _1000**%_41-60_yrs* _1000
5	148.263	*dist_to_road mean;_patch_size* _750; *%_41-60_yrs* _1000; *%_RW; nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs; %_RW *%_RW*
6	148.329	*dist_to_road mean;_patch_size* _750; *%_6-20_yrs* _1000; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
7	148.335	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _1000; *%_RW; nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
8	148.348	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
9	148.393	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _750; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
10	148.455	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _500; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
11	148.574	*mean_patch_size* _750; *%_41-60_yrs* _200; *%_41-60_yrs* _400; *%_41-60_yrs* _750; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
12	148.672	*mean_patch_size* _750; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
13	148.707	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _1000; *%_41-60_yrs* _750; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
14	148.713	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _750; *%_RW; nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs; %_RW *%_RW*
15	148.790	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _750; *%_41-60_yrs* _750; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
16	148.812	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs; mean_patch_size* _750*mps_750
17	148.819	*mean_patch_size* _750; *%_41-60_yrs* _300; *%_41-60_yrs* _400; *%_41-60_yrs* _500; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
18	148.820	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _750; *%_RW; nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
19	148.843	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _400; *%_41-60_yrs* _1000; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
20	148.857	*dist_to_road; mean_patch_size* _750; *%_41-60_yrs* _750; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*
21	148.869	*dist_to_road; mean_patch_size* _750; *%_6-20_yrs* _500; *%_41-60_yrs* _750; *nearest_0-5_yrs; nearest_6-20_yrs; nearest_21-40_yrs; nearest_41-60_yrs; nearest_61-80_yrs; nearest_>80_yrs*

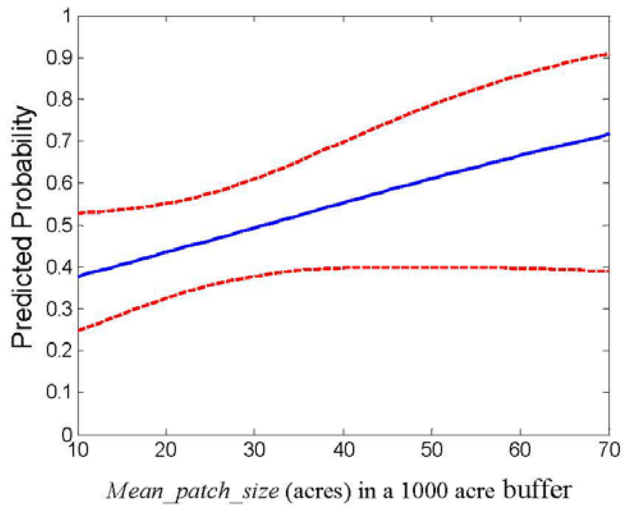


Figure 1.1. Predicted probability of site abandonment as a function of *mean_patch_size* in a 1000 acre buffer (solid blue line) with 95% confidence intervals (red dashed lines) calculated using the top logistic regression model. For this graph, the *%_41-60_yrs* was held at its median value.

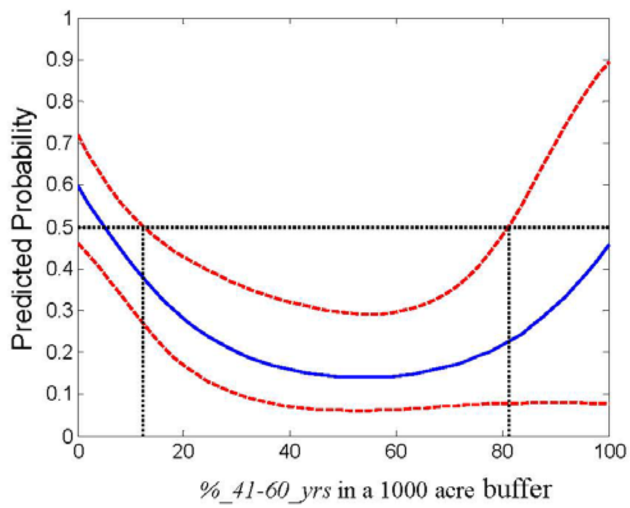


Figure 1.2. Predicted probability of site abandonment as a function of *%_41-60_yrs* in a 1000 acre buffer (solid blue line) with 95% confidence intervals (red dashed lines) calculated using the top logistic regression model. For this graph, mean patch size (mps_1000) was held at its median value. Probability of abandonment was less than 0.5 for *%_41-60_yrs* between 12% and 81% (black vertical dashed lines), based on the upper 95% confidence limits.

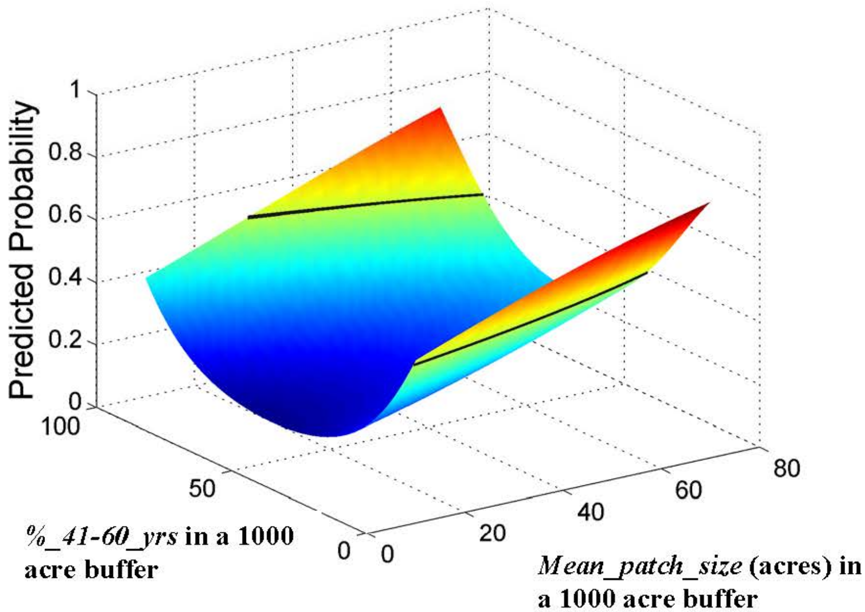


Figure 1.3. Predicted probability of site abandonment as a function of percentage in *%_41-60_yrs and mean_patch_size* in a 1000 acre buffer *%_41-60_yrs* as predicted using the top logistic regression model. Solid black lines represent contours where probability of abandonment = 0.5.

CHAPTER 2 – SPOTTED OWL HABITAT

This chapter is based on the requirement for "a comparison of actual and estimated distribution of owl habitat."

2.A Comparison of the actual versus projected amount and distribution of habitat based on the original Habitat Conservation Plan definition of habitat.

A major premise of Green Diamond's (GD) Northern Spotted Owl Habitat Conservation Plan (HCP) was that habitat suitable for owls would increase throughout the 30-year period of the plan. The HCP defined suitable spotted owl habitat as forest stands >30 years old because at least some stands in this age class were known to be used by spotted owls for foraging, roosting, and nesting (Folliard 1993). At the time, it was assumed that recently regenerated stands (0-5 years) had no direct value to owls. Stands 6-30 years were known to be woodrat habitat (Hamm 1995) and therefore potential spotted owl foraging habitat. Foraging, roosting, and occasional nesting occurred in stands 31-45 years old, and forest stands >45 years old were considered to be prime nesting and roosting habitat as well as foraging habitat.

The distribution of area in each of the forest stand age classes changes through time as stands age and enter older age classes or as stands are harvested and enter younger age classes. In addition, land acquisition and disposal by GD also affects the distribution of stand ages. Re-mapping of stands due to improved timber cruise data was believed to have a negligible effect on the distribution of stand ages.

During development of the HCP, timber harvest and growth modeling predicted that the amount of spotted owl habitat would increase on GD land through 2022. We used GIS to estimate the area of spotted owl habitat between 1992 and 2002 over a common land area for this time period. Based on the original HCP definition, owl habitat increased 38%, from 64,375 ha (159,075 acres) in 1992 to 88,870 ha (219,602 acres) in 2002 (Table 2.1). The largest gain in owl habitat over the ten-year time period resulted from the growth of young stands <30 years of age into the 31-45 year age class. Forest stands also matured into the "prime" nesting habitat category (>46 years); however, this is the age class where timber harvesting occurs so that only a modest increase (~12.5%) in the amount of prime nesting habitat was realized over the same time period.

2.B Development of new definitions of Northern Spotted Owl habitat

There has been extensive research on Northern Spotted Owl habitat requirements over the years. The focus of most of these habitat studies has been to understand the structural characteristics, areal, and spatial requirements of nesting, roosting, and foraging habitat (Forsman et al. 1984, Carey et al. 1990, Solis and Gutiérrez 1990, Ripple et al. 1991, Lehmkuhl and Raphael 1993, Hunter et al. 1995, Buchanan et al. 1995, Zabel et al. 1995). The majority of these studies have been conducted in landscapes with significant amounts of mature or old forests, which are the principal habitat for this species in most areas where it has been studied (Courtney et al. 2004).

One outgrowth of this research has been considerable interest in identifying forest stand treatments and harvesting regimes which can accelerate development of suitable owl habitat in areas that currently lack the necessary structural characteristics (Carey 2003, Franklin et al. 2002 and Irwin et al. 2007). These efforts are complicated by the fact that most current owl habitat required many decades or even centuries to develop (Forsman et al. 1984, Gutiérrez et al. 1984, Solis and Gutiérrez 1990, Bart and Forsman 1992, Carey et al. 1992), and it may take many additional decades before the success of these forest stand treatments can be ascertained. Young landscapes, however, that have been subjected to a variety of past harvesting practices and that are currently occupied by owls provide an opportunity to elucidate the forest stand components and configurations that are critical to the development of suitable spotted owl habitat.

As early as 1990, the coastal region of northern California was recognized as being somewhat unique for spotted owls (Thomas et al. 1990). In this region, spotted owls were known to frequently nest in relatively young managed stands, a phenomenon that does not commonly occur in other parts of the owls range. Several factors contribute to the uniqueness of the habitat in this region. Habitat structure develops more rapidly in the moist coastal region due to the rapid regeneration of redwoods (*Sequoia sempervirens*) and other conifers, but it is the coppice growth from the stumps of a variety of hardwood species (e.g. tanoak, *Lithocarpus* densiflorus, madrone, *Arbutus menziesii*, and California bay, *Umbellularia californica,*) that produces high structural diversity in these managed even-aged stands. The occurrence of dusky-footed woodrats (*Neotoma fuscipes*) also contributes to the habitat quality of the region. Woodrats are found in high abundance in young regenerating stands (Sakai and Noon 1993, Hamm 1995, Hughes 2006) and are the primary prey of spotted owls in this region (Section 3.A.1, below). Since the primary prey occurs in young stands, a certain amount of timber harvesting may benefit owls through increased prey availability (Carey et al. 1992, Carey and Peeler 1995, Franklin et al. 2000 and Olson et al. 2004) It is likely that the rapid development of forest structure and the presence of woodrats both contribute to early development of suitable habitat. In this region, spotted owls can be found occupying landscapes predominately composed by stands as young as 30 years of age (Folliard et al. 2000).

It is unlikely that spotted owls in this region are uniquely adapted to the coastal redwood region given documented movement rates and distances (Green Diamond, 2006). Based on genetics studies (Haig et al., 2001 and Haig et al., 2004), owls in coastal California are a part of the northern spotted owl population that extends from coastal California north to the Klamath Province and into southern Oregon. This suggests that an investigation of the habitat utilized by spotted owls in this young managed landscape would not only provide useful management information for the coastal region, but may also provide insights into habitat requirements throughout a much broader portion of the range of the northern spotted owl.

2.B.1 Nocturnal Habitat Selection by Northern Spotted Owls

The nocturnal activities of owls are generally assumed to represent foraging activities (Courtney et al. 2004), and as such it is critical for long-term viability of the species to maintain habitat suitable for these activities. We use the term "nocturnal activities" and "nocturnal habitat", rather than "foraging activities" and "foraging habitat", because we have no way to separate foraging behaviors from other nocturnal activities. Besides foraging, nocturnal activities of owls include a substantial amount of time in behaviors such as preening, resting, social interactions, territory exploration, territory defense, predator avoidance and etc.

The primary objective of this study was to identify habitat selected during nocturnal activity by spotted owls living in an actively managed young landscapes. We report on nocturnal habitat selection using a resource selection function (RSF; Manly et al. 2002) that predicts relative selection of habitat by an "average" owl given a set of habitat characteristics. The main use of this model was to identify those combinations of environmental factors that produced favorable conditions for selection during nighttime activities, and that could therefore be considered to represent "nocturnal activity habitat". In addition, the RSF model was used to assess the influence of management practices on the location and amount of future "nocturnal activity habitat" by incorporating appropriate covariates that could be predicted into the future. We also used nocturnal habitat selection probabilities as a covariate to assist in the prediction of "nesting habitat" in a subsequent analysis (Section 2.B.2, below).

Methods

Field Methods

We captured spotted owls by hand or with the aid of a snare pole, and fitted the owls with radio transmitters. To avoid impacts on spotted owl reproduction, we did not capture females from two weeks prior to incubation (7 March) until they were determined to be non-nesting or had finished brooding young (approximately 15 May). We fitted owls with tail-mounted radio transmitters (Holohil, model RI2C 6 g) equipped with either a one- or two-year battery (total mass = 5.5 or 7.5 g, respectively). We attached radio transmitters to the proximal portion of the rachis of the two central rectrices using small zip-ties and epoxy (#332 Titan Corp., Lynnwood, WA). Transmitters remained attached to the rectrices until the rectrices were molted. The time that transmitters remained attached to individual birds ranged from 1 to 15 months (mean $\geq$ 7 months). Some instances of premature molting probably occurred (molted within 3 months), either due to the damage to the feather that may have occurred during the process of attaching the transmitter, or because the bird pulled excessively on these feathers in an attempt to preen away the attached object. Owls fitted with radio transmitters were tracked with a two-element, hand-held directional H-antenna (Telonics model RA-14) and portable receiver (Telonics model TR-4).

We radio tracked owls during all seasons, from April 1998 through September 2000, in the North and South regions of Green Diamond Resource Company (GD) land (Fig. 2.1). Owls were included in this study if they met the following criteria: (1) they occurred in a contiguous region within the ownership that was sufficiently large to contain multiple pairs of owls whose likely home ranges did not overlap adjacent areas of non-GD land; (2) the owls occurred in areas where the silvicultural and harvesting practices were representative of GD current and future typical practices; and (3) the owls occurred in a region that had sufficient road access to allow for efficient telemetry work.

Nighttime radio telemetry and visual locations were collected on 28 owls as reported in

McDonald et al. (2006). Of the 28 owls, 5 resided in the Northern area, and 23 resided in the Southern area. Triangulations were attempted on 2 to 4 birds per night from roadside locations throughout the study area, with subsequent visual sightings if possible. With this schedule, a set of locations was obtained on each bird approximately weekly. When located, a bird was followed for 4 to 8 hr or until lost. Locations were recorded when the bird changed roosting sites, or every 30 minutes, whichever came first. All locations of the same roosting site in a single night were entered as 1 location in the database to reduce site autocorrelation. Roosting sites were defined as the vicinity near (generally <50 m) the roosting tree.

Analytical Methods

We developed a nocturnal resource selection model from telemetry locations collected in 2 areas contained within the North and South regions of the study area (Fig 2.1). After estimation, we applied the nocturnal resource selection model to the entire North and South study area regions because both had similar physiographic characteristics and management history to the areas where the telemetry locations were collected. The "excluded" areas in Fig. 2.1 did not contain telemetry locations, were fundamentally different habitats (e.g., higher elevation, different forest type, or less precipitation), and had different management histories than the included areas.

We used data from two sources: (1) nocturnal locations of owls; and (2) a sample of random points within the discrete area used by each owl during its nocturnal movements. For reasons listed in McDonald et al. (2006), we limited our analysis to owl locations and random locations within 250 m (820 ft) of a road. Radio-signal strength declined appreciably >250 m from roads, compromising our ability to obtain fixes at greater distances from roads. However, we did not believe that this would introduce any bias in our analysis, because roads were ubiquitous in our study area and <5% of the study area was >250m from a road. In addition, because our habitat information stopped at the boundaries of our study area, we eliminated owl and random locations within 250 m of any GD property boundary to allow for correct characterization of habitat surrounding all locations (Fig. 2.2). After eliminating points >250m from roads or <250m from a boundary, we had 2,396 nocturnal owl locations to use in our analysis (mean = 85 locations/owl, range 31-235; mean duration of tracking = 9 months, range 1-24).

We defined an owl's habitat "choice set" as the 95% adaptive kernel utilization distribution (Wand and Jones 1995) estimated from the individual owl's telemetry locations. We did not consider the 95% adaptive kernel estimates to represent owl home ranges, as it was not our objective to obtain enough locations over a sufficient interval of time to provide a valid estimate of home range size. We selected one systematic sample with random start from within each owl's 95% adaptive kernel utilization distribution and considered these to be "available" locations. The systematic sample of available locations was obtained from a randomly placed square grid of points with 100-meter spacing. The number of available points over all choice sets was 6,342.

We tracked 4 of the owls in the North for two successive years. Because GD updates habitat information in its forestry database on January 1 of each year to reflect the previous year's timber harvest, each of these 4 owls had 2 choice sets. The used points collected in one year were considered to have been selected from one choice set, while the used points collected in the next year were considered to have been selected from a different choice set. For example, if an owl was followed in 1999 and 2000, telemetry locations in 1999 were compared to habitat information for 1999 and telemetry locations in 2000 were compared to habitat information for 2000. With these 4 owls contributing 2 choices sets each, there were a total of 32 choice sets from 28 owls available for modeling.

Covariates

We selected landscape and forest stand-level characteristics (Table 2.2) similar to those used by Folliard et al. (2000) as covariates to model habitat selection. The specific forest stand attributes we measured were largely dictated by the data maintained in the GD forest inventory system. In addition, other spatially explicit variables were computed using a custom designed Fortran routine that read information exported from the GD GIS. This Fortran routine computed so-called fragmentation statistics on a sample of circular buffers, and was tested extensively against Fragstats (http://www.umass.edu/landeco/research/fragstats/fragstats.html) to make sure both packages were producing identical calculations. Forest stands in our GIS were polygons of similarly aged trees, the boundaries of which were not necessarily real edges relative to habitat selection by a spotted owl. Patches in our landscape were defined to be contiguous stands of the same age class. For example, a 23 year old stand sharing a border with a 39 year old stand was considered one patch, because both were in age class 3 (21- 40 years old). Discrete age classes were identified rather than using age as a continuous variable, because we hypothesized that owls may use forest stands of different ages for very different activities (e.g. foraging versus roosting). The specific age classes were identified based on previous studies in the same study area (Folliard et al. 2000, Hamm 1995). Quadratic terms were considered for all continuous variables in Table 2.2.

Estimation

We estimated a resource selection function (RSF) using a discrete choice model (McCracken et al. 1998, Cooper and Millspaugh 1999, Arthur et al. 1996, McDonald et al. 2006) to estimate the relative probability of an owl selecting a particular site on GD land. The discrete choice model estimated coefficients in the RSF by maximizing the "with replacement likelihood" as described by McDonald et al. (2006, eqn. 7) for all birds in the analysis. The likelihood of the observed data was:

$$L(\beta) = \prod_{i=1}^{n} \frac{\sum_{u_j \in U_i} \exp(x_j \beta)}{\sum_{u_j \in U_i} \exp(x_j \beta) + \sum_{u_j \in A_i} \exp(x_j \beta)}$$

where n was the number of owls in the data set, U_i was the set of used locations with the utilization distribution associated with owl i, A_i was the set of available locations sampled from within the utilization distribution associated with owl i, x_j was a vector of characteristics associated with location u_j, and β was a vector of unknown coefficients. Standard errors for elements in β were estimated from the second derivative of $L(\beta)$ with respect to β. Maximization was carried out using the stratified Cox proportional hazards routine available in SAS (Kuhfeld 2000; Manly et al, 2002, p. 208; McDonald et al. 2006).

Model Development

Given the covariates of interest (Table 2.2), we used a model ranking procedure to identify a reasonable subset of covariates that explained a large portion of the variation in the relative probability of selecting a site for nocturnal activity. The RSF model ranking we performed contained a pre-ranking collinearity (i.e., correlation) analysis (Neter et al. 1985), followed by model selection and model ranking.

The pre-ranking collinearity analysis estimated a correlation coefficient for every pair of covariates under consideration. We found perfect correlation (i.e., $r = 1.00$) between *edge_density* and *total_edge* because *edge_density* = *total_edge* / (buffer size). Because *edge_density* could be interpreted without regard to buffer size, *total_edge* was dropped from the analysis. A similar situation existed between *patch_density* and *num_of_patches* because *patch_density* = *num_of_patches* / buffer size. *Num_of_patches* was dropped from the analysis. In the GIS, height of a stand was largely derived from age of the stand. This induced collinearity between *tree_height* and other stand age related variables (e.g., *age*, *6-20_yrs*, *21-40_yrs*, *41+_yrs*) that we eliminated by dropping *tree_height* from the analysis. We also dropped *Age* from the analysis due to collinearity with age class of the stand ($r = 0.85$) and *RW_ba* ($r = 0.74$). The collinearity analysis also revealed that *WW_ba* was highly correlated with *%WW* ($r = 0.82$), *HW_ba* was highly correlated with *%HW* ($r = 0.77$), and *residual_ba* was highly correlated with *%residual* ($r = 0.86$). Because percent of white wood, percent of hardwood, and percent of residual wood were easier to measure and more transportable to other areas than total basal area of white wood, hardwood, and residual basal areas, *WW_ba*, *HW_ba*, and *residual_ba* were dropped from the analysis. *Total_ba* was found to be highly correlated with *%_41+_yrs* ($r = 0.61$) and the age class of the stand ($r = 0.90$), and so *total_ba* was dropped from the analysis. *RW_ba* was dropped from the analysis due to high collinearity with age class of the stand ($r = 0.72$).

We also found relatively high collinearity (Pearson's correlation coefficient $\tilde{<}0.6$ or >0.6) between several additional sets of variables which we deemed potentially important explanatory variables and chose not to drop. First, we found high correlation between *edge_density* and *patch_density* ($r = 0.80$), *mean_patch_size* and *edge_density* ($r = -0.75$), and *mean_patch_size* and *patch_density* ($r = -0.81$). We did not allow two or more of these three variables in the same RSF model. Second, we found high correlation between *dist_to_edge* and *edge_density* ($r = -0.73$), and *dist_to_edge* and *mean_patch_size* ($r = 0.67$). We did not allow *dist_to_edge* in the same model as *edge_density* or *mean_patch_size*. Third, we found high correlation between *CV_patch* and *mean_patch_size* ($r = -0.71$), and *CV_patch* and *patch_density* ($r = 0.64$). We did not allow *CV_patch* in the same model as *edge_density* or *mean_patch_size*. Finally, we found *%_41+_yrs* to be highly correlated with *%6-20_yrs* ($r = -0.69$) and the age class of the stand ($r = 0.65$). We did not allow *%_41+_yrs* in the same model as *%6-20_yrs* and the age class of the stand.

Due to the relatively large pool of variables that could potentially be included in the RSF, we performed model selection in two stages. During the first stage, we estimated a set of "best" models from each of the six sets of potential variables using best subset selection (SAS Institute, 2000; Furnival and Wilson, 1974). In each best subset selection run, we identified the 50 "best" models from each variable set. These 50 models consisted of the five "best" models containing one variable, the five "best" models containing two variables, and so on up to ten variables. If two models contained the same number of variables, the "best" model was the one with larger global score chi-squared statistic (SAS Institute, 2000). Cumulatively, these six best subsets runs had the potential of identifying 300 "best" models (50 models x 6 runs). During stage one of model selection, we included quadratic terms for all continuous variables listed in Table 2.2. As indicated in Table 2.2, we also modeled the interaction between age class of the stand (*6-20_yrs, 21-40_yrs, 41+_yrs*) and age class of the nearest stand (*6-20_yrs, 21-40_yrs, 41+_yrs*), resulting in the creation of 8 additional indicator variables.

A minor complication of stage one was that the SAS best subset routine does not automatically include a linear term for a variable if its quadratic term is present in the model. Nor does the SAS routine recognize that all indicator variables for a categorical covariate should be considered as a group during the model fitting process. To correct for these shortcomings, modifications to the 300 "best" models were made by hand to ensure that a linear term was included for each selected quadratic terms and to ensure that all indicator variables were present in a model if at least one indicator of a categorical variable was chosen. Finally, we eliminated any duplicates among the 300 best models.

In stage two of model selection, we ranked models according to Schwartz's Bayesian Criterion (SBC; Schwartz 1978). The top-ranking model (i.e., smallest SBC) from this set was reported as our final model. SBC was defined as

$$-2log(Likelihood) + plog(n_p),$$

where p was the number of variables in the model, n_p was the number of owl locations plus the number of available locations ($= \Sigma_i \|U_i\| + \|A_i\|$), and *Likelihood* was the value of the maximized value of the likelihood for that particular model, and *log* was the natural logarithm.

We assessed the significance of coefficients in the final model using Wald t-tests. Wald t-tests compare the ratio of each coefficient and its standard error to the 95-th quantile of a standard normal distribution. If the absolute value of this ratio was greater than 1.96 (equivalent to a significance level of $\alpha = 0.05$), we deemed the coefficient significantly non-zero. In addition, we computed selection ratios and confidence intervals for appropriate variables in the final model. Because of the difficulty interpreting selection ratios for quadratic effects, we did not compute selection ratios for variables with both quadratic and linear terms in the final model. Selection ratios measure the multiplicative change in relative probability that occurs when a variable increases by one unit and all other variables remain constant. We computed selection ratios as *exp(coefficient)*, and computed approximate 95% confidence intervals on selection ratios as *exp(coefficient* $\pm$ *1.96·standard error)*. A selection ratio whose confidence interval does not contain 1.0 was considered significant.

Model Validation

To assess predictive ability of the nocturnal RSF, we used the validation technique described by Howlin et al. (2004), which was similar in nature to the *k*-fold validation techniques of Boyce et al. (2002) and Johnson et al. (2006),. This validation technique was based on the assumption that if the model has good predictive abilities, used points should have higher predicted relative probabilities of selection on average than the available points. For our validation, all locations (used and available) within choice sets in the North region (owls 1 - 5) were temporarily dropped from the data set and the final model was re-estimated using data from the remaining 27 choice sets within the South region. We used the re-estimated coefficients for the nocturnal RSF to predict the relative probability of selection for all available and used locations in each of the 5 dropped choice sets.

For each dropped choice set, predicted relative probability of selection for all available locations was scaled to sum to the number of used locations in the choice set. We then divided the scaled probabilities into 20 bins based on percentiles (i.e., 0% - 5%, 5% - 10%, … etc.). We summed the scaled relative probabilities of selection in each bin to produce an expected count for the number of used points that should fall in each bin. We then scaled predictions for all used points using with the same scalar applied to the available locations, and assigned each used point to one of the 20 bins. We regressed the actual number of used points in each bin onto the expected number of used locations based on the model, using normal theory linear regression. If the estimated relationship between the predicted and observed number of used points within each bin is greater than zero and not statistically different from 1 (i.e. 95% confidence interval on slope included 1 and not zero) we concluded the model had good predictive abilities, because expected use was similar to observed use. A model with moderate predictive abilities had a slope greater than zero but 95% confidence intervals that did not contain 1. A model with poor predictive abilities would have a slope not statistically different from zero.

We conducted further model validation following a more traditional k-fold cross validation technique (Fielding and Bell, 1997) in which we temporarily dropped a random sample of 25% of the choice sets (25% of 32 = 8 choice sets) in both regions (North and South) and re-estimated the final model using data from the remaining 24 choice sets. Using the re-estimated coefficients for the nocturnal RSF, we predicted the relative probability of selection for all available and used locations in each of the 8 temporarily dropped choice sets. We then used the same validation process described above to estimate the relationship between observed and expected use for each of the 8 choice sets. We repeated this process 32 times and calculated the average slope over all 32 validation runs, along with 95% confidence intervals for each of the 32 slopes.

Results

The set of 5 "best" habitat selection models ranked according to SBC after stage two of model selection appear in Table 2.3. The top model (smallest SBC) for relative probability that a northern spotted owl selected a particular point in the landscape during nocturnal hours was (see also Table 2.4)

$$w(x) = \exp\{0.25792\ (nearest\_6\text{-}20\_yrs) + 0.26918\ (nearest\_21\_40\_yrs) - 0.02632\ (nearest\_41+\_yrs) + 0.02686\ (\%\_41+\_yrs) - 0.0001953\ (\%\_41+\_yrs)^2 + 0.00479\ (\%\_HW) - 0.00966\ (slope\_position)\}$$

where *w(x)* represents relative probability of selecting a point in the landscape with characteristics *x*..

Relative probabilities of selection for each variable in the final model are plotted in Figures 2.3 to 2.5, holding all other variables constant at their median (Table 2.5). For example, Fig. 2.3 shows the predicted change in relative probability of selection as a function of slope position (%) with *%_41+_yrs* and *%_HW* held at their median values of 39.98 and 18.00, respectively. A separate line for the relative probability of selection was plotted for each age class of the nearest stand. From this graph, it can be seen that the probability of selecting a point for nocturnal activity decreased with increases in slope position. Fig. 2.4 shows that the relative probability of selection increased as the percent of stands in age class 4 (*41+_yrs*) in a surrounding 250-m circle increased up to approximately 75%, then declined. Probability of selection increased as the % hardwood increased in a stand (Fig. 2.5). In all plots, probability of selection was higher when the age class of the nearest stands was 2 (*6-20_yrs*) or 3 (*21-40_yrs*) and lowest when the next nearest stands were in age classes 1 (*0-5_yrs*) or 4 (*41+_yrs*).

Model validation indicated that the final nocturnal site selection model had good predictive abilities for three of the five owls in the North region (Table 2.6). The 95% confidence intervals for slope were greater than 0 and included 1 for owls 1, 3, and 5. The 95% confidence interval on slope for owl 2 was 1.10 to 1.76, indicating moderate predictive abilities. The 95% confidence interval on slope for owl 4 was -1.30 to 1.11, indicating poor predictive ability for this owl. Investigation into resource use by this owl indicated that the home range for owl 4 had substantially different percentages of age classes 2 and 4. Overall, 4 of 5 home ranges indicated a strong positive relationship between the observed and expected habitat use, and the average slope for the 5 owls was 1.36.

Model validation by *k*-fold cross-validation indicated that overall, the model had good predictive abilities. Twenty-seven of 32, or 84% of the cross-validation runs had 95% confidence intervals that were greater than 0 and included 1 (Table 2.7). Three of the 32 runs showed no relationship between observed and expected resource use, and 2 of the runs indicated high correlation between observed and expected use, but confidence intervals for the relationship were greater than 1. The average slope was 1.13 for the 32 cross-validation runs.

Discussion

Estimation of habitat selection based on triangulation using radio telemetry has some potential biases that need to be considered before interpreting the results. In our study, it typically required about 10 minutes to get three convergent azimuths, and points were not included if it required much more than 15 minutes to complete the triangulation. This probably did not interfere with triangulation when an owl was only making minor adjustments in position (e.g. approximately <20m), but triangulation was not possible for an owl that was moving over longer distances. We did not specifically quantify the number of times that triangulation was not possible because an owl was moving, but it was probably less than 20% of the triangulation attempts. Although we do not believe this was a major source of bias, there was certainly some bias associated with successfully triangulating on points where the owls were stationary for longer time intervals as opposed to areas where they were actively moving. Another potential source of bias in our study was that owls had to be within 250m of a road to get reliable telemetry points. We were able to test this potential bias by comparing available habitat within and beyond the 250m limit.

The top model for habitat selection by spotted owls at night on GDRC ownership indicated that owls tended to be found low on the slope in areas composed of approximately 70% age class 41+ years with a high percentage of hardwood. Selection was highest if the nearest stand to the owl's location was either 6-20 or 21-40 years, and lower if the nearest stand was either 0-5 or 41+ years. Interpretation of this model should be considered with respect to all of the potential nocturnal activities of a spotted owl. Frequently, nighttime telemetry locations of owls are called "foraging locations" even though basic life history requirements would suggest that at night when the owls are active they must be engaged in preening, resting, interactions with mates, territory defense, and a variety of other social and physiological activities not directly related to foraging. Our data suggest that spotted owls in our study area select the older stands available in a managed landscape for most of their nighttime activities. More hardwoods (mostly tanoak and other evergreen hardwoods) in the stand probably increase selection, because they increase the structural diversity of the stand (providing more perches and greater stem density to favor maneuverability of spotted owls over larger owls) and diversity of prey species. Probability of selection of a site also increased when the nearest stand was 6-20 or 21-40 years, probably because those were the stand ages in which dusky-footed woodrats (primary prey for spotted owls in this region) were most abundant. Being near another older stand or a recent clearcut likely decreased selection, because there would be few woodrats in either of those stand types (see Chapter 3, Section B, Woodrat Ecology). Our results are consistent with the concept that spotted owls benefit from habitat heterogeneity in those portions of its range where dusky-footed woodrats are the primary prey (Franklin et al. 2000 and Olson et al. 2004.)

The reason why spotted owls selected for a position low on a slope during nocturnal activity was not readily apparent. It potentially was related to the observation that spotted owls tended to roost and nest low on the slope (Blakesley et al. 1992 and Folliard et al. 2000). Nocturnal activity begins and ends at the diurnal roost/nest site and some of the activity during the night must involve resting or loafing, which may explain the association with the roost and nest sites. Assuming these behaviors were linked, it still does not provide an ultimate causal mechanism for this phenomenon, since the relationship between slope position and roost and nest sites (Blakesley et al.1992 and Folliard et al. 2000) was strictly correlational. In addition, our spotted owls telemetry study was done throughout the year including the winter months when the owls were not tied to their breeding season roost or nest sites. The causal mechanism for roosting, nesting and spending more time during their activity period low on the slope remains highly speculative, although it seems possible that the causal mechanism for each of these behaviors may be linked.

2.B.2 Nesting Habitat Selection by Northern Spotted Owls

The primary objective of this study component was to identify habitat selected for nesting by northern spotted owls living on Green Diamond Resource Company's (GD) managed lands. Based on the locations of successful nests (fledged at least one young) from 1990 through 2003, we estimated a resource selection function (RSF; Manly et al., 2002) to characterize nesting habitat of an "average" successfully nesting owl on GD property. The main use of this model was to identify landscape and stand-level variables that contribute to suitable "nesting habitat" on GD land. This RSF model was also be used to assess the influence of GD management practices on the location and amount of future nesting habitat.

Methods

Field Methods

The study area for the nesting component of our study was similar to that used to develop the nocturnal activity RSF (Figure 1.1 in Chapter 1). Each year from 1990-2003, we attempted to located all individual territorial spotted owls within the study area. Surveys were initiated each year beginning 1 March using protocols initially adapted from Forsman (1983) and further modified to support Green Diamond Resource Company's approved spotted owl habitat conservation plan (GDRCo, unpublished report). Owls were initially located primarily at night using vocal imitations or recordings of their calls. Daytime surveys were used primarily to locate roosts and determine the status of owls at sites where they had been previously located or where nighttime responses had been heard. Once an owl was located, it was typically offered live mice to determine its identity (if previously captured and marked), paired and reproductive status (Forsman 1983). Most nests were initially located by following the male back to the nest where the male would commonly attempt to deliver the mouse to the female. Once a nest was located, it was revisited one or more times after the typical period for fledging (late May through early June) to determine the status of the nesting attempt. A nesting attempt was considered successful if at least one fledgling was determined to have left the nest and the immediate vicinity of the structure supporting the nest.

Analytical Methods

Data available for analysis consisted of two sets of points in the study area. The first set of points were locations of successful (≥1 fledged young) northern spotted owl nest sites during the years 1990 through 2003, excluding 1993. The 1993 nest locations were excluded from analysis because a key habitat measurement (basal area) contained our in GIS system was unavailable and could not be replaced. The second set included a systematic sample of random locations on GD property from the same years in which the nests were used. Associated with each point in both data sets were values of landscape and habitat covariates.

In earlier analyses, we found that a buffer-induced bias along the GD property boundary affected predictions of the relative probability of northern spotted owl selection for nocturnal activity (Chapter 1). Therefore, to be included in this analysis, all nest and random locations had to meet

2 spatial conditions. The first spatial condition required that the location (nest and random) be >250 m (820 ft) away from any GD property boundary. This ensured that northern spotted owl nocturnal activity resource selection values (Chapter 1) could be accurately predicted and included as a covariate in this analysis. GD

The second spatial condition, in addition to the >250m condition, required that the locations be surrounded by a sufficient amount of GD property to admit reliable computation of our buffer statistics. Coverage of the GD geographic information system (GIS) did not extend beyond GD ownership boundaries, and this condition ensured that a large proportion of 4 circular buffers of different radii were contained on GD ownership. GDGDA point was defined to be "interior", and was included in analysis, if its location was on GD property >250 m (820 ft) from GD property boundaries and if at least 75% of buffers with radii of 400 m (1312 ft), 600 m (1969 ft), 800 m (2625 ft), and 1100 m (3609 ft) were on GD land.

Before excluding nests located <250 m from a GD boundary, we had information on 275 successful nests from 1990 to 2003, exclusive of 1993. Excluding nests that were <250 m from a boundary as well as those whose buffers were not >75% on GD property left 182 nest sites for analysis. The 182 nest sites were distributed among 71 unique spotted owl sites (territories) indicating an average of 2.56 nest trees per owl territory. Multiple nest trees from the same owl site (territory) were included in the analysis either because the nest trees were spatially distinct (commonly >100m apart) or the nest trees were not spatially distinct, but timber harvesting within the owl site had substantially modified the quantification of total habitat for the owl site.

We selected random locations for analysis in two steps. First, we constructed a dense grid of points, spaced 10 m (33 ft) apart and spanning all of GD ownership. Second, we placed a sparse grid of points, spaced 400 m (1312 ft) apart, on the dense grid using a random start point. We took as our random locations those points in the 10 × 10 m grid that coincided with points in the 400 × 400 m grid. Values from the 400 × 400 m grid were used for estimation. For predictive purposes, we reverted to the 10 × 10 m grid. That is, we computed selection ratios using the final model for every point in this fine grid.

Covariates

From data in the GD forest inventory system (GIS database), we identified a suite of explanatory variables (Table 2.8) that had the potential to impact spotted owl nest site selection.
Our habitat covariates were computed at all successful nest and all random locations in the dense grid. The environmental information available at each used and random location consisted of yearly GIS data on stand characteristics (e.g. age and tree species), important landmarks (roads), and information from a digital elevation map (DEM). Using this information, we computed covariates from point attributes (*dist-to-road* and *slope_position*), forest stand characteristics (*managed, age, %_HW, %_RWWW, %_residual,* and *interior_area*), and attributes of circular areas (buffers) surrounding a point (*open_edge_density with 400-1100m buffers, patch_density with 4 buffers, mean_patch_size with 4 buffers, nta_hsi_400, nta_annulus_1,* and *nta_annulus_2*). The circular buffers were of four radii; 400, 600, 800 and 1100 m. These buffer sizes were selected to bracket the size of habitat areas that best differentiated owl nest

sites from random sites in previous studies (Myer et al. 1998, Folliard et al. 2000). For *patch_density with 4 buffers* and *mean_patch_size with 4 buffers*, forest stand age classes 1 through 6 were defined as stands dominated by trees 0-5, 6-20, 21-40, 41-60, 61-80, and 81 years or older, respectively. Patches were defined as areas containing 1 or more adjacent stands in the same age class. This definition of a patch was used in the calculation of

We estimated slope position based on each nest or random point's elevation, the valley or ravine elevation directly downhill from the point, and the ridge or hilltop elevation directly uphill from the point. Slope position was the change in elevation from the valley to the nest or random location divided by the change in elevation from the valley to the ridge top. Higher values of slope position (i.e., closer to 100%) indicated locations closer to the top of a ridge or hill. Lower values (i.e., closer to 0%) indicated points closer to the valley or ravine bottom.

We computed *interior_area* from the patch, where patch was defined as uniform age class, containing the point by first removing a 100 m buffer around the inside perimeter of the patch containing the point and then measuring the remaining area. For consistency, any portion of a stand more than 1100 m from the point of interest (straight-line distance) was ignored when calculating *interior area*.

Certain stands were defined to be "old growth" by GD foresters, and their ages were not estimated or tracked by the GD forest inventory system because these stands were not planned for harvest in the near or distant future. While the proportion of "old growth" on GD landscape was very small (approximately 1%), we could not ignore its potential as nesting habitat for spotted owls. Therefore, we constructed the *managed* indicator variable to differentiate between indeterminate age old growth and younger, second and third growth managed stands.

In addition, residual basal area recorded for old growth stands did not represent true residual basal area, as it is usually defined in forestry, and use of the *managed* variable allowed us to eliminate this potential source of bias. In forestry, "residual" basal area refers to basal area of trees that survived previous stand-replacing events and are a minor older component within younger even-aged stands. While true residual basal area only occurs in young second and third-growth stands by definition, the GD inventory system recorded residual trees that were left from a previous harvest and that had "old growth form" (i.e., the trees were not aged, but showed signs of decadence). Consequently, residual basal area of old growth stands was recorded as the total basal area of the stand even though no true residual existed. Because studies have shown that true residual trees have the potential to be very important to nesting owls in managed forests (Thome et al. 1999, Folliard et al. 2000), the *managed* indicator variable and its interactions with *age* and *%_residual* allowed us to estimate separate models in "old growth" and "managed" stands and thereby eliminate bias associated with incorrect age and residual basal area measurements.

We included the top resource selection function model for nocturnal activity (section 2.B.1, above) in modeling the resource selection function for nesting habitat, because we hypothesized that successful nesting habitat must include nocturnal habitat at some spatial scale around the nest site. We computed the average owl nocturnal activity habitat suitability index within a 400 m (1312 ft) radius disk (*nta_hsi_400*), and the average nocturnal activity suitability index in annuli of 2 different sizes (Fig. 2.6). The two annuli measurements were included because we hypothesized that owls may require different foraging and roosting habitat near the core of the nest site compared to habitat outside the core. We scaled the nocturnal activity suitability indices by a multiplier of 10,000 / max(nta_hsi_{1992}), where max(nta_hsi_{1992}) was the maximum suitability index in 1992 within all of GD ownership common to all years from 1992 to 2002, but excluding a 250 m internal buffer around GD property boundary. The max(nta_hsi_{1992}) value was 5.3209. The scaled nocturnal habitat suitability values averaged over the 400 m disk ranged from 656 to 6811 in the combined sample of used and available points.

Estimation

We required that the RSF model estimation procedure allow for annual changes in nest locations and changes in forest age structure due to active timber harvest and re-growth of stands. Thus, we viewed the set of locations available for nesting as unique to each year (1990–2003, excluding 1993), and we estimated a discrete choice model (Arthur et al. 1996, McCracken et al. 1998, Cooper and Millspaugh 1999, McDonald et al. 2006). The discrete choice model estimated coefficients in the RSF by maximizing the with replacement likelihood of McDonald et al. (2006, eqn. 7). The likelihood of the observed data was

$$L(\beta)=\prod_{i=1}^{n}\frac{\sum_{u_j\in U_i}\exp(x_j\beta)}{\sum_{u_j\in U_i}\exp(x_j\beta)+\sum_{u_j\in A_i}\exp(x_j\beta)} \qquad (0.1)$$

where n was the total number of years (choice sets) in the data set, U_i was the set of successful nest locations from the i^{th} year , A_i was the set of available locations sampled from the i^{th} year, x_j was a vector of characteristics associated with location u_j, and β was a vector of unknown coefficients. The set of available locations, A_i, was defined to be a systematic sample of locations (spacing = 400 m) taken from all GD ownership in the year that nest i was established. Standard errors for elements in β were estimated from the second derivative of $L(\beta)$ with respect to β.

Model Development

Given the covariates of interest (Table 2.8), we used a model ranking procedure to identify a reasonable subset of covariates that explained a large portion of the variation in the relative probability of selecting a site for a successful nest. The RSF model ranking we performed contained a pre-ranking collinearity (i.e., correlation) analysis (Neter et al. 1985), followed by model selection and model ranking.

The pre-ranking collinearity analysis estimated a correlation coefficient for every pair of covariates under consideration. During this analysis, we found relatively high collinearity (Pearson's correlation coefficient $\lesssim -0.6$ or >0.6) between mean patch size (*mean_patch_size with 4 buffers*), patch density (*patch_density with 4 buffers*), and interior area (*interior_area*). Because we deemed all three of these variables potentially important explanatory variables, and they measured habitat in slightly different ways, we chose not to allow two or more of these three variables in the same RSF model. Opening edge density (*open_edge_density with 4* *buffers*) within a buffer was also found to have high correlation with patch density (*patch_density with 4 buffers*); therefore opening edge density was not allowed in the same model with patch density.

Following the collinearity analysis, stage 1 of model selection involved selecting a reasonably large set of models that warranted further consideration. The stage 1 set of models that warranted further consideration potentially contained 150 models that were deemed "best" during three runs of a best subset selection procedure (Furnival and Wilson 1974, SAS Institute 2000). SAS Proc PHREG (SAS Institute, 2000) was used during the best subset selection procedure to estimate the discrete choice RSF model. Although Proc PHREG was not designed to fit discrete choice habitat selection functions, Kuhfeld (2000) described a method by which PHREG could be "tricked" into maximizing the likelihood in Equation **Error! Reference source not found.**, by instructing SAS to fit a stratified Cox proportional hazards model (Manly et al. 2002, p. 208, McDonald et al 2006).

Because we chose to disallow *mean_patch_size with 4 buffers, patch_density with 4 buffers*, and *interior_area* in the same model, best subset selection was performed three times; once including all 4 *mean_patch_size with 4 buffers*, but not *patch_density with 4 buffers* or *interior_area*; once including all 4 *patch_density with 4 buffers* but not *mean_patch_size with 4 buffers* or *interior_area;* and once including *interior_area* but not *mean_patch_size with 4 buffers* or *patch_density with 4 buffers.* During each best subset selection run we identified the 50 "best" models containing the variables currently under consideration. These 50 models consisted of the five "best" models containing one variable, the five "best" models containing two variables, and so on up to ten variables. If two models contained the same number of variables, the "best" model was the one with larger global score chi-squared statistic (SAS Institute 2000). Quadratic terms of all continuous variables were considered during model selection.

The SAS best subset routine we used did not automatically include a linear term for a variable if its quadratic term was present in the model. Nor did the SAS routine recognize that the indicator variable for managed should be included in a models containing variables that interact with it (e.g., *managed* should be included when [*age*]*x*[*managed*] or [*%_residual*]*x*[*managed*] were included). To correct these shortcomings, we modified the 150 "best" models by hand to ensure that a linear term corresponding to every quadratic term was included, and to ensure that *managed* was present in a model if it was involved in an interaction.

In addition to requiring lower order terms when higher order terms were present, and that the main effect for managed was present when required, we also required that no variable be represented at more that one scale in the 150 "best" models because these variables were highly correlated. For example, we did not allow mean patch size measured in a buffer of radius 400 m to be in a model at the same time as mean patch size measured in a buffer of radius 600 m. If a model selected by the automated best subsets routine contained the same variable at two or more scales, we created two new models. One of the new models contained the covariate measured at one scale (i.e., the 400 m buffer in the example), while the second new model contained the covariate measured at the second scale (i.e., the 600 m buffer in the example). This approach was taken with models that contained opening edge density (*open_edge_density with 4 buffers*), patch density (*patch_density with 4 buffers*), mean patch size (*mean_patch_size with 4 buffers*), and average owl nocturnal activity habitat suitability index (i.e., *nta_hsi_400*, *nta_annulus_1*, and *nta_annulus_2*).

During stage 1 of model selection, duplicate models arose if none of the *mean_patch_size with 4 buffers, patch_density with 4 buffers*, or *interior_area with 4 buffers* variables were selected during best subsets selection, or when lower order terms were added, or when variables measured on two different scales were separated. Prior to stage 2 of model selection, duplicate models among the 150 "best" models were eliminated and discarded. Consequently, between 50 and 150 "best" models ultimately advanced to stage 2 of model ranking.

For stage 2 of model selection, we ranked the models identified during stage 1 according to Schwartz's Bayesian Criterion (SBC) (Schwartz, 1978). SBC was defined as

$$-2log(Likelihood) + p(log(n)),$$

where p was the number of variables in the model, $n = \Sigma_i \|U_i\| + \|A_i\|$ was the number of successful nest locations plus the number of available locations, and *Likelihood* was the value of the maximized likelihood for that particular model. For each model in the set, the SBC differences were calculated as

$$\Delta_i = SBC_i - \min(SBC),$$

where SBC_i was the SBC for the ith model and min(SBC) was the minimum SBC value over all models.

We also calculated SBC weights (similar to Akaike weights; Burnham and Anderson 2002) for each model identified during stage 1 of model ranking. SBC weights were calculated as

$$w_i = \frac{\exp\left(-\frac{1}{2}\Delta_i\right)}{\sum_{r=1}^{n_m}\exp\left(-\frac{1}{2}\Delta_r\right)} \quad ,$$

where n_m was the total number of unique models that advanced to stage 2 of model ranking. These weights allowed ranking of the models (larger weight was better) and comparisons of the relative differences between models. The bigger the SBC difference, Δ_i, the smaller the weight, w_i, and "the less plausible is model i as being the actual best model… based on the [study] design and sample size used," (Burnham and Anderson, 2002:75).

In addition to providing a comparison among models, the SBC weights allowed us to compute and compare the relative importance of each variable considered in the model ranking process. We calculated importance values for each variable by summing the SBC weights for all models that contained the variable. Thus, variables in the RSF with most weight were considered relatively more important when compared to variables in models with less weight. However, even if a variable was not present in the final model, it was assigned some importance if it occurred in other models that had relatively high SBC weights.

Once the final RSF was determined, we assessed the significance of coefficients in the final model using Wald *t*-tests. Wald *t*-tests compare the ratio *coefficient / standard error* to the 95th quantile of the standard normal distribution. If the absolute value of this ratio was greater than 1.96 (equivalent to a significance level of $\alpha = 0.05$), we deemed the coefficient significantly non-zero. We also computed selection ratios and confidence intervals (when appropriate) for variables in the final model. Because of the difficulty interpreting selection ratios for quadratic effects, we did not compute selection ratios for variables with both quadratic and linear terms in the final model. A selection ratio measures the multiplicative change in relative probability that occurs when a variable increases by one unit and all other variables remain constant. We computed selection ratios as *exp(coefficient)* and approximate 95% confidence intervals for these ratios as *exp(coefficient ± 1.96standard error).*

Model Validation

We conducted model validation to assess the strength of predictions from the final northern spotted owl nest site selection model. This model validation compared the predicted relative probabilities of nest site selection between successful (having ≥ 1 fledged young) and unsuccessful (having 0 fledglings) nests. This validation technique was based on the assumption that habitat conditions for unsuccessful nest sites differed when compared to successful nesting locations. Ideally, the nest site selection model should accurately differentiate between successful and unsuccessful nesting locations, and not just between successful nesting locations and random locations.

During validation, we computed covariates at the locations of all unsuccessful nest sites in the study area from 1990-1992 and 1994-2003 and used the covariates to compute nesting suitability indices for unsuccessful nests based on the final RSF model. We identified 83 unsuccessful nest sites on GD land, but only 48 of those were located within the study areas we considered and otherwise satisfied the two "interior" criteria. Model validation then compared the two samples (successful and unsuccessful nest site RSF values) to determine if differences in RSF values existed. Because predicted RSF values were positively-skewed (long right-hand tail) and non-normally distributed, we employed the Wilcoxon Rank-Sum test (Conover, 1999) to test the null hypothesis H_0: *the distributions of RSF values for successful and unsuccessful nest sites are equivalent*, versus the one-sided alternative H_1: *the distribution of RSF values at unsuccessful nest sites is stochastically smaller than the distribution of RSF values at successful nest sites.* A stochastically smaller distribution at unsuccessful nest sites implies that RSF values at unsuccessful nest sites tend to be lower than those at successful nest sites. The Wilcoxon Rank-Sum test compared the $n = 48$ RSF values from the sample of unsuccessful nest sites with the $m = 182$ RSF values from the sample of successful nest sites. An exact one-sided permutation-based significance level was computed using SAS Proc Npar1way (SAS Institute, 2000). We rejected the null hypothesis of equivalent distributions if significance of the Wilcoxon Rank-Sum was less than $\alpha = 0.05$.

Results

Stage 1 of model selection (best subsets) yielded 74 models after inclusion of linear terms when quadratic terms were present, separation and replication of models with the same covariate at two different scales, and elimination of duplicate models. The low number of unique models realized from the potential set of 150 was a result of opening edge density (i.e., *open_edge_density_600*) being a stronger predictor than mean patch size (all *mean_patch_size with 4 buffers*), patch density (all *patch_density with 4 buffers*), or interior area of the stand (*interior_area*).

The highest ranking RSF at the end of stage 2 (i.e., model with lowest SBC among the 74 stage 1 models) was

$$w(x) = \exp\{-1.86937(managed) + 0.02636(age)*(managed) +$$

$$0.05983(\%\_residual)*(managed) - 0.00054(\%\_residual^2)*(managed)$$

$$+ 0.00298(nta\_hsi\_400) - 0.0000002891(nta\_hsi\_400^2)$$

$$+ 0.01514(open\_edge\_density\_600) + 0.02999(\%\_HW) - 0.00048(\%\_HW^2)\}.$$

This model implied that in a stand classified as "old growth" (i.e., *managed* = 0), the RSF was

$$w(x) = \exp\{+ 0.00298(nta\_hsi\_400) - 0.0000002891(nta\_hsi\_400^2)$$

$$+ 0.01514(open\_edge\_density\_600) + 0.02999(\%\_HW) - 0.00048(\%\_HW^2)\}.$$

In a stand classified as "managed" (i.e., *managed* = 1), the RSF was

$$w(x) = \exp\{-1.86937 + 0.02636(age) + 0.05983(\%\_residual) - 0.00054(\%\_residual^2)$$

$$+ 0.00298(nta\_hsi\_400) - 0.0000002891(nta\_hsi\_400^2)$$

$$+ 0.01514(open\_edge\_density\_600) + 0.02999(\%\_HW) - 0.00048(\%\_HW^2)\}.$$

Here, $w(x)$ represents the relative probability of a spotted owl or owl pair selecting a point in the landscape with characteristics x for a successful nest.

Model weights and variables in all models with an SBC weight >0.001 are listed in Table 2.9. The evidence ratio (Burnham and Anderson, 2002:77) for model 1 versus model 2 was approximately 2.1 (i.e., $(SBC\ weight)_1 / (SBC\ weight)_2 = 2.144$). Model weights (Table 2.9) indicated that most of the weight (97%) was assigned to models ranked 1 through 7, and those seven models were strikingly similar. Each of the top seven models contained variables *managed*, *(age)x(managed)*, *open_ edge_density* on some buffer, *%_HW* and *%_HW*^{2}, and *nta_hsi_400* and *nta_hsi_400*^{2}. The only differences between the top seven models was the scale, or buffer size, used to calculate opening edge density (*open_edge_density*) and whether or not percent residual was in the model.

Importance values for every variable in the 74 models chosen by best subset selection are presented in Table 2.10. *Managed*, *(age)x(managed)*, *%_HW*, *%_HW*^{2}, *nta_hsi_400*, and *nta_hsi_400*^{2} (all variables in the final nest site model) were in the top 14 models and so received weights approximately equal to 1. The highest importance value among variables not in the top model was 0.027 for *slope_position*.

Standard errors and selection ratios of the final model are presented in Table 2.11. The selection ratio for *open_edge_density_600* indicated that the relative probability of selecting a site for a successful nest increased by 1.5% for every 0.75 m/ha (1 ft/acre) increase in opening edge density within a 600 m radius buffer around the point. The selection ratio for *managed* indicated that the relative probability of selecting a site for a successful nest decreased by 85% if the location was in a managed stand, rather than old growth. If the potential successful nest site was in a managed stand, the selection ratio for *age* indicated that the relative probability of selection increased by 2.7% for every 1-year increase in the stand's age.

Relative probabilities of selection for each variable in the final model were plotted in Figures 2.7 and 2.8 for locations in managed and old growth stands, respectively. For example, the top left plot in Fig. 2.7 shows the predicted change in relative probability of a successful nest location in managed forests as a function of stand age, assuming all other variables remain constant at their median values (Table 2.12). Predicted relative probabilities of selection for each plot were scaled so the maximum value was 1.00.

Model validation revealed that predicted relative probabilities of selection for unsuccessful nest sites were significantly lower than relative probabilities of selection for successful nest sites (Wilcoxon Rank-Sum Test Statistic = 4087; $p < 0.01$). Fig. 2.9 compares the distribution of predictions for successful and unsuccessful nests. The histograms in Fig. 2.9 are plotted on the natural log scale because the predictions were highly skewed, with many values near zero. The minimum, median, and maximum values of the predicted relative probability of nest site selection in the sample of unsuccessful nest sites were 16.17, 631.04, and 4997.11, respectively. The same statistics for the sample of successful nest sites were 18.47, 1385.27, and 35445.37.

Discussion

From Fig. 2.7, we concluded that the relative probability of locating a successful nest in a managed stand increased with age of the stand and open edge density within 600 m of the nest. In addition, selection was greatest in stands with approximately 55% residual old growth basal area, 30% hardwood basal area and a large amount of good nocturnal habitat within 400 m. The relationship with stand age and residual old growth basal area in the stand indicated that spotted owls were selecting for the oldest stands and stands with a large residual component in managed forests. This is consistent with numerous previous studies that have shown selection for large decadent trees during nesting (Folliard et al. 2000, Courtney et al. 2004) However, the magnitude of increased selection with age should be viewed with caution, because low sample size in the upper tail of this variable's distribution results in high uncertainty in the magnitude of selection for these older trees. The data indicated a selection ratio of approximately 3.3 for older stands since 7.8% of the successful nest (used) versus 2.4% of the available locations were in stands >80 years old. However, uncertainty surrounding this selection ratio was high due to the nature of ratios that contain small numbers in their denominators.

Having a component of hardwood in the nest stand created greater structural diversity when a mixture of conifers and hardwood were present. Such conditions would produce more perch and roost sites as well as potentially increase the prey base near the nest site. Selection was maximized when there was a substantial hardwood component, but the major component of the stand was still composed of conifer. Selection was also maximized when there was high open edge density and relatively high levels of nocturnal habitat around the nest site. Because dusky-footed woodrats, the primary prey of spotted owls in our study area, occurred in highest densities in young stands (Hamm 1995, Hughes 2005), high open edge density would reflect nesting habitat in close proximity to good foraging areas.

From Fig. 2.8, we concluded that the relative probability of selection in old growth stands was maximized for stands with approximately 30% hardwood, a large amount of nocturnal activity habitat within 400 m, and as much open edge density as possible within 600 m. The biological interpretation of this analysis was essentially identical to that of managed stands except the old growth stands replaced the older managed stands with a high component of residual old growth structure.

According to the final model, the relative probability of selecting a managed stand with median values for all of the variables (age, % residual, % hardwood, open edge density and nocturnal habitat, Table 2.12) was 101. In comparison, relative probability of selecting an old growth stand with median values for % hardwood, open edge density and nocturnal habitat was 312. By this measure, a "median" old growth stand has a higher probability of being selected for nesting compared to a "median" managed stand on the GD study area. However, estimated selection was higher for an older managed stand with a significant residual component as compared to a median old growth stand.

Comparisons of old growth versus managed young growth selection should be made with caution because there was little old growth available in the study area (3.8% and 11.1% of the available and used locations, respectively), it all occurred in the northern portion of the study area and because these old growth stands occurred in small (mostly 10-20 ha) isolated stands surrounded by managed young growth stands that were typically 10-30 years old. This means that nesting owls in northern reaches of the study area never had the opportunity to directly choose between old growth and mature managed stands. The lack of a direct choice between old growth and mature managed stands in the portion of the study area containing all our information about old growth selection may have artificially elevated the apparent probability of selection for old growth stands. A study area containing old growth and multi-aged managed stands would be necessary to fully resolve this uncertainty.

2.B.3 Comparison of the actual versus projected amount and distribution of Northern Spotted Owl habitat on Green Diamond Resource Company land

Nocturnal Activity Habitat

Following estimation of the final nocturnal site selection model, we compared nocturnal habitat on GD ownership at 10 year intervals, from 1992 to 2022 (Table 2.13, Fig. 2.10). We used only locations common to GD ownership in all years for this comparison, except that 2521 ha were sold between 2002 and 2012 (white area in Fig. 2.6). The nocturnal activity RSF was applied to areas of GD ownership with similar management history and physiographic characteristics as the areas where we collected telemetry data (Fig. 2.1). We predicted the relative probability of selection for each point in the landscape for each year and identified the maximum prediction in 1992. We then scaled all predictions for each year by 10,000/max_{1992}. We defined five categories of selection (low to high selection) using the 1992 data. These five categories were based on the 20th, 40th, 60th, and 80th percentiles of the distribution of the scaled predictions for 1992. Under this classification scheme, 20% of GD land in 1992 was guaranteed to be in the "best" habitat category, but more or less than 20% of GD land could have been in the "best" category in subsequent years. Using these categories, we created maps of the relative probability of an owl selecting a foraging site in the area for the 1992, 2002, 2012, and 2022 landscapes (Fig. 2.10) and tabulated the percent of GD ownership within each category (Table 2.13).

The total area in the best nocturnal habitat increased from nearly 18,000 ha in 1992 to over 23,400 ha in 2002, an increase from 20% to 25% of the ownership (Table 2.13). The "best" nocturnal habitat is projected to increase to 39% of GD ownership by 2012 and 44% of GD ownership by 2022. Fig. 2.11 illustrates how locations changed in relative probability of nocturnal site selection from 1992 to 2022, over 10 year intervals.

Nesting Habitat

Following the methods of McDonald and McDonald (2002), we compared nesting habitat on GD ownership at 10 year intervals from 1992 to 2022 (Table 2.14, Fig. 2.12). We used only locations common to GD ownership in all years for this comparison, except that 2521 ha were sold between 2002 and 2012 (white area in Fig. 2.12). Furthermore, we considered only areas within 250 m of GD property boundary, as the final RSF was not applicable to locations close to the property boundary (see Methods). We predicted the relative probability of selection for each point in the study area at each time point, and identified the maximum prediction in 1992. All predictions were then scaled by 10,000/max(hsi_{1992}), and five categories of selection (low to high) were defined using the 1992 data. These five categories were based on the 20th, 40th, 60th, and 80th percentiles of the distribution of the scaled predictions for 1992. Under this definition, each category contained 20% of the landscape in 1992. We considered the top 20% of the relative probabilities from 1992 to be the "best" nesting habitat in 1992. Because the same cut points were used to classify the landscape in each year, more or less than 20% of GD land could have been classified in one of the classification categories in subsequent years. Using these categories, we created maps of the relative probability of an owl selecting a successful nest site in the area for the 1992, 2002, 2012, and 2022 landscapes (Fig. 2.12), and a tabulated the percent of GD ownership within each category (Table 2.14). The total area in the best nesting habitat increased from nearly 18,000 ha in 1992 to over 23,500 ha in 2002, an increase from 20% to 26% of the ownership (Table 2.14). The "best" nesting habitat is projected to increase to 42% of GD ownership by 2012 and 54% of GD ownership by 2022. Figure 2.13 illustrates how the GD land base changed in relative probability of nest site selection from 1992 to 2002 and how the land base is projected to change through 2022.

2.C Summary

The GD HCP for Northern Spotted Owls, completed in 1992, defined suitable habitat as forest stands of a specific age (>30 years old = foraging habitat and >45 years = roosting and nesting habitat), but data were not available to develop the spatial patterns of forest stands in the landscape used by spotted owls. By the HCP definition, suitable habitat on GD land increased by 38% from 1992-2002. In contrast, resource selection functions for spotted owl nocturnal and nesting habitat included spatial metrics. Nocturnal habitat was a function of the age class of the nearest stand, the percentage of a 250 m radius buffer in age class 41+ years, the percent hardwood trees within a stand, and position on the slope. Based on this resource selection function, the best nocturnal spotted owl habitat increased from 20 to 25% of the ownership from 1992-2002. Projections of future habitat created by in-growth and harvesting patterns indicated that the "best" nocturnal habitat is projected to increase to 39% of GD ownership by 2012 and 44% of GD ownership by 2022. Nesting habitat was a function of the nocturnal RSF, whether a stand was managed or "old growth", open edge density, percent hardwood in a stand, and for managed stands, stand age, and the percent residual trees within a stand. Based on this resource selection function, the best spotted owl nesting habitat increased from 20 to26% from 1992-2002. The "best" nesting habitat is projected to increase to 42% of GD ownership by 2012 and 54% of GD ownership by 2022.

Estimated increases in the highest quality nocturnal and nesting habitat from 1992 to 2002 and the projected increases in the future are a function of changes in stand age distributions throughout the ownership and changes in harvesting patterns. In 1992, only 21.6% of the ownership was greater than 40 yrs old, which increased to 24.9% in 2002. These older age stand classes are projected to increase to 41.4% in 2012 and 48.7% in 2022. A change in the size of clearcuts from a mean of approximately 55 acres (maximum of 80) in 1992 to 23 acres (maximum of 40) by 2002 is another key factor that influenced increases in the estimated amount of high quality nesting habitat. Smaller clearcuts resulted in greater amounts of open edge density, which we hypothesize increases foraging opportunities for spotted owls. In addition, increases in riparian buffers associated with Class I (fish bearing) and Class II (provides habitat for non-fish aquatic life) streams since 1992 and increased protection of geologically unstable areas will result in more patches of older forests and increases in residual structure within GD's ownership. Since we do not know the location of all unstable areas and small headwater streams, it is not possible to accurately estimate the total amount of structure associated with these features in future landscapes. However, GD estimated that approximately 75% of riparian reserves will be composed of stands from 51 to over 100 yrs in age by the year 2020 (GD aquatic HCP). Although the exact amount is not known, mature trees associated with riparian reserves and unstable areas will be a substantial proportion of future forested landscapes relative managed forests in the past. In some areas with multiple tributary junctions and/or unstable inner gorges, these reserve areas will likely constitute core areas for spotted owl roosting and nesting habitat. In other areas, the linear structure associated with watercourses will most likely serve as foraging corridors and residual structure within younger stands.

The lands excluded from the analysis (Fig. 2.1) have been subjected to the same changes in harvesting practices compared to the majority of GD's ownership and may show similar trends in the amount of future high quality nocturnal and nesting habitat. However, many of these excluded areas have substantial differences in basic forest structure and stand composition. Since data from these areas were not available for inclusion in the nocturnal and nesting resource selection models, it would be inappropriate to speculate on future trends in spotted owl habitat for the excluded areas.

Table 2.1. Area of Green Diamond Resource Company land (hectares) in spotted owl habitat, 1992 and 2002, as defined in the 1992 Northern Spotted Owl Habitat Conservation Plan and changes in the amount of spotted owl habitat as a function of increasing stand age and timber harvest.

Stand Age (yrs)	1992	Gain due to Increased Stand Age	Loss due to Timber Harvest	2002	Net Change
31-45	31,265	20,345	0	51,610	20,345
46+	33,111	16,400	-12,250	37,260	4,150
Owl habitat	64,375	36,745	-12,250	88,870	24,494

Table 2.2. Explanatory variables considered in modeling a resource selection function for northern spotted owl nocturnal activity on Green Diamond Resource Company land. Except where noted, all measurements were taken at a geographic point in the landscape. Variables in bold were calculated within a circular buffer (radius 250 m) centered on a point in the landscape. Variables preceded by an asterisk were dropped from the analysis due to colinearity with other variables (see text).

Variable	Description
6-20_yrs	indicator variable for age class of stand = 6 to 20 years
21-40_yrs	indicator variable for age class of stand = 21 to 40 years
41+_yrs	indicator variable for age class of stand = 41+ years
nearest_6-20_yrs	indicator variable for age class of nearest stand = 6 to 20 years
nearest_21-40_yrs	indicator variable for age class of nearest stand = 21 to 40 years
nearest_41+_yrs	indicator variable for age class of nearest stand = 41+ years
(y_yrs)·(z_nearest)	8 indicator variables for the interaction of age class of stand (y) by age class of nearest stand (z)
%_6-20_yrs	percentage of buffer in age class 6 to 20 years
%_21-40_yrs	percentage of buffer in age class 21 to 40 years
%_41+_yrs	percentage of buffer in age class 41+ years
**age*	age (yrs) of stand
dist_to_edge	distance to nearest edge (meters)
edge_density	edge density (m/ha) in buffer (edge defined as change in age class)
****total_edge***	total edge in buffer
mean_*patch_size*	mean patch size (ha) in buffer (patch defined as uniform age class)
****number_patches***	number of patches in buffer
patch_density	patch density (n/100 ha) in buffer
CV_patch	coefficient of variation (%) of patch sizes in buffer
dist_to_road	distance to nearest road (meters)
tree_height	height of trees (meters)
%_residual	% residual trees retained from a previous harvest
%_HW	% hardwood trees (e.g. tanoak, madrone, CA bay, etc.)
%_RW	% redwood trees
%_WW	% whitewood trees (e.g. Douglas-fir, grand fir, hemlock, etc.)
**residual_ba*	residual basal area (m/ha)
**HW_ba*	hardwood basal area (m/ha)
RW_ba	redwood basal area (m/ha)
WW_ba	whitewood basal area (m/ha)
**total_ba*	total basal area (m/ha)
predom_RW	indicator variable for predominate species = redwood
predom_WW	indicator variable for predominate species = whitewood
slope_position	slope position (%) with bottom = 0 and top of ridge = 1

Table 2.3. Top ranked resource selection models for nocturnal activity of northern spotted owls on Green Diamond Resource Company land. Models predict the relative probability, *w(x)*, of a northern spotted owl selecting a point in the landscape characterized by *x* for nocturnal activity. Models were ranked according to Schwarz Bayesian Criterion (SBC).

Rank	SBC	Resource Selection Model
1	26755.8	$w(x) = \exp\{0.25792(nearest\_6\text{-}20\_yrs) + 0.26918(nearest\_21\_40\_yrs) - 0.02632(nearest\_41+\_yrs) + 0.02686(\%\_41+\_yrs) - 0.0001953(\%\_41+\_yrs)^2 + 0.00479(\%\_HW) - 0.00966(slope\_position)\}$
2	26759.2	$w(x) = \exp\{-0.00079(dist\_to\_edge) + 0.01044(\%\_41+\_yrs) + 0.00469(\%\_HW) - 0.00880(slope\_position)\}$
3	26764.3	$w(x) = \exp\{0.25265(nearest\_6\text{-}20\_yrs) + 0.25861(nearest\_21\_40\_yrs) - 0.02779(nearest\_41+\_yrs) + 0.02617(\%\_41+\_yrs) - 0.00019(\%\_41+\_yrs)^2 + 0.00268(\%\_HW) + 0.00003(\%\_HW)^2 - 0.00960(slope\_position)\}$
4	26765.5	$w(x) = \exp\{-0.00075(dist\_to\_edge) + 0.00998(\%\_41+\_yrs) - 0.00060(\%\_HW) + 0.00007(\%\_HW)^2 - 0.00871(slope\_position)\}$
5	26766.5	$w(x) = \exp\{0.22298(nearest\_6\text{-}20\_yrs) + 0.27325(nearest\_21\_40\_yrs) - 0.06655(nearest\_41+\_yrs) + 0.02674(\%\_41+\_yrs) - 0.00019(\%\_41+\_yrs)^2 - 0.00954(slope\_position)\}$

Table 2.4. Estimated coefficients, standard errors (SE), Wald *t*-tests, selection ratios, and 95% confidence interval (CI) on selection ratios of variables in the top ranked resource selection model for nocturnal activity of northern spotted owls on Green Diamond Resource Company land. Selection ratios were not calculated for variables with both quadratic and linear terms in the final model because these selection ratios depend on values of the other variables.

					95% CI on Selection Ratio	
Variable	Estimate	(SE)	*t*-test	Selection Ratio	Lower	Upper
nearest_6-20_yrs	0.25792	0.05847	4.41	1.294	1.154	1.451
nearest_21_40_yrs	0.26918	0.08559	3.14	1.309	1.107	1.548
nearest_41+_yrs	– 0.02632	0.05947	– 0.44	0.974	0.867	1.094
%_41+_yrs	0.02686	0.00261	10.29	NA	NA	NA
%_41+_yrs^2	– 0.00020	0.00003	– 7.57	NA	NA	NA
%_HW	0.00479	0.00110	4.35	1.005	1.003	1.007
slope_position	– 0.00966	0.00082	– 11.77	0.990	0.989	0.992

Table 2.5. Descriptive statistics for continuous variables in the top ranked resource selection model for nocturnal activity of northern spotted owls on Green Diamond Resource Company land.

Variable	Minimum	Median	Mean	Maximum
%_41+_yrs	0.00	39.98	42.30	100.00
%_HW	0.00	18.00	19.76	95.00
slope_position	0.00	36.00	39.77	100.00

Table 2.6. Model validation for the top ranked resource selection model for northern spotted owl nocturnal activity using 5 owl home ranges from the North region of Green Diamond Resource Company land. Ninety-five percent confidence intervals for slope that are greater than 0 but include 1 indicate that the final model had good predictive abilities (owls 1, 3, and 5). Ninety-five percent confidence intervals greater than 1 (owl 2) indicate high correlation between observed and expected use but not a 1:1 relationship. Ninety-five percent confidence intervals that include 0 indicate no relationship between observed and expected use and indicate poor predictive abilities of the model (owl 4).

Owl				95% Confidence Interval	
Number	Intercept	Slope	SE(slope)	Lower	Upper
1	– 0.9973	1.20	0.29	0.59	1.81
2	– 3.8122	1.43	0.16	1.10	1.76
3	– 3.6989	1.52	0.54	0.40	2.65
4	4.9389	– 0.10	0.57	– 1.30	1.11
5	– 3.0822	2.76	0.88	0.92	4.61
Average		1.36			

Table 2.7. K-fold cross-validation for the top ranked resource selection model for northern spotted owl nocturnal activity on Green Diamond Resource Company land, using 32 simple random samples of 8 owl home ranges from both regions (North and South). Ninety-five percent confidence intervals that are greater than 0 but include 1 indicate that the model had good predictive abilities. Ninety-five percent confidence intervals greater than 1 indicate high correlation between observed and expected use but not a 1:1 relationship. Ninety-five percent confidence intervals that include 0 indicate no relationship between observed and expected use and indicate poor predictive abilities of the model.

Run	Number of Home Ranges	Average Slope	SE(slope)	95% Confidence Interval Lower	95% Confidence Interval Upper
1	8	1.08	0.36	0.22	1.94
2	8	1.18	0.38	0.27	2.08
3	8	1.35	0.38	0.45	2.25
4	8	0.89	0.16	0.53	1.26
5	8	1.11	0.27	0.48	1.74
6	8	1.50	0.31	0.76	2.24
7	8	0.84	0.32	0.09	1.59
8	8	1.61	0.32	0.85	2.38
9	8	0.53	0.27	-0.12	1.18
10	8	1.27	0.33	0.50	2.05
11	8	0.89	0.25	0.30	1.48
12	8	1.14	0.25	0.56	1.72
13	8	0.91	0.27	0.28	1.54
14	8	1.17	0.34	0.37	1.97
15	8	0.46	0.74	-1.28	2.20
16	8	1.78	0.24	1.21	2.36
17	8	0.89	0.28	0.23	1.56
18	8	1.37	0.33	0.59	2.14
19	8	1.34	0.19	0.90	1.78
20	8	1.13	0.39	0.20	2.05
21	8	0.62	0.20	0.15	1.09
22	8	1.20	0.25	0.61	1.79
23	8	1.24	0.16	0.85	1.62
24	8	1.00	0.29	0.32	1.68
25	8	1.30	0.19	0.86	1.74
26	8	1.85	0.35	1.02	2.69
27	8	0.85	0.45	-0.21	1.91
28	8	1.12	0.29	0.43	1.82
29	8	1.37	0.40	0.42	2.32
30	8	1.00	0.27	0.36	1.65
31	8	1.37	0.19	0.92	1.81
32	8	0.95	0.21	0.45	1.45
Average		1.13			

Table 2.8. Explanatory variables considered in models of northern spotted owl nest site selection on Green Diamond Resource Company land. Except where noted, all measurements were taken at a geographic point on the landscape. Variables in bold were taken from a circular buffer centered on a point whose radius was 400, 600, 800, or 1100 m. *Interior_area* was taken from the stand that contained the 1100 m buffer's center, and was calculated after removing 100 m from the stand's perimeter (see Methods). *Nta_hsi_400*, *nta_annulus_1*, and *nta_annulus_2* were calculated using circular buffers and annuli of different radii (see Methods and Fig. 2.6). Quadratic terms were considered for all variables except *managed*.

Variable	Description
managed	indicator for managed
age	age (yrs) of stand
dist_to_road	distance to road (meters)
slope_position	slope position (%)
%_HW	% hardwood
%_RWWW	% redwood + % whitewood
%_residual	% residual
open_edge_density_400	opening edge density (m/ha) in 400 m radius circular buffer[a]
open_edge_density_600	opening edge density (m/ha) in 600 m radius circular buffer[a]
open_edge_density_800	opening edge density (m/ha) in 800 m radius circular buffer[a]
open_edge_density_1100	opening edge density (m/ha) in 1100 m radius circular buffer[a]
patch_density_400	patch density (n/100 ha) in 400 m radius circular buffer[b]
patch_density_600	patch density (n/100 ha) in 600 m radius circular buffer[b]
patch_density_800	patch density (n/100 ha) in 800 m radius circular buffer[b]
patch_density_1100	patch density (n/100 ha) in 1100 m radius circular buffer[b]
mean_patch_size_400	mean patch size (ha) in 400 m radius circular buffer[b]
mean_patch_size_600	mean patch size (ha) in 600 m radius circular buffer[b]
mean_patch_size_800	mean patch size (ha) in 800 m radius circular buffer[b]
mean_patch_size_1100	mean patch size (ha) in 1100 m radius circular buffer[b]
interior_area	amount of 'interior' habitat in patch at center (hectares) [b]
nta_hsi_400	average owl nocturnal activity habitat suitability index in 400 m radius buffer
nta_annnus_1	average owl nocturnal activity habitat suitability index in annulus with outer radius = 800 m and inner radius = 400 m
nta_annnus_2	average owl nocturnal activity habitat suitability index in annulus with outer radius = 1100 m and inner radius = 800 m

[a] "Open" defined as age <6 yrs or non-forest.

[b] "Patch" defined as uniform age class; age classes defined as: 0-5, 6-20, 21-40, 41-60, 61-80, and 81+ yrs old.

Table 2.9. Rankings of all nest site selection models for northern spotted owls on Green Diamond Resource Company land, based on Schwartz's Bayesian Criterion (SBC). Models were chosen by best subsets selection with SBC weights ≥0.001. Direction of the relationship between relative probability of selection and each variable in a model is indicated by a '+' (positive) or '-' (negative) sign.

Model	SBC	SBC Weight	managed	(age)x(managed)	(age^2)x(managed)	slope_position	$slope\_position^2$	(%_residual)x(managed)	$(\%_residual^2)$x(managed)	open_edge_density_600	$open\_edge\_density\_600^2$	open_edge_density_800	$open\_edge\_density\_800^2$	open_edge_density_1100	% HW	$\% HW^2$	patch_density_600	nta_hsi_400	$nta\_hsi\_400^2$
1	2842.26	0.431	-	+				+	-	+					+	-		+	-
2	2843.78	0.201	-	+				+	-			+			+	-		+	-
3	2844.70	0.127	-	+						+					+	-		+	-
4	2845.79	0.074	-	+	-			+	-	+					+	-		+	-
5	2845.86	0.071	-	+								+			+	-		+	-
6	2846.71	0.047	-	+				+	-					+	+	-		+	-
7	2848.65	0.018	-	+										+	+	-		+	-
8	2850.10	0.009	-	+		-									+	-		+	-
9	2850.55	0.007	-	+		-		+	-						+	-	+	+	-
10	2850.92	0.006	-	+		+	-								+	-		+	-
11	2851.01	0.005	-	+		+	-	+	-						+	-	+	+	-
12	2852.96	0.002	-	+				+	-	+	-				+	-		+	-
13	2855.14	0.001	-	+								+	-		+	-		+	-
14	2855.44	0.001	-	+						+	-				+	-		+	-

Table 2.10. Importance values for every variable in the 74 models of northern spotted owl nest site selection on Green Diamond Resource Company land, chosen by best subset selection. Importance values are the sum of Schwarz Bayesian Criterion weights from all models containing the variable. 'Number of Models' is the number of models, out of 74, that contained the variable.

Variable	Number of Models	Importance Value
managed	69	1.0000
(age) x (managed)	69	1.0000
%_HW	61	1.0000
%_HW^2	59	1.0000
nta_hsi_400	40	1.0000
nta_hsi_400^2	32	1.0000
(%_residual) x (managed)	45	0.7680
(%_residual^2*) x (managed)*	45	0.7680
open_edge_density_600	13	0.6346
open_edge_density_800	8	0.2732
(age^2*) x (managed)*	19	0.0738
open_edge_density_1100	2	0.0644
slope_position	10	0.0265
patch_density_600	19	0.0125
slope_position^2	5	0.0111
open_edge_density_600^2	2	0.0026
open_edge_density_800^2	1	0.0007
open_edge_density_400	9	0.0004
nta_annulus_2	31	<0.0001
nta_annulus_2^2	19	<0.0001
%_RWWW	11	<0.0001
%_RWWW^2	11	<0.0001
open_edge_density_400^2	2	<0.0001
nta_annulus_1	1	<0.0001

Table 2.11. Estimated coefficients, standard errors (SE), Wald *t*-tests, selection ratios, and 95% confidence interval (CI) on selection ratios of variables in the top ranked nest site selection model for northern spotted owls on Green Diamond Resource Company land. Selection ratios were not calculated for variables with both quadratic and linear terms in the final model because these selection ratios depend on values of the other variables.

					95% CI on Selection Ratio	
Variable	Estimate	(SE)	*t*-test	Selection Ratio	Lower	Upper
managed	-1.86937	0.32497	-5.75	0.154	0.082	0.292
(age)x(managed)	0.02636	0.00391	6.74	1.027	1.019	1.035
(%_residual)x(managed)	0.05983	0.01210	4.94	na	na	na
(%_residual^2)x(managed)	-0.00054	0.00015	-3.64	na	na	na
nta_hsi_400	0.00298	0.00055	5.42	na	na	na
nta_hsi_400^2	-2.891E-07	7.743E-08	-3.73	na	na	na
open_edge_density_600	0.01514	0.00289	5.24	1.015	1.010	1.021
%_HW	0.02999	0.00961	3.12	na	na	na
%_HW^2	-0.00048	0.00011	-4.44	na	na	na

Table 2.12. Descriptive statistics for each variable in the top ranked model of northern spotted owl nest site selection on Green Diamond Resource Company land.

Stand Age	Variable	Minimum	Median	Mean	Maximum
Managed (n = 159)					
	age	0	28	30	119
	nta_hsi_400	757	2187	2394	6811
	open_edge_density_600	0	10	19	140
	%_residual	0	0	3	100
	%_HW	0	26	31	100
Unmanaged (n = 20)					
	nta_hsi_400	1358	3427	3463	6708
	open_edge_density_600	0	11	18	92
	%_HW	0	56	49	96

Table 2.13. Area of Green Diamond Resource Company land in each of five categories of relative probability of selection based on the spotted owl resource selection model for nocturnal activity, 1992, 2002, 2012, and 2002. Category break points (column 2) were defined to guarantee 20% ownership in each class during 1992. The same break points were applied to predicted values for subsequent years.

Nocturnal Activity Relative Probability of Selection	Category		Total Area 1992		2002		2012		2022	
			%	ha	%	ha	%	ha	%	ha
≥ 3027	5	High	20	18,032	25	22,579	39	33,712	44	38,623
2276 to 3027	4		20	17,962	20	17,728	20	16,968	20	17,541
1796 to 2276	3	Med.	20	17,849	19	16,635	16	13,810	14	12,568
1385 to 1796	2		20	17,814	18	16,132	13	11,407	11	9,356
0 to 1385	1	Low	20	17,823	18	16,407	13	11,062	10	8,871
	Total		100	89,480	100	89,480	100	86,959	100	86,959

Table 2.14. Area of Green Diamond Resource Company land in each of five categories of relative probability of selection based on the spotted owl nest site selection model, 1992, 2002, 2012, and 2002. Classification break points (column 2) were defined to guarantee 20% ownership in each class during 1992. The same break points where applied to predicted values for subsequent years.

Nesting Relative Probability		Total Area							
		1992		2002		2012		2022	
of Selection	Category	%	ha	%	ha	%	ha	%	ha
≥ 175	5 High	20	17,898	26	23,560	42	36,623	54	47,295
55 to 175	4	20	17,897	20	17,754	24	20,563	22	18,859
25 to 55	3 Med.	20	17,896	17	15,651	13	11,672	10	8,580
12 to 25	2	20	17,898	19	16,612	12	10,526	8	6,960
0 to 12	1 Low	20	17,897	18	15,909	9	7,579	6	5,269
	Total	100	89,486	100	89,486	100	86,964	100	86,964

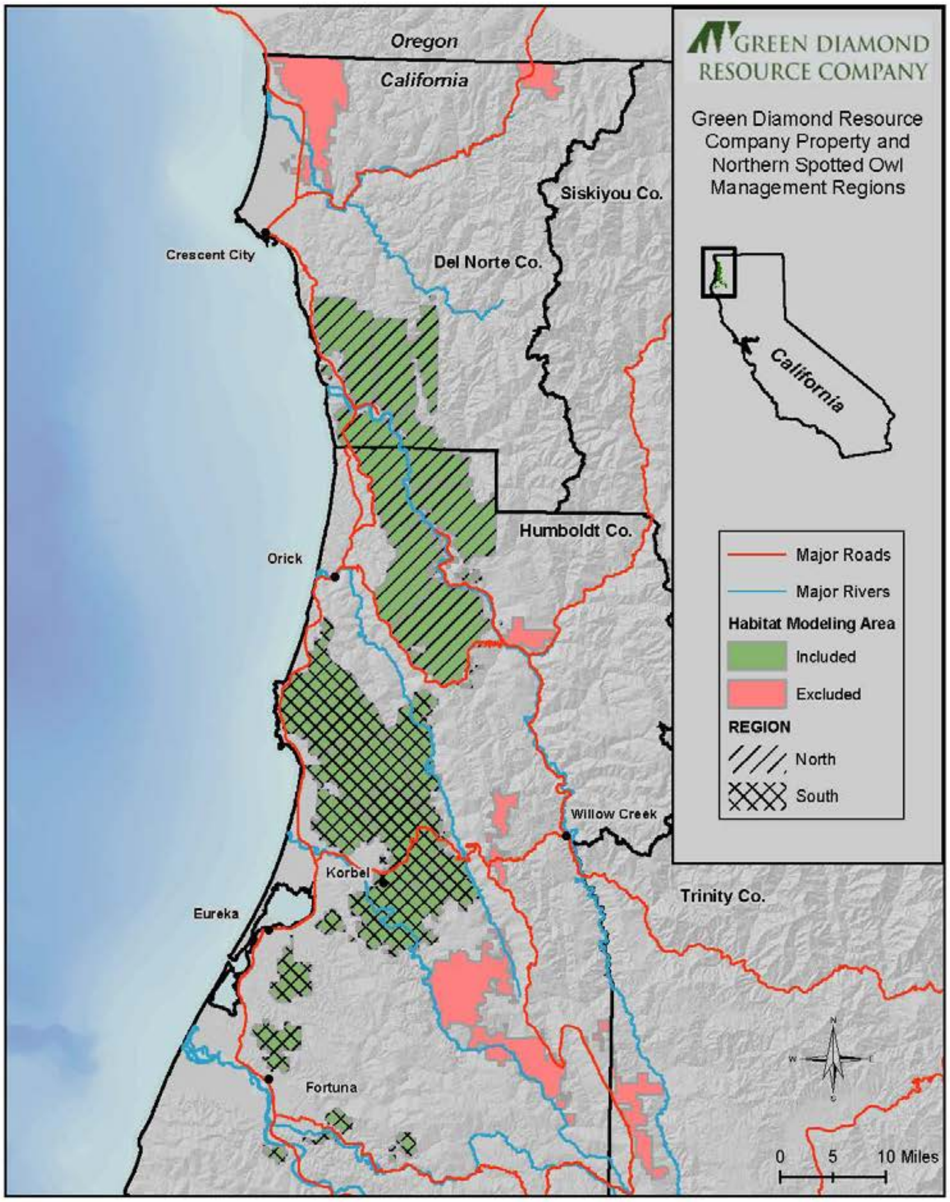


Figure 2.1. Location of Green Diamond Resource Company land, indicating the area for which Northern Spotted Owl resource selection functions were developed.

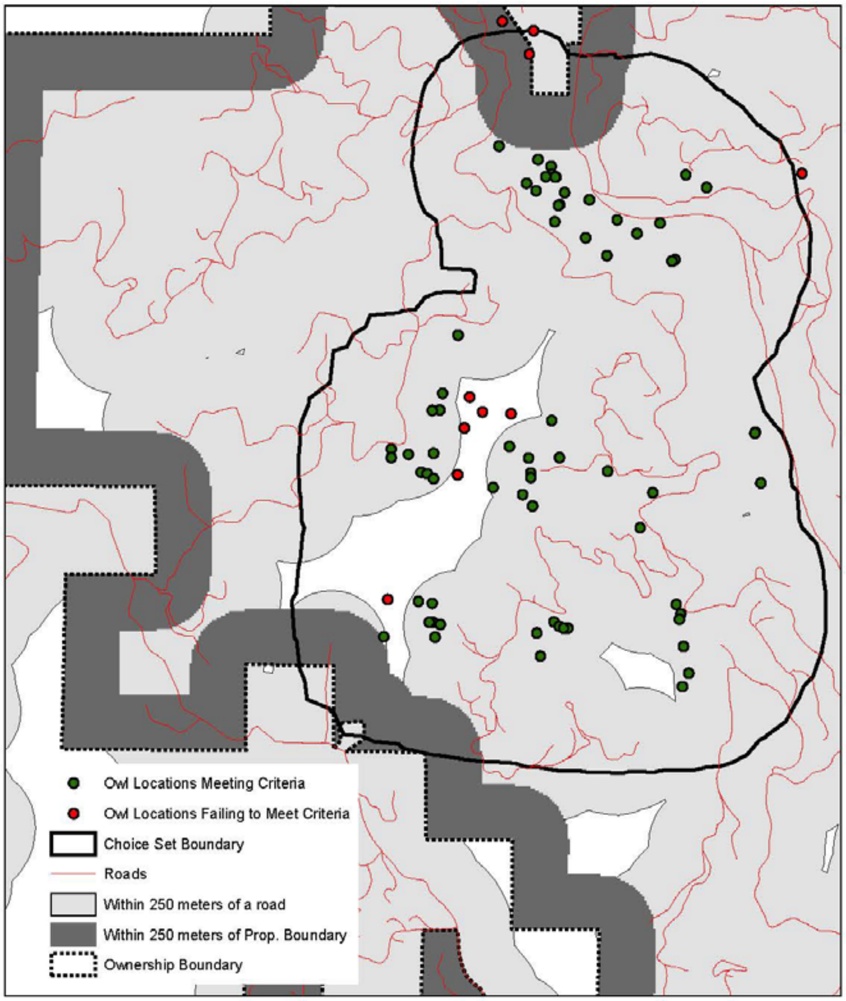


Figure 2.2. Example of the spatial requirements for used and random locations to be included in estimation of a resource selection function for Northern Spotted Owl nocturnal activity on Green Diamond Resource Company land. Locations within each home range were required to be >250 m (820 ft) from property boundaries and ≤250 m from any road.

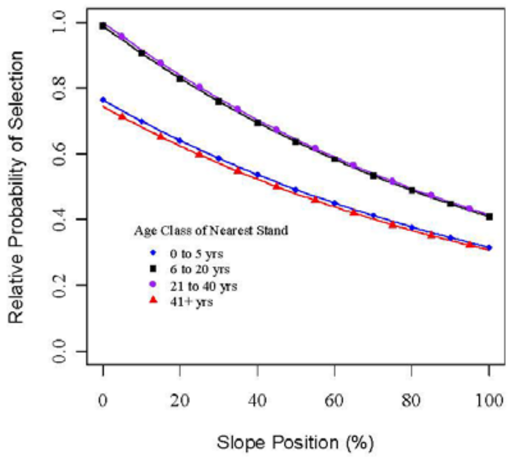


Figure 2.3. Relative probability of a Northern Spotted Owl selecting a point in the Green Diamond Resource Company landscape for nocturnal activity, as a function of slope position. Relative probabilities were predicted from the final nocturnal resource selection function. Levels of variables not in the plot were held constant at their median values (Table 2.5).

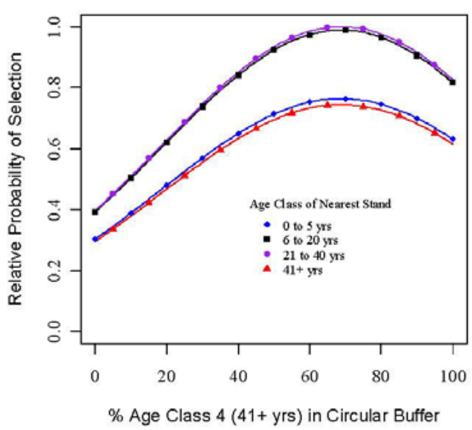


Figure 2.4. Relative probability of a Northern Spotted Owl selecting a point in the Green Diamond Resource Company landscape for nocturnal activity, as a function of percent of circular buffer composed of age class 4 stands (41+ yrs old). Relative probabilities were predicted from the final nocturnal resource selection function. Levels of variables not in the plot were held constant at their median values (Table 2.5).

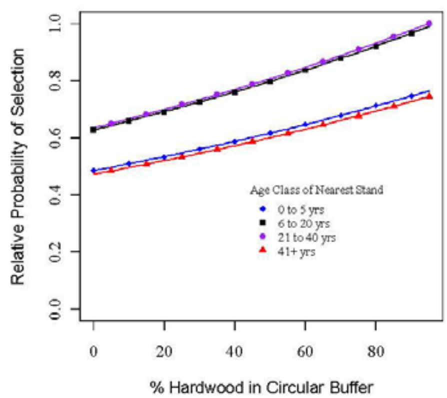


Figure 2.5. Relative probability of a Northern Spotted Owl selecting a point in the Green Diamond Resource Company landscape for nocturnal activity, as a function of percent of circular buffer composed of hardwood stands. Relative probabilities were predicted from the final nocturnal resource selection function. Levels of variables not in the plot were held constant at their median values (Table 2.5).

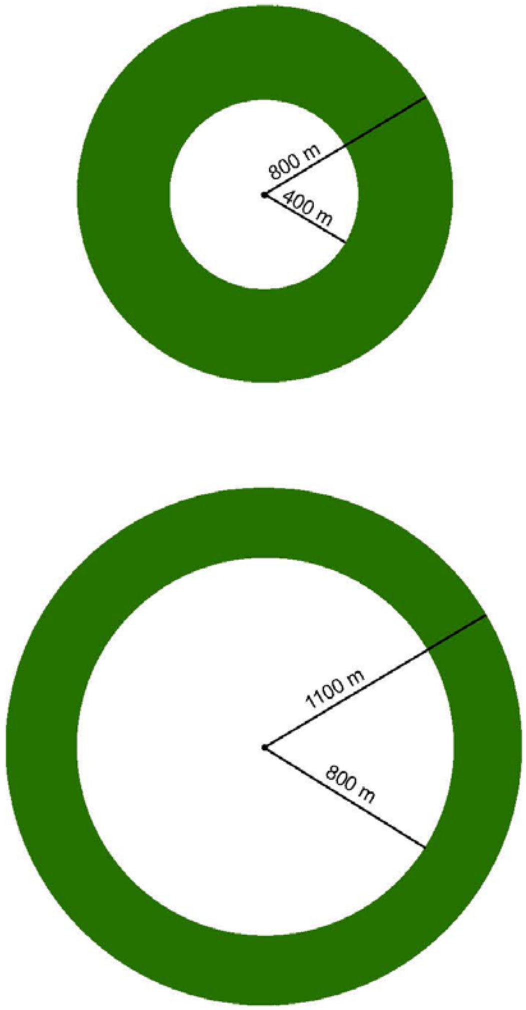


Figure 2.6. Schematic illustration of the disk and annuli used to compute average *nta_annuli* values on Green Diamond Resource Company land. Average *nta_hsi* values were calculated first on the buffer of radius 400 m (i.e., the center disk at top), then on the annulus with inner radius 400 m and outer radius 800 m (top), and finally on the annulus with inner radius 800 m and outer radius 1100 m (bottom).

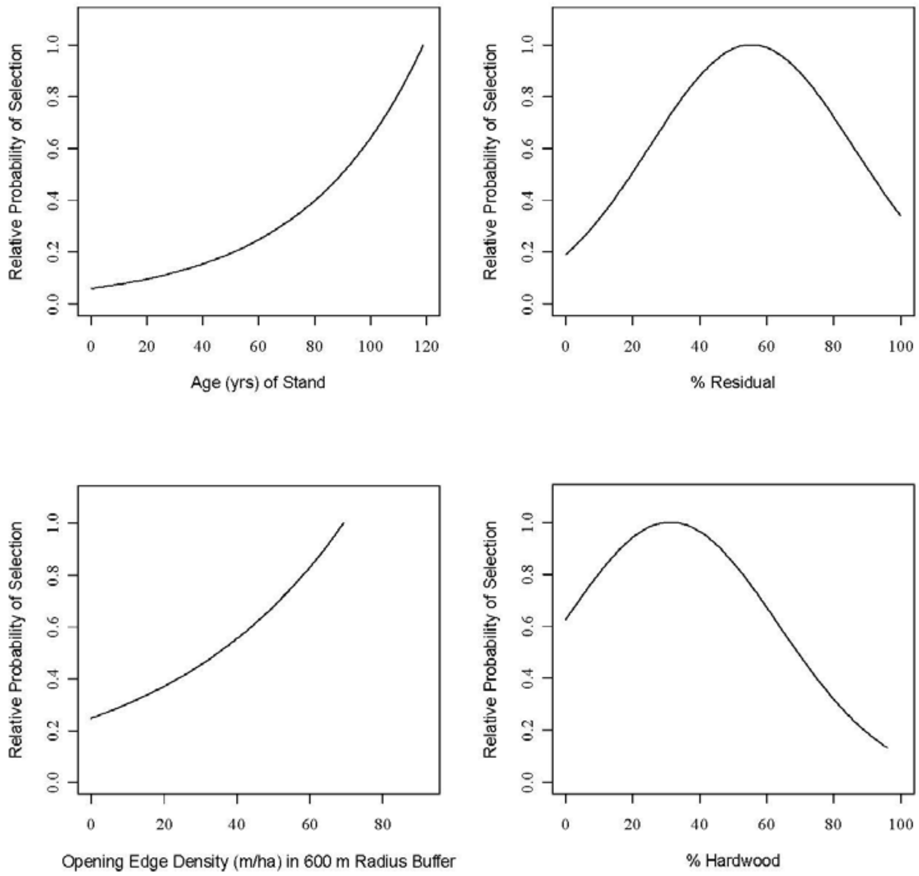


Figure 2.7. Relative probability of a Northern Spotted Owl selecting a point in the landscape for a successful nest in a managed stand on Green Diamond Resource Company land, as a function of the age of stand (upper left), % residual (upper right), opening edge density in the 600 m radius buffer (lower left), and percent hardwood (lower right). Relative probabilities were predicted from the final spotted owl nest site selection model. Levels of variables not in the plots were held constant at their median values (Table 2.13).

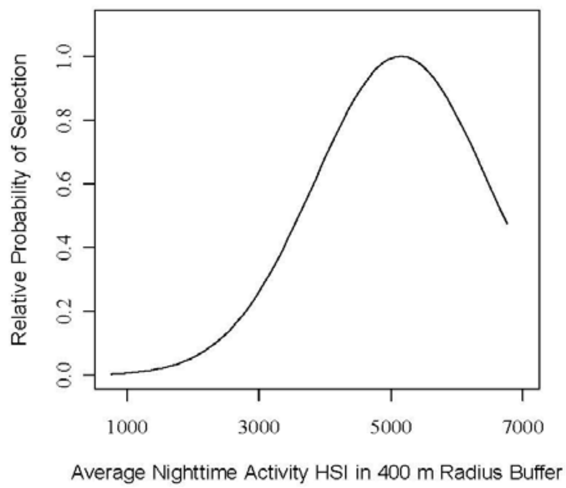


Figure 2.7, continued. Relative probability of a Northern Spotted Owl selecting a point in the landscape for a successful nest in a managed stand on Green Diamond Resource Company land as a function of the average nocturnal activity HSI in the 400 m radius buffer. Relative probabilities were predicted from the final spotted owl nest site selection model. Levels of variables not in the plot were held constant at their median values (Table 2.13).

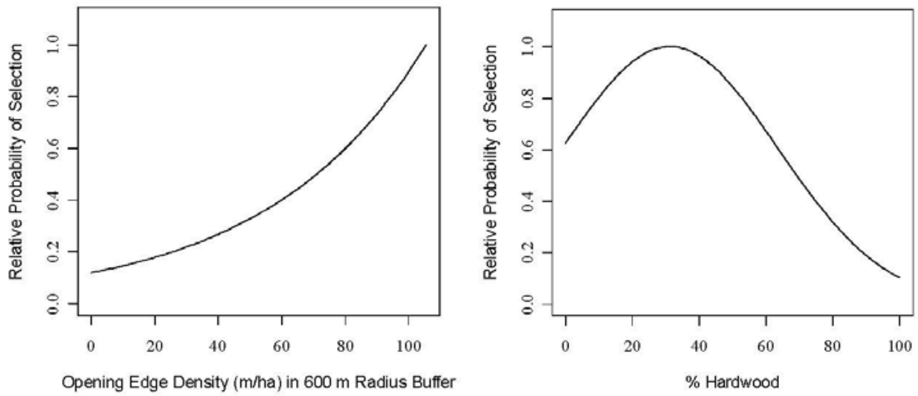


Figure 2.8. Relative probability of a Northern Spotted Owl selecting a point in the landscape for a successful nest in an old growth stand on Green Diamond Resource Company land, as a function of opening edge density in the 600 m radius buffer (left), and percent hardwood (right). Relative probabilities were predicted from the final spotted owl nest site selection model. Levels of variables not in the plots were held constant at their median values (Table 2.13).

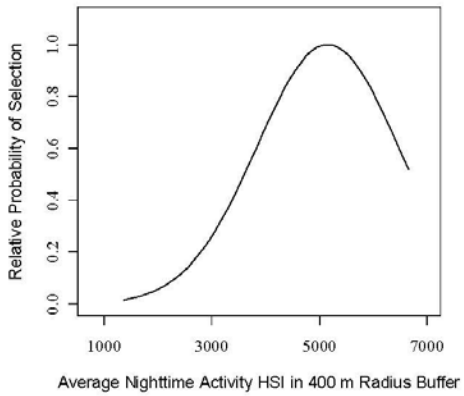


Figure 2.8, continued. Relative probability of a Northern Spotted Owl selecting a point in the landscape for a successful nest in an unmanaged stand on Green Diamond Resource Company land as a function of the average nocturnal activity HSI in the 400 m radius buffer. Relative probabilities were predicted from the final spotted owl nest site selection model. Levels of variables not in the plot were held constant at their median values (Table 2.13).

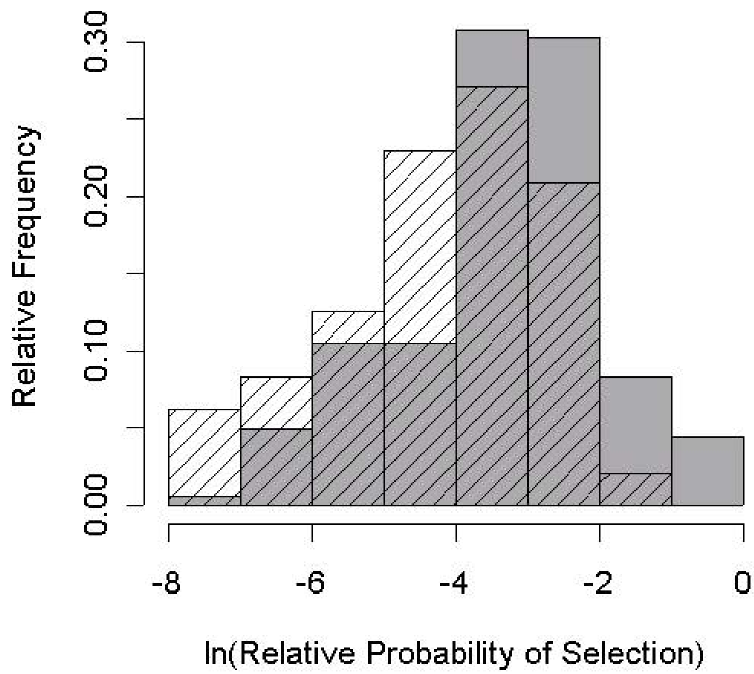


Figure 2.9. Natural log of the relative probability of selection for successful nests (grey bars) and unsuccessful nests (open bars with 45-degree lines) by Northern Spotted Owls on Green Diamond Resource Company land.

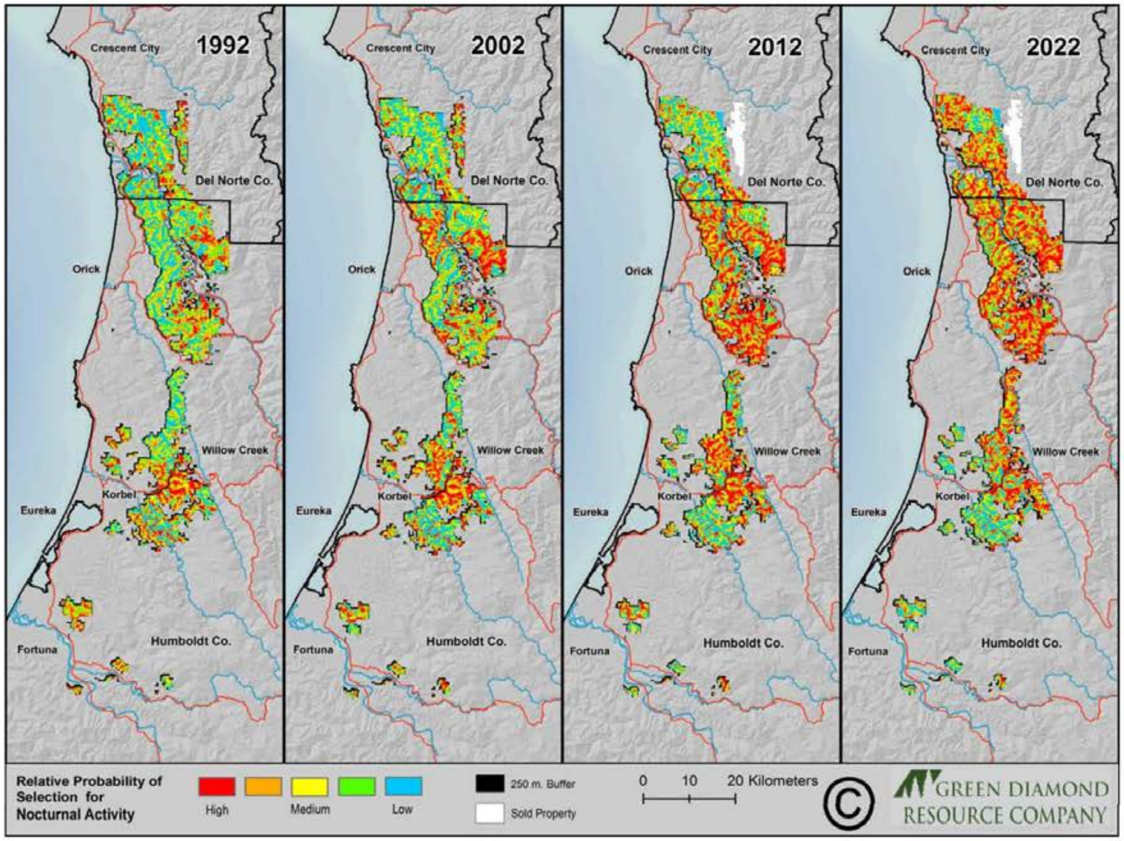


Figure 2.10. Relative probability of a Northern Spotted Owl selecting a site for nocturnal activity on Green Diamond Resource Company land in 1992, 2002, 2012, and 2022. Mapped area is limited to regions considered in analyses.

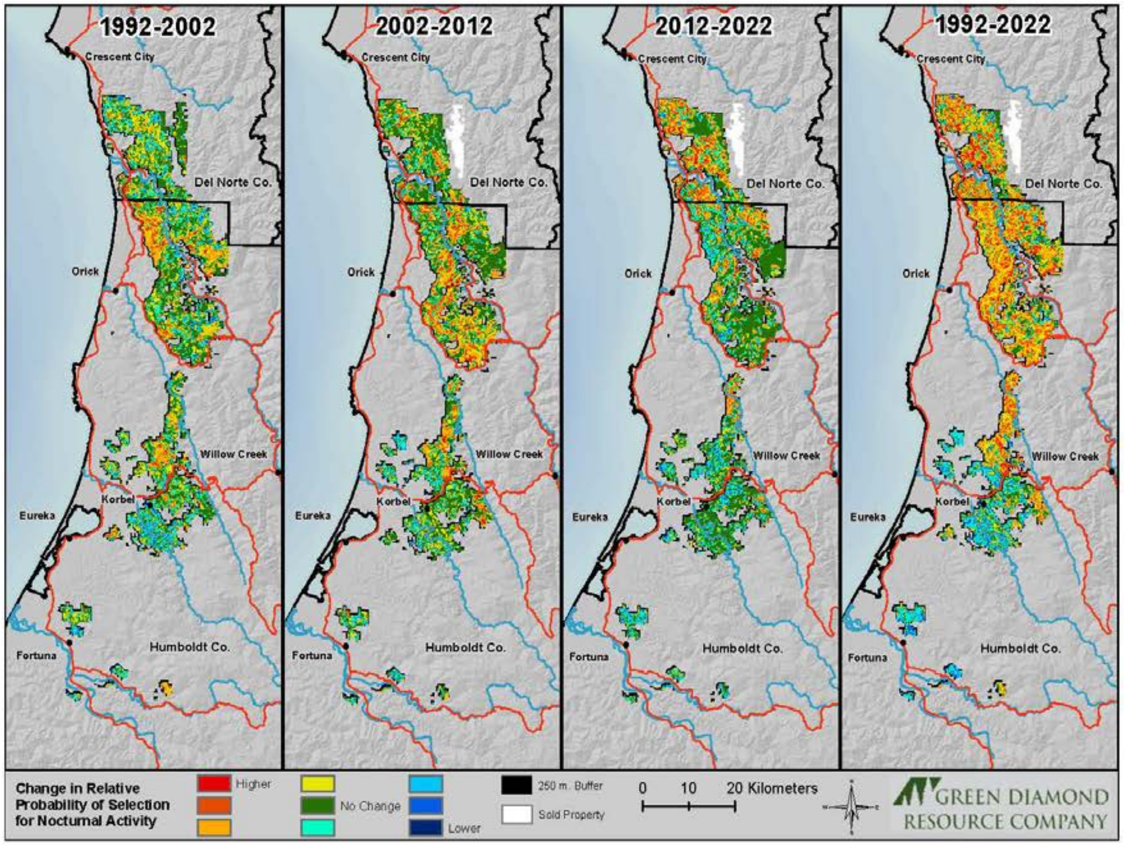


Figure 2.11. Change in relative probability of nocturnal site selection by Northern Spotted Owls on Green Diamond Resource Company land at 10-year intervals and over 30 years from 1992 to 2002.

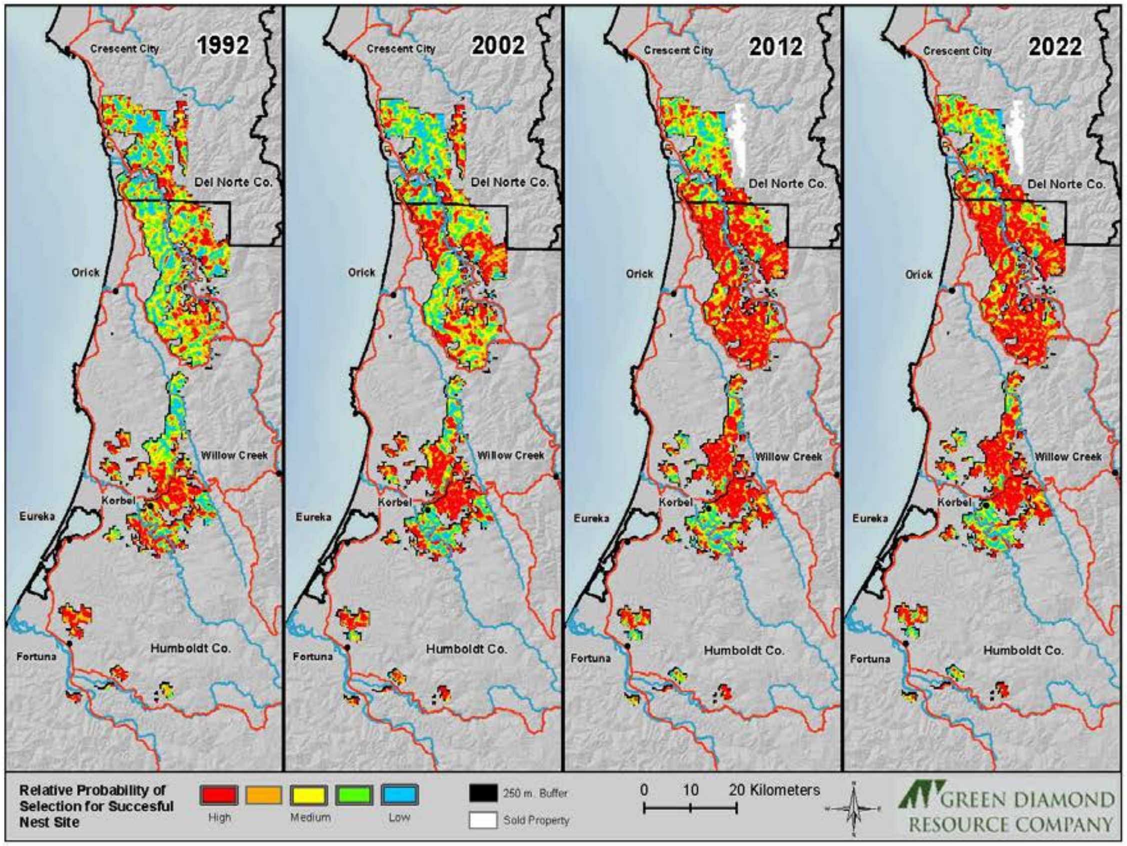


Figure 2.12. Relative probability of a Northern Spotted Owl selecting a successful nest site on Green Diamond Resource Company land in 1992, 2002, 2012, and 2022. Mapped area is limited to regions considered in analyses.

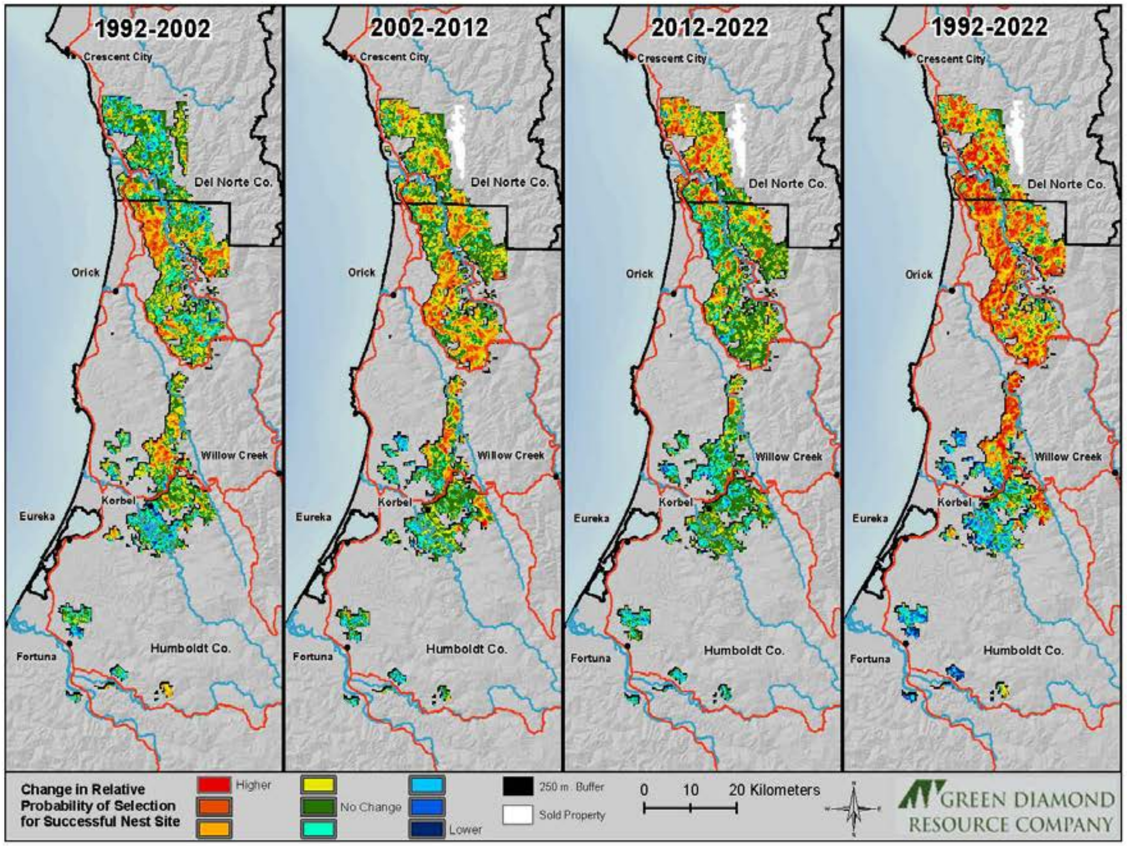


Figure 2.13. Change in relative probability of nest site selection by Northern Spotted Owls on Green Diamond Resource Company land at 10-year intervals and over 30 years from 1992 to 2002.

CHAPTER 3 – BIOLOGY

This chapter is based on the requirement for "a reevaluation of the biological basis for the conservation strategy based on the data collected through the research program and other sources." This chapter provides an overview of all known studies conducted within Green Diamond Resource Company's (GD) land or other studies within the range of the Northern Spotted Owl, which are relevant to the Habitat Conservation Plan (HCP) conservation strategy.

3.A Northern Spotted Owl Diet

Spotted owl diets are easily inferred from analysis of pellets (egested prey remains) found below owl nesting and roosting sites. Five studies have reported the frequency of prey items and the relative biomass of prey items at 13 study sites from across the range of the northern spotted owl (Cutler and Hays 1991, Ward et al. 1997, Forsman et al. 2001, Hamer et al. 2001, Forsman et al. 2004). Across studies, small mammals made up 81-98% of the prey items and 81-99% of biomass consumed by owls. Northern flying squirrels (*Galucomys sabrinus*) were the primary prey species in the Olympic Peninsula (1 study area), Washington Cascades (3 study areas), Oregon Cascades (4 study areas), and 2 of 3 study areas in the Oregon Coast Range, comprising 29-52% of prey items and 45-75% of prey biomass. Woodrats (*Neotoma* spp.) dominated the diet in the Oregon and California Klamath province (1 study area each), comprising 28-39% of prey items and 49-71% of prey biomass. In the southern Oregon Coast range (1 study area), flying squirrels made up 36% and woodrats made up 18% of prey items, but each prey group made up 37-39% of prey biomass.

Rabbits (primarily *Sylvilagus bachmani* – brush rabbit) and/or hares (primarily *Lepus americanus* – snowshoe hare) were important components of spotted owl diets, especially in Oregon and Washington, where they comprised up to 16% of prey biomass. Microtine voles (*Microtus* spp.), comprised up to 10% of prey biomass, pocket gophers (*Thomomys* spp.) comprised up to 9% of prey biomass, western red backed voles (*Clethrionomys californicus*) comprised up to 8% of prey biomass, American pikas (*Ochotona princeps*) comprised up to 6% of prey biomass, and deer mice (*Peromyscus* spp.) comprised up to 5% of prey biomass on individual study areas (Cutler and Hays 1991, Ward et al. 1997, Forsman et al. 2001, Hamer et al. 2001, Forsman et al. 2004).

Other prey groups found in owl pellets and comprising 0-5% of prey biomass in each study area include shrews (*Sorex* spp), shrew-moles (*Neurotrichus gibbsii*), moles (*Scapanus* spp.), bats (*Chiroptera*), Douglas squirrels (*Tamiasciurus douglasii*), chipmunks (*Tamias* spp.), gray squirrels (*Sciurus griseus*), tree voles (*Arborimus* spp.), heather voles (*Phenacomys intermedius*), frogs, snakes, snails, insects, crayfish, and a scorpion (Cutler and Hays 1991, Ward et al. 1997, Forsman et al. 2001, Hamer et al. 2001, Forsman et al. 2004). Forsman et al. (2004; Appendix) listed 49 mammalian and 41 avian species found in owl pellets in Oregon.

Although woodrats and/or flying squirrels are the primary component of the northern spotted owl's diet, there is evidence that secondary species may be seasonally important and/or influence spotted owl survival and reproduction. For example, predation by spotted owls on snowshoe hares in Washington occurred mostly in spring and summer. Rosenberg et al. (2003) found that deer mouse abundance was positively associated with spotted owl reproductive success in western Oregon ($r^2 = 0.68$), even though deer mouse made up < 2% of the owl diet over all years (0-4% in each of 9 years).

Home range size of northern spotted owls was shown to be linked to the owls' primary prey in the Klamath province of southern Oregon and northern California (Zabel et al. 1995). Home ranges were larger where flying squirrels dominated the diet, and smaller where dusky-footed woodrats (*Neotoma fuscipes*) dominated the diet. This was attributed to the larger body size and higher population density of the woodrats (Zabel et al. 1995).

3.A.1 Northern Spotted Owl Diet on Green Diamond Resource Company Land

As noted above, the diet of spotted owls varies throughout its range. This has the potential to have a variety of ecological impacts on owl populations including influencing home range size (Zabel et al. 1995) and habitat selection (see Section 2.B). The objective of this study was to determine the specific prey species utilized by spotted owls on GD's managed timberlands.

Methods

Beginning in 1989, we collected regurgitated pellets opportunistically during spotted owl demographic studies and other spotted owl surveys pursuant to GD's NSO Habitat Conservation Plan (HCP). Pellets were collected below roosts or nest sites during breeding season site visits or whenever spotted owls were encountered as part of HCP surveys. Consequently, not all collections were from spotted owls with established territories. Pellets were placed in small plastic bags, labeled, and frozen. Pellets were periodically dissected for content analysis. Where possible, pellet contents were identified to species or placed in categories at the most detailed taxonomic level possible. Pellet contents were also examined for hair fragments of species that may be underrepresented by bone fragments and teeth (e.g. brush rabbits, *Sylvilagus bachmanii*). A collection was comprised of ≥1 regurgitated pellet or prey item collected at a specific site or area during a survey or site visit. A paucity of collections in certain years prevented comparisons between all years and prey species. Therefore, collections were combined as "time periods" one through three. Years 1989-1993 were time period one, 1994-1998 period two, and 1999-2004 period three. GD ownership was divided into four geographic areas for analysis: Klamath, Korbel, Upper Mad River and Redwood Creek. These areas represented latitudinal as well as longitudinal differences in vegetation types and forest age classes. For reporting purposes and due to difficulty in identification of all prey items to species, we organized pellet contents into seven major groups of species (Table 3.1). Data were summarized as percent composition and percent biomass for all sites combined. Calculations of prey biomass were made from data presented in Forsman (1984) and from in-house data collection on woodrats by multiplying mean weights of species by the number of individuals indentified. We examined differences in observed and expected counts of species and species group occurrences between years, time periods and geographic areas using a Chi-square test of independence.

Results

From 1989-2004 we made 965 collections that were composed of 3,056 identifiable prey items

($\bar{x}$ =1.40, SE = 2.15) on the GD study area. A minimum of 32 different animal species (Appendix A) were identified in the pellets collected at 245 different owl sites or locations across the study area. Mammals represented 93.8% of the diet, birds 4.0%, insects 1.5% and reptiles 0.7%. The overall mean weight of prey items was 150.5g (SE = 2.0). The major species or groups identified and percent composition of the diet is shown in Table 3.1. Rodents and insectivores comprised 90.8% of the owls' diets. Birds, lagomorphs and other prey items accounted for the remaining 9.2%. Many of the avian prey could not be identified to species, but band-tailed pigeon (*Columba fasciata*) and Stellar's jay (*Cyanocitta stelleri*) were two notable species of avian prey. The most common rodent species in the diets was the dusky-footed woodrat (*Neotoma fuscipes*) with 48.4% frequency and 73.9% of the biomass. Woodrats were present in pellets collected at 89.8% of the owl sites or collection locations. The northern flying squirrel (*Glaucomys sabrinus*) occurred at a frequency of 10.0%, comprised 7.7% of the biomass and was found at 53.5% of the owl sites or locations. The Sonoma tree vole (*Arborimus pomo*) and red tree vole (*A. longicaudus*) comprised 16.3% of the diet, 2.9% of the biomass and were found at 50.2% of the sites or locations. The brush rabbit was the primary lagomorph present in the diet with 2.7% of the frequency and 8.9% of the biomass. Lagomorphs occurred at 24.9% of the sites. Deer mice (*Peromyscus maniculatus*) were present but in relatively low frequency (5.0%) and biomass (0.7%) but they occurred at 33.9% of the sites.

Table 3.1. Percent frequency and percent biomass of major animal species or species group identified from 3,056 prey items in 965 collections of regurgitated northern spotted owl pellets collected on the Green Diamond Resource Company study area, 1989-2004.

	Neotoma	*Sylvilagus*	*Glaucomys*	*Arborimus*	Aves	*Peromyscus*	OSRI[1]	Other[2]
% frequency	48.4	2.7	10.0	16.3	4.0	5.0	11.1	2.5
% biomass	73.9	8.9	7.7	2.9	1.8	0.7	3.9	0.2

[1] OSRI (Other Small Rodent or Insectivore)
[2] Other (Insecta, Chiroptera, Mustelidae, Teleolstei, Reptilia)

The chi-square tests for independence of observations resulted in rejection of the null hypothesis of no difference when comparing species observed and expected occurrences across years, time periods and geographic areas. The analysis of time periods indicated a significant difference in species occurrences across the three time periods ($\chi2 = 60.29$, $P = 0.000$, d.f. = 14). The prey species groups that varied the most over time (greatest chi-square contribution) were Aves, OSRI and Other. The presence of tree voles also appeared to be variable over time with more observations than expected in the second time period. The most common prey item, dusky-footed woodrats, showed the least amount of variation over time. The analysis of geographic areas also showed a significant difference in observed and expected counts of prey items across the four regions ($\chi2 = 143.72$, $P = 0.000$, d.f. = 21). The species that exhibited the greatest amount of variation across geographic areas were tree voles, flying squirrels, OSRI and brush rabbits. Birds, dusky-footed woodrats, and Other exhibited the least amount of variation across areas. A chi-square test for independence between the three most common rodent species (tree voles, flying squirrels and woodrats) and all other species combined from 1989-2000, resulted in a significant difference in observations across years ($\chi 2 = 159.21$, $P = 0.000$, d.f. = 33). The analysis of annual data for tree voles, flying squirrels, woodrats and Other from 1989-2000, indicated that the occurrence of woodrats in diets varied the least over this 12-yr period. Tree voles showed the greatest amount of variation over the 12-yr period, followed by flying squirrels.

Discussion

Composition of Diet

In our study area, spotted owl diets consisted of a variety of small mammals, birds, reptiles and insects. Our results were similar to other studies where small mammals dominated the diets but a few species in particular contributed to the majority of the biomass and frequency. Our results of the prey base analysis are consistent with other studies within the California range of the northern spotted owl where woodrats predominate. Barrows (1980) found that dusky-footed woodrats were the predominant prey item in northern California and that northern flying squirrels and tree voles ranked second and third respectively in biomass. Zabel et al. (1995) found that woodrats were the most frequently encountered prey items in the northern California portion of their study area. Similarly, Smith et al. (1999) found that dusky-footed woodrats dominated the diets of California spotted owls in terms of frequency and biomass. Our results closely mirrored those of Smith (1999) in frequency of woodrats and overall biomass of mammals. In our study area, the dusky footed woodrat dominated the diets comprising almost three-fourths of the biomass. In southwestern Oregon, Cutler and Hays (1991) found that northern flying squirrels dominated the diets at four high elevation sites. They also found that bushy-tailed woodrats (*Neotoma cinerea*) were an important component of the diet biomass. Rosenberg et al. (2003) also found that northern flying squirrels dominated the diets in western Oregon. Leporids and bushy-tailed woodrats were other important components of the diet in overall biomass. Forsman et al. (2004a) reported that spotted owl diets in Oregon were dominated by mammals with northern flying squirrels most numerous across their seven regional study areas. Woodrats were most important in the interior southwest and south coast regions of their study and red tree voles were important in the south coast and central coast areas. The interior southwest and south coast regions were nearest to our study area. Zabel (1995) also found that northern flying squirrels and woodrats were taken in similar numbers in their northernmost California study area and flying squirrels and red tree voles dominated the Oregon study area. In Washington, Forsman et al. (2001) found that northern flying squirrels were the most important prey item in most areas. Northern flying squirrels were the third most frequent species encountered in diets in our study area and analyses across regions indicated that flying squirrels were more abundant in diets in the Klamath region (from the Klamath River north to the Oregon border) indicating a similar shift in prey as observed in other studies. The three most common species in the diet (woodrat, tree vole and flying woodrat) are arboreal or semi-arboreal, consistent with the observation that spotted owls spend most of their time foraging in the forest canopy (Forsman 1984, 2001), although it is unknown where the prey were located at the time of capture.

Annual Variation

In our analysis, the observed variation in diets of spotted owls across time periods and years is likely due to annual fluctuations in prey species abundance. However, this variation does not appear to represent large shifts in the owls' diets from one prey species to another. We do not have annual data on prey species abundance to compare with percentages represented in the diets. Similar to our observation that woodrats varied the least over time, Smith (1999) found that the percentage of woodrat biomass in diets of California spotted owls did not differ among years. The variation in numbers of birds taken between time periods in our study could be a result of opportunistic prey switching in certain years when some species of birds were more abundant. We were not able to analyze the contribution of birds to diets on an annual basis or determine which species were more abundant, but their frequency in the diet could be related to climatic conditions that favor greater reproductive success for bird species and subsequently a more abundant prey source for spotted owls. Small mammals (mainly rodents and insectivores) and "Other" prey items exhibited more variation than the two most abundant prey species, woodrats and flying squirrels. However, combining the data into time periods will likely mask any substantial annual fluctuations in prey species abundance. We could not analyze all years separately due to a low number of collections toward the end of the study period, but annual comparisons of the more prolific prey species over decade one suggested that tree voles and northern flying squirrels exhibited greater variation than woodrats and all other prey species combined. The variation in tree voles over time is consistent with the observation of others regarding annual fluctuations in populations of Microtine rodents (Pugh et al. 2003). We have anecdotal observations that vole nests were rather ephemeral and data from Thompson and Diller (2001) indicated that the median persistence of vole nests was 28.6 months with $P < 0.1$ for a nest to persist more than 60 months. In Washington, Forsman et al. (2001) observed small changes in the annual diets of owls at certain territories where the primary source of biomass shifted from flying squirrels to snowshoe hares, and in Oregon Forsman et al. (2004) observed similar small annual fluctuations overall, but red tree voles and deer mice did have larger fluctuations in frequency at certain territories. Their data did not suggest large annual changes in relative abundance of different prey items across the regions. We suspect some bias in the pellet collections in that territories where pairs successfully reproduce may tend to over represent the prey items being taken because these owls are more easily located than non-nesting owls and a greater number of pellets can be collected at these sites.

Regional Variation

Our data on composition of spotted owl diets suggested that woodrats were widespread across the study area, and on an annual basis, they provided a relatively stable prey base for spotted owls. Studies of woodrat abundance and habitat use on GD lands (Hamm 1995, Hughes 2005, see below) indicated that woodrats were present in all stand ages represented on the ownership, but were most abundant in the young seral stages (5-30 yrs) of redwood and Douglas-fir forest. Smith et al. (1999) observed a positive relationship between elevation and percent biomass of woodrats in pellets of California spotted owls. They speculated that this relationship may have resulted from a vegetation gradient and a lack of other medium sized small mammals at higher elevations. We did not examine the relationship with elevation in our study.

Tree voles exhibited the second greatest amount of variation among regions within our study. Given the life history characteristics of this species, it was not surprising that their occurrence varied across geographic area as did the tree species that was the primary component of their diet. The coastal redwood zone does not likely provide the optimum habitat for this species, which feeds almost exclusively on conifer needles except for redwood. Hemlock, Douglas-fir and white fir are present in the redwood dominated areas, and tree voles do occur there, but the amount of fir increases along an eastern gradient and with increasing elevation. Given the food habits of this species, we may expect to see an increasing occurrence of this species as palatable conifer species become more prevalent on the landscape. Tree voles did occur at approximately one-half of the collection locations, indicating a well-dispersed prey base. Tree voles occurred more often than expected in pellets collected from owl sites at our easternmost region. This area is comprised entirely of Douglas-fir and oak woodland habitat that may be favored by tree voles.

Northern flying squirrels were the third most frequent species encountered in pellets in our study area and analyses across regions indicated that flying squirrels were more abundant in diets in the Klamath region (from the Klamath River north to the Oregon border). This is consistent with other studies in Oregon where flying squirrels become the predominate prey item for spotted owls. Our sample sizes for some species were not large enough for valid comparisons, but the empirical data on species such as pocket gophers and other microtenes suggested that they were preyed upon more frequently in the southeastern portion of the ownership in the Douglas-fir/oak woodlands with intermixed natural grasslands, which is the typical habitat for these species.

Size of Prey

The majority of prey base studies indicated that spotted owls forage on medium sized small mammals such as woodrats and flying squirrels (Courtney et al. 2004). Our data were consistent with these findings, but we do not know if owls in are study area were selectively taking certain prey species since we did not collect data on the relative abundance of the more common prey items and we have no information on the relative accessibility of these prey items among owl territories. In our region, we speculate that spotted owls may be taking more of the larger prey items in proportion to their availability, because woodrats appear to be a relatively abundant and widespread food source for spotted owls. Dusky-footed woodrats exhibited the least amount of variation over time and geographic area. In addition, this species was found at almost 90% of the collection locations. This suggests a well-dispersed primary prey item within this region. The extent to which woodrats exhibit circannual cycles of abundance is unknown. The mean mass of prey in our study was generally greater than observed in other studies (Forsman et al. 2001, 2004), which is explained by the greater percentage of woodrats in the diet of owls in our area. Woodrats generally weigh 1.5-2 times the average flying squirrel, the primary prey item observed in Washington and Oregon.

Conclusions

Dusky-footed woodrats were the most important prey item in our study area, but tree voles and flying squirrels were also important in overall composition of the diet. In some areas, brush rabbits may be an important seasonal component of the diets by contributing substantially to the biomass. Relative to any other forest management activities, managing forest seral stages to promote an abundance of woodrats is likely to have the greatest positive influence on spotted owl populations in our area. However, consideration for the habitat requirements of the other important prey species such as tree voles, flying squirrels and brush rabbits will provide for a more diverse prey base for spotted owls.

3.A.2 Summary of Northern Spotted Owl Diet from Nearby Areas

In Redwood National and State Parks, 369 individual prey items were identified from 194 spotted owl pellets (Schmidt 2005). The majority of prey items were woodrats (31%), Sonoma tree voles (18%; *Arborimus pomo*), northern flying squirrels (10%), and microtine voles (9%). Deer mice, pocket gophers, birds, brush rabbits, shrews, gray squirrels, California red-backed voles, and bats each comprised < 5% of prey items (Schmidt 2005).

3.B Woodrat Ecology

3.B.1 Woodrat Ecology on Green Diamond Resource Company Land

The dusky-footed woodrat (*Neotoma fuscipes*) is a nocturnal rodent that is semiarboreal and endemic to the Pacific coastal states. The species occurs in a wide variety of habitats including chaparral, oak woodlands, piñon and juniper woodlands, and coniferous forests from Baja California north to the Columbia River. In California, the woodrat is found from sea level at the coast to 2700 m at its eastern limits of distribution in Baja California and in the Warner Mountains of northeastern California (Murray and Barnes 1969, Hall 1981). There is little information on the abundance patterns and habitat associations of dusky-footed woodrats in the coastal redwood (*Sequoia sempervirens*) and transitional redwood/Douglas-fir (*Pseudotsuga menziesii*) region of California.

Dusky-footed woodrats typically are associated with dense vegetation that offers protective cover, an abundant food source and sites for construction of stick "houses" (Hooven 1959, Horton and Wright 1944, Murray and Barnes 1969). Cover for protection is vital and as such, the dusky-footed woodrat is absent from open grasslands and woodlands lacking underbrush (Hooven 1959). As a packrat constructing large dwellings composed of sticks and plant clippings, the woodrat attracted the interest of researchers investigating its habitat associations and abundance patterns in oak (*Quercus* sp.) woodlands (Linsdale and Tevis 1951, Vreeland and Teitje 1999), Douglas-fir (*Pseudotsuga menziesii*) associations (Hooven 1959), juniper (*Juniperus* sp.) woodlands and chaparral habitats (Cranford 1977). The dusky-footed woodrat was also identified as an important small mammal reservoir for tick-borne agents such as *Borrelia burgdorferi* (Lyme disease; Brown and Lane 1992, 1994), granulocytic ehrlichiae (Nicholson et al. 1999), the piroplasm parasite *Theileria youngi* (Kjemtrup et al. 2001), a contributor to tree damage in young Douglas-fir forests (Nettleton 1957, Hooven 1959) and as an important prey species for forest carnivores and raptors, particularly the northern spotted owl (Thomas 1990).

The predator-prey association between northern spotted owls and dusky-footed woodrats also initiated studies on abundance of dusky footed woodrats (Sakai and Noon 1993), spotted owl reproduction and fitness (Ward 1998, Thome et al. 1999), and spotted owl habitat use (Carey 1995, Zabel 1995). In California, dusky-footed woodrats were most abundant in early stages of Douglas-fir forest regeneration (Sakai and Noon 1993), but in Oregon, Raphael (1988) observed a bimodal distribution where dusky-footed woodrats were abundant in young as well as mature and old growth stands. Carey et al. (1999) found that empirical counts of dusky-footed woodrats in mixed conifer forests of Oregon suggested abundance was greater along streams and in old forest than young (40–90 yr old) managed forests. In Oregon, there is a shift in prey consumption by spotted owls with northern flying squirrels becoming predominant. The dusky-footed woodrat is rare in spotted owl diets in northern Oregon and absent in Washington since its northern distribution ends at the Columbia River. The dusky-footed woodrat may function in a role as a keystone species in coniferous forests of northwest California, because of its potential influence on populations of spotted owls and other forest predators.

GD conducted studies of dusky-footed woodrats in redwood forest in 1992-1993 (Hamm 1995) and in Douglas fir forests in 2000-2001 (Hughes 2005). We also conducted a retrospective study to investigate woodrat abundance in relation to stand age and forest thinning in redwood forests in 1999.

The woodrat studies were conducted on private timberlands owned by GD. The study area was located in Humboldt County, California within the Redwood Creek, Mad River and Little River watersheds. Within the Redwood Creek and Mad River portion of the study area, the majority of the forested areas were clearcut harvested at least once starting ca. 1920 resulting in a landscape of second and third growth forest from zero to 80 years of age. In the Little River watershed, the second growth land base was managed by the Louisiana–Pacific Corporation (LP) until July of 1998 when GD purchased the approximate 28,340 ha ownership. This area was also subjected to clearcut harvesting starting ca 1920, but after 1991, LP began conducting large acreage commercial thinnings where 25–50% of the conifer basal area was removed in one or more logging entries. Under this silvicultural regime, most of the poorly formed and defective conifers were removed as well as the hardwood component. This management regime resulted in stands that were relatively homogeneous in overstory tree species composition and age. Coast Redwood was the predominant conifer over most of the coastal Mad River and Llittle River watersheds with Douglas-fir becoming common in the higher and more xeric locations in the inland Mad River and Redwood Creek areas. Hardwoods such as Tanoak (*Lithocarpus densiflorus*), Red Alder (*Alnus rubra*), Pacific Madrone (*Arbutus menziesii*), California Bay (*Umbellularia californica*), and Big-Leaf Maple (*Acer macrophylum*) were common stand components. Elevations ranged from near sea level to 1828 m. Mean summer temperatures were 18 C, and annual precipitation was 81 cm in 1992, 110 cm in 1993 and 100 cm in 1999 (National Weather Service, Eureka, CA).

3.B.1.i Woodrat studies in redwood forests

Objectives

Objectives of the woodrat studies in redwood forests were to: (1) estimate abundance of dusky-footed woodrats in four seral stages of coastal redwood forest that had been clearcut harvested; (2) estimate abundance of woodrats in redwood forest that had been subjected to varying levels of commercial thinning as the silvicultural treatment; and (3) develop habitat models predicting woodrat occurrence within the thinned stands.

Methods

We conducted fieldwork from April to October 1992–1993 and from August to November 1999.

We used a stratified random sampling design to select 24 forested stands in 1992–1993 and 15 stands in 1999 that were >16 ha and accessible by vehicle or a short hike (< 15 min). We sampled ≥ four stands from four age categories: seedling/shrub (5–9 yr); sapling/brushy pole timber (10–20 yr); small sawtimber (21–60 yr); large sawtimber (61–80 yr). The age categories corresponded to stand development criteria used in other studies (Carey 1991, Sakai and Noon 1993). We used forest inventory data contained in GD's Geographic Information System to ensure that sampling was restricted to redwood dominated stands. In 1999, we sampled four clearcuts 9–15 yrs of age and 11 stands 50–70 yrs old with varied levels of commercial thinning harvest. For sampling purposes, we categorized thinned stands as light, medium and heavy based on the basal area removed (light = least volume removed). We placed thinned stands into discrete categories for comparative purposes; however, the thinning gradient exists as a continuum. The thinned stands were harvested 6–8 yrs prior to this study. Based on our previous studies in 1992–93, this provided sufficient time for woodrats to colonize the thinned stands.

We used a random process to locate two live-trapping grids in each selected stand with the following constraints: (1) Grids were >100 m apart; (2) Grids were randomly placed 15–30 m from roads. Live-trapping grids were 1.2 ha and consisted of 100 Tomahawk live traps (Model #201 Tomahawk Live Trap Co., Tomahawk, WI) placed at the intersections of a 12-m grid. We baited traps with dry COB horse feed (rolled corn, oats, and barley) and covered them on three sides with four mil black plastic to minimize exposure of captured animals. We trapped for five nights. However, trapping was discontinued after three nights if no woodrats were captured and sign of woodrats (houses, latrines, fresh clippings of vegetation) was absent from the area. Dusky-footed woodrat sign is typically very conspicuous, and if resident individuals are present, they are easily captured within three nights of trapping even when in low abundance (K. Hamm, pers. obs.).

We checked traps every morning and tagged captured woodrats in both ears with identically numbered ear tags (#101, National Band and Tag Co., Newport, KY). At each capture location, we recorded age class (adult, subadult, juvenile; Linsdale and Tevis 1951), sex, mass (g), reproductive condition and trap number. We promptly released individuals at the site of capture following handling. We did not trap during the week of a full moon or during precipitation. We estimated abundance of woodrats on each trapping grid as the minimum number known to be alive (MNA).

In 1999, we sampled vegetation at 15 trap stations within the 100-trap grid. We randomly selected 1 of 10 trap lines and then randomly selected a number between 1 and 10, which corresponded to a trap station, to begin sampling. Once the first trap station was selected we selected every third station within the line and every other trap line. At each of the 15 trap stations, we sampled ground cover along an 8 m transect. The 8 m transect was oriented in a random direction from 1–360°. Ground cover was classified into 1 of 5 categories (Table 3.2). We estimated the percent slope at each station and averaged it across the grid. Orientation of each trapping grid was estimated using stereo-pair aerial photographs and placed into 1 of 8 categories (N, NE, E, SE etc.). We estimated log volume (m^3/ha) by measuring the length and diameter of logs (≥ 9 cm on the small end) when the log was located within a 4 m wide belt transect established between the trap stations sampled on each line within a grid. We calculated stem density and basal area of trees using variable radius (20 basal area factor glass prism) plots centered at the 15 trap stations. We recorded species and diameter at breast height (dbh) for trees within plots.

In 1999, we assessed understory foliage density (shrub layer) through ocular estimates of the percentage vegetation obscuring a cover board (Nudds, 1977). Foliage density (vertical cover) was the relative amount of leaf-bearing stems and leaves present. The cover board was 2.0 m high, 30.5 cm wide and it was divided into 4-0.5 m segments alternately painted red and white. We estimated foliage cover at the 15 randomly chosen trap stations by selecting a random direction and placing the board 8 m from the trap station in the random direction. The distance of 8 m was chosen because this distance produced the greatest variability in percent cover in a pilot study in our area. We ranked the foliage cover for each height interval as a single density score ranging from 1 to 5, which corresponded to the mean percent concealment for the following ranges: 0–20; 21–40; 41–60; 61–80; 81–100. We recorded the predominant type of vegetation obscuring each 0.5 m band and calculated the proportion for each vegetation type across the grid. We used non-parametric tests (Kruskal and Wallis 1952, Zar 1974) on data from each of the 4 age classes and thinning treatments to assess differences in woodrat abundance among age classes and thinning treatment groups. We identified differences among age classes and treatment groups using Tukey-Kramer multiple comparisons.

We fit a Poisson generalized linear model with logarithmic link (McCullagh and Nelder, 1989) in the regression analyses using MNA from individual trapping grids in thinned forested stands as the response variable. We excluded clearcuts from regressions, because woodrat abundance estimates were different in clearcuts and management interest resided in the mature stands. We fit all possible Poisson regression models relating MNA to stand and understory variables (Table 3.2) and ranked them according to AICc (Burnham and Anderson, 1998). We adjusted standard errors of model coefficients for estimated over-dispersion (McCullagh and Nelder, 1989; Venables and Ripley, 1994). We chose to model woodrat numbers with conifer stems >45.7 cm because this diameter was relevant to seed tree retention standards under the California Forest Practice rules (California Forest Practice Rules, 2005) and these trees represented dominant or codominant overstory trees. Due to high correlation among conifer stems >45.7 cm, conifer and hardwood stems >45.7 cm, basal area of conifers >45.7 cm and basal area of conifers and hardwoods >45.7 cm, only 1 of these variables was allowed in the model at a time. We considered all two-way interactions between the stand variables and topography variables (slope and aspect). We developed an understory vegetation model using the same approach as described for the stand model.

Results

During 1992–1993, we captured 1,527 individual woodrats. Woodrat abundance was greatest in the 2 youngest age classes of forest ($\chi^2 = 13.6$, df = 3, $P = 0.003$) and estimates were 12 to 90 times greater than the 2 older age classes of forest. Woodrat abundance decreased as age of forest increased ($r = -0.66$, $P < 0.001$). In 1999, we captured 258 woodrats. Our abundance estimates obtained in clearcuts trapped in 1992–93 and 1999 were similar and confidence intervals overlapped, but we did not test for differences in estimates, because trapping occurred at different times of the year. Woodrat abundance differed between clearcuts and thinned forests ($\chi^2 = 12.54$, df = 3, $P = 0.006$, Table 3.3) and mean estimates of abundance in stands <20 years old were ≥ 12 times the estimates from thinned mature stands (Table 3.3). Abundance estimates from mature unthinned stands and mature thinned stands were similar, although woodrats were rare or absent in mature stands (Table 3.3).

The top stand model based on AICc contained only density of conifer stems >45.7 cm (Table 3.4, Fig. 3.1). The top AICc model estimated that the average number of woodrats per grid decreased 4.1% for every conifer stem/ha >45.7 cm (~95% C.I. = 1.5%–6.7%). A model equivalent to the top model contained basal area of trees >45.7 cm (ΔAICc = 0.04,Table 3.4). The basal area model indicated that the average number of captured woodrats per grid decreased by 11.1% for every additional m^2 of basal area in conifers >45.7 cm (approximate 95% confidence interval = 4.3% to 17.4%). Woodrat abundance increased with increasing cover of shrub layer vegetation (Fig. 3.2). The estimated coefficients in the top AIC_c understory model were negative for log volume, rhododendron cover and salal while the estimated coefficient for total understory cover was positive (Table 3.4). We did not model woodrat abundance with understory vegetation in clearcuts, but our data demonstrated that of the total understory cover in clearcuts, manzanita (*Arctostaphylos manzanita*) and blueblossom (*Ceanothus thrysiflorus*) comprised nearly 40% of the mean proportion of understory cover. These species were absent in thinned stands.

Discussion

The results of this study were consistent with other studies of woodrat abundance and habitat associations. Sakai and Noon (1993) found dusky-footed woodrat abundance highest in the sapling brushy poletimber stage (15–40yrs) in Douglas-fir forests in northwest California. They found that woodrats were absent in small sawtimber and large sawtimber, which equated to the 2 older age classes of forest in this study. Woodrats were rare in redwood forests >40 yrs old in our study. A recent study (Hughes 2006) in the Douglas-fir region of GD ownership found a similar pattern in abundance where woodrats were most abundant in stands 5–20 yrs old, moderately abundant in stands 21–40 yrs old and rare or absent in stands >41 yrs. In Oregon, Hooven (1959) found woodrats to be abundant in young Douglas-fir regeneration interspersed with hardwood brush. Fitts and Northern (1992) found woodrat abundance was greatest in 7 and 11-year-old clearcuts in coastal redwood forest in California. Raphael (1988) reported a bimodal distribution of woodrat abundance with a peak in young stands and again in old growth Douglas-fir forests in Oregon. Older stands sometimes have natural openings created by toppling of the large trees or other disturbances, and within these openings, the young trees and shrubs support woodrats (Carey et al. 1992). In southern Oregon and northwest California, early seral stages of forest with dense vegetation had the greatest woodrat abundance.

We observed high but variable numbers of woodrats in young stands in our study. The variability of woodrat numbers was likely a result of differences in vegetative quality, number of suitable nest sites, or species interactions. As forest stands mature following a disturbance such as clearcut timber harvest, they go through stages during which they are unsuitable for woodrats (recently burned clearcut), potentially optimum habitat, and then they gradually decline to marginal habitat. The shrub layer that develops likely contributes to the relative suitability of early successional stages for woodrats. The variable rate at which a stand matures may also explain the variation in woodrat numbers in young stands. The decline in woodrat numbers as a stand matures may be caused by the change in understory floristics and available food, lack of sites suitable for supporting houses, or vulnerability to predation. The number of appropriate sites for construction of houses was likely a limiting factor. Hamm (1995) found that 82% of houses encountered in young stands (5–20 yrs) were associated with redwood sprout clumps. In older stands, houses were evenly distributed among fallen trees, logs, stumps and sprout clumps. The variable density of sprout clumps (and other suitable structures) within a stand may limit the number of suitable sites for construction of houses and subsequently, the number of woodrats. Hughes (2006) also observed a high degree of variability in captures of woodrats in the 5–20 yr age class in Douglas-fir stands on GD ownership and suggested that the structure and composition of sub-canopy vegetation is likely the primary influence on woodrat numbers.

Since dusky-footed woodrats are typically associated with dense vegetation, it could be expected that removal of overstory trees and the subsequent increased growth of understory vegetation may promote woodrat abundance. When forests are thinned, there is generally a short-term increase in the amount of solar radiation reaching the understory until the remaining overstory trees respond and crown growth reduces gaps in the canopy. While we did not quantify pre-harvest and post-harvest species diversity or density of understory vegetation, others studying Pacific coastal coniferous forests have quantified vegetation responses to thinning. Bailey and Tappeiner (1998) who studied paired thinned and unthinned Douglas-fir forests >50 yrs old in the Coast and Cascade Ranges of western Oregon, found that total low shrub cover (0.5–1.5 m) was negatively related to trees/ha, and the greater shrub cover in thinned stands was influenced by increased salal (*Gaultheria shallon*) and bracken fern (*Polystichum sp*) cover. Thomas et al. (1999), studying young Douglas-fir plantations in Washington, found that understory cover was greater under the most intense thinning levels, but that understory cover was highly variable and stands with low levels of thinning exhibited less shrub cover than unthinned controls. We also observed an increasing trend in average understory cover with thinning intensity, but species exhibited different responses to the treatment. For example, huckleberry (*Vaccinium ovatum*) cover was highest at intermediate levels of thinning, rhododendron (*Rhododendron macrophylum*) exhibited a consistent increase and tanoak exhibited a consistent decrease.

In young clearcut stands, manzanita and blueblossom comprised a large proportion of the shrub layer cover, but these species were absent from the older thinned stands. A common practice after clearcutting in our study area was to broadcast burn the harvested area in preparation for reforestation. The goal of burning was to reduce the amount of small organic materials with a "cool" or low intensity burn so that conifer seedlings were more easily planted. Manzanita and blueblossom were species that invaded harvested areas where the topsoil had been disrupted and their propagation and release was increased when areas were subjected to burning (Hilton, 1989). Lack of burning and reduced soil disruption in thinned areas may preclude these species from inhabiting the site. In addition, these species are heliophilic (shade intolerant), which further precludes their establishment in forests with relatively dense canopies.

The model competing with the top model ($\Delta AIC_c<2.0$) relating woodrat abundance to understory vegetation showed positive coefficients for average understory and redwood cover and negative coefficients for salal and rhododendron cover. While woodrat abundance can be correlated to density of shrub layer vegetation, it likely was the presence of a few plant species that ultimately influenced the carrying capacity of a particular area. Dusky-footed woodrats are considered generalist herbivores (Vestal 1938, Horton and Wright 1944); however, this species may show a preference for certain oak species (Horton and Wright 1944, Linsdale and Tevis 1951, Cameron 1971). Contrary to the prediction for many small mammal herbivores, dusky-footed woodrats are capable of digesting fibrous vegetation containing tannins and other polyphenolics (Atsatt and Ingram 1983) through ingestion of large quantities of the foliage and through storage at their houses, which may permit detoxification of vegetation during desiccation. As central place foragers, woodrats are adapted to locate their large houses near palatable vegetation and store large quantities of vegetation at these dwellings. The houses also give woodrats increased thermoregulatory abilities. Further investigation of woodrat food habits in coast redwood forest would lend insight into the patterns of their distribution and abundance in various seral stages and forest types. Although we did not quantify this, we hypothesize that certain types of vegetation in the young stands act as food sources for woodrats, because the heliophilic vegetation that grows in open situations is more palatable than shade tolerant species in mature forest. In addition, the coppice regeneration exhibited by redwood, tanoak, madrone, and maple provides sites for woodrat houses as the trees mature. Conversely mature stands that have self-thinned provide fewer sites for woodrats to construct houses. The top model for stand variables indicated a negative association of woodrats with conifers >45.7 cm. Woodrats in our area are probably not directly tied to presence or absence of overstory trees, but rather to the understory plant species diversity, vegetation density and sites suitable for constructing houses.

The dusky-footed woodrat is a key prey item for the spotted owl in California and in our study area comprises approximately 45% frequency and 74% biomass of the owls' diet. Woodrats may become available to owls when they make forays into adjacent older stands occupied by spotted owls (Sakai and Noon 1997). In northern California (Franklin et al. 2000) where woodrats are the primary prey for spotted owls, landscapes with a mixture of old and young forest appeared to promote spotted owl fitness. Understanding the habitat associations and abundance patterns of prey species such as dusky-footed woodrats may allow biologists and forest managers to make the most informed decisions as to how various forest management scenarios may influence prey populations and owl demographics over time.

3.B.1.ii Woodrat study in Douglas-fir/hardwood forests

Objectives

Objectives of the woodrat study in Douglas-fir/hardwood forests were to: (1) determine whether abundance of woodrats was correlated with age of forest stands; (2) assess whether measurements of habitat composition were correlated with woodrat abundance; and (3) evaluate whether vegetation differed between woodrat house sites and random sites.

Methods

<u>Field methods</u>

We conducted this project in June-December 2000-2001. We randomly selected stands from a GIS database. Selected stands met the following criteria: (1) area greater than 20 ha; (2) overstory dominated by Douglas-fir and/or hardwoods (>50% of the trees within the stand); and (3) located within a 30 minute hike from accessible roads. We selected stands from four age classes (5-20, 21-40, 41-60, 61+ years). We attempted to include all of the natural variation by using even-aged management units as study units; our goals were to sample the stands at a scale relevant to commercial forest management and to assess the habitat variables at a scale representative of woodrat home ranges.

During 2000, we set transects of live traps (model #201, Tomahawk Live Trap Company, PO Box 323, Tomahawk, WI USA). Traps were covered on the top and sides with black plastic sheeting to limit the exposure of captured animals to weather. A small amount (approximately the size of a closed fist) of synthetic "polyfill" was provided as material for bedding, and traps were baited with a commercially available mix of dry corn, oats and barley. Captured animals were aged as juveniles or adults, sexed, weighed, and marked on the ventral fur with hair dye (Clairol Nice'n Easy, Clairol Inc., 1 Blachley Road, Stamford, CT USA). Temporarily dyed fur was evident throughout the period of each trapping session.

We set traps along transects, rather than as grids, because transects are thought to result in reduced variation in the estimates of abundance when sampling a patchy distribution (Sakai and Noon 1993, Pearson and Ruggiero 2003). A 30m buffer-zone was established around the perimeter of each timber unit to be studied. Within this buffer, two parallel trapping transects separated by 50m were placed across the widest section of each stand. Each transect contained 25 trap stations with 10m intervals between stations. Traps were placed beside logs or under shrubs when available but all traps were set within a 1m radius of the center of the trap station to limit biases in captures. Each stand was trapped for five nights. Occasionally, trapping was postponed for one to two day periods due to inclement weather; therefore at some locations the five nights were not trapped consecutively.

We measured vegetation in seven, 0.04 ha (22.6 m diameter) circular plots placed equidistant along each set of trapping transects. We estimated overstory tree density, understory tree density (<10 cm diameter at breast height and >2 m in height), shrub cover and ground cover within each plot. We computed species-specific basal areas (James and Shugart 1970) using a Biltmore stick. Stems from sprout-clumps of overstory and understory trees were measured separately if they diverged close (< 0.5 m) to the ground. Shrub cover was measured along two "line-intercept" transects (Cook and Stubbendieck 1986) of 20 m length set perpendicularly within each plot. Ground cover was estimated within eight 1 m^2 quadrats with species or cover type recorded as Daubenmier cover classes (Table 3.5; Cook and Stubbendieck 1986). When different species created layers of cover in the ground and shrub cover estimates, only the cover of the dominant (highest) species was recorded.

During 2001, we quantified habitat variables within 20 m diameter circular plots centered on active woodrat house sites and randomly selected unoccupied plots. We searched transects perpendicular to the trapping transects in an attempt to locate and map all active houses within the area. Each house was evaluated for evidence of occupancy as described by Vreeland and Tietje (1999) with the exception that we did not use the presence of an entrance hole as an indicator of occupancy. On several occasions, we have found houses that appeared to have well developed entrances that were also covered with a heavy layer of spider webs, indicating that an entrance hole may remain long after the house has been abandoned. We recorded vegetation measurements from 10 or fewer randomly selected house plots per stand. We located an equal number of unoccupied plots in each stand by choosing locations randomly and then checking the selected locations to ensure that no active woodrat houses were located within 40 m of the plot center. However, several locations contained woodrat houses in such high density that the number of potential unoccupied plots was limited to less than ten, and in one stand, we were unable to locate any unoccupied plots. All measured plots within a stand were non-overlapping. Vegetation measurements were identical to those described above with the following exceptions: additional ground cover categories for hardwoods and conifers were estimated directly.

Analytical methods

We modeled woodrat abundance as a function of habitat variables using Poisson regression (Cameron and Trivedi 1998). Poisson regression is well suited for analysis of abundance data because; it assumes a Poisson distribution that is commonly appropriate for count data (Jones et al. 2002). We analyzed a model with all potential predictor variables included. This "global model" was then used to test whether the variance exceeded the mean in the data, a condition known as over-dispersion (Burnham and Anderson 2002). We found there was a limited amount of over-dispersion present in the data set. Therefore, the software S-plus (S-plus 2000, Insightful corporation, Seattle WA 98109) was used to evaluate the relationship between woodrat abundance and multiple habitat variables using "quasi-maximum likelihood estimation." Quasi-maximum likelihood adjusts the standard errors of the variable coefficients to provide more conservative estimates of coefficient variance when overdispersion is present.

We grouped variables into categories considered to be of functional importance (Table 3.6). "Primary" variables were those considered to be most likely to influence woodrat habitat use directly; these variables included ground cover, shrub cover and understory tree density. "Secondary" variables were those variables considered to influence woodrat habitat use indirectly; these variables included small woody debris (used as house building material), large woody debris (used as house building material or structural support with interstitial spaces incorporated into houses) or basal area of overstory trees. We first tested univariate relationships between the number of woodrats captured and all primary variables. Two and three variable models from primary variables were then constructed. At each stage of the model building, only those models where the coefficients of all variables were significant ($P < 0.01$) were considered for additional model development by adding additional variables. When all biologically meaningful combinations of primary variables had been considered, secondary variables were added to any suitable two variable models. All models were limited to three variables to control over-fitting of the data. Not all combinations of variables were considered to be candidate models. Variables that were derivatives of other variables were not included in the same model. For instance, shrub-level tan oak is a component of shrub-level hardwoods, all live woody shrubs and all shrub cover. Therefore, we did not combine "shrub tan oak" with these variables because the probability of autocorrelation was considered to be too high and the biological basis for doing so seemed of questionable validity. Since stand age was considered a proxy for the overall stand development in the trapping data, we did not include it as a variable in the same model that contained basal area of overstory trees.

We modeled woodrat house presence/absence using multiple logistic regression (SPSS v9.0- SPSS Inc. 233 S. Wacker Drive, Chicago Illinois 60606) following the same model building strategy as described in the population level analysis. Forty five woodrat house plots and 45 unoccupied plots were included in the analysis.

Results

We obtained 384 captures of 207 individual woodrats over 1450 trap nights. The mean weight of 106 adult female woodrats was 192.1 grams (SE = 5.25) whereas the mean weight of 73 adult males was 228.6 grams (SE = 8.53). There was no significant difference in the mean weight of woodrats trapped in stands of different age classes (Kruskal-Wallis one-way ANOVA on ranks, $\chi^2 = 2.77$, df = 2, $P = 0.25$).

Although the number of woodrats captured was significantly correlated with age of stands ($R^2 = 0.422$, $P < 0.001$), there was considerable unexplained variance in woodrat abundance, predominantly in the younger age classes (Fig. 3.3). One hundred forty-eight woodrats were captured (range = 1-55) in 9 stands in the 5-20 years-post-harvest-age-class. Fifty-one woodrats were captured (range = 0-19) in eight stands aged 21-40 years post harvest. Eight woodrats captured (range 0-3) in nine stands of the 41-60 year age class, and there were no woodrats captured in the three stands last harvested 60 or more years prior to trapping.

The results of the multivariate Poisson regression of woodrat abundance are shown in Table 3.7. The 10 best fitting models are shown ranked by QAICc, and Akaike weights (w_i) are presented to illustrate the relative ranking of each model; the w_i value can be interpreted as being the relative probability that a given model explains the greatest amount of the variation within a data set (Burnham and Anderson 2002). The 95% confidence set of models includes only the first model shown ($w_i = 0.98$); thus no other model accounted for a considerable amount of the variation in woodrat abundance.

We found 188 woodrat houses in 13 of the 29 stands previously trapped for woodrats (range 0-89 houses/stand). The number of nests found in each stand was significantly correlated with the number of animals captured in a unit (Spearman-rank correlation R = 0.791, $P < 0.001$).

The results of logistic regression of woodrat house presence/absence are shown in Table 3.8. The 10 best fitting models are shown ranked by AICc and w_i values. The 95% confidence set of models includes the top 8 models. Understory hardwood density was included in four of the ten top ranking models. Woodrat houses were frequently located in sprout clumps or aggregated patches of tan oak tobacco brush and other types of hardwood shrubs. Similarly shrub tan oak cover was positively related to woodrat house site presence in four of the top ranking models. Understory conifer density and overstory conifer basal area were negatively related to woodrat house site location and were present in five of the top ranking models respectively.

Discussion

In the analysis of woodrat abundance, the model that included only a single variable for "timber management unit age" was negatively related to the abundance of woodrats, supporting the results of Sakai and Noon (1993) and Hamm (1995). However, correlations were greater when measures of the sub-canopy hardwood component such as hardwood shrub cover, ground cover of tanoak, or understory hardwood density was added to the stand age model. Our finding that shrub and understory hardwood development may influence woodrat habitat use was suggested in previous studies (Raphael 1987; Sakai and Noon 1993; Hamm 1995).

We observed evidence of extensive pruning of tan oak and other hardwoods such as madrone

(*Arbutus menziesii*), blueblossom (*Ceanothus thyrsiflorus*), and tobacco brush (*Ceanothus velutinus)* in several of the high abundance timber management units we trapped. This suggests that these tree and shrub species may be important food sources for woodrats.

In the house site analysis, sub-canopy hardwoods were positively associated with house presence and sub-canopy conifers were negatively associated with house presence. In the top 5 models, basal area of overstory conifers was negatively associated with house presence. Hamm (1995) suggested that in older timber management units large woody debris and fallen hardwood trees might have provided house sites in older timber management units where understory cover was limited. In older timber management units or young timber management units with limited hardwood shrub/understory cover, we typically found woodrat houses in areas that contained remnant patches of hardwood shrubs or fallen tan oak and madrone trees. However, woodrats did not seem to utilize brush patches or downed trees unless they were still alive, suggesting that use of these features may be related to forage availability in addition to cover for house locations. Woodrat house sites in older timber management units were frequently found in remnant hardwood brush patches resulting from topographical features such as rocky slopes and ridge tops which created small areas of low growing tan oak in a timber management unit that would otherwise be classified as mature conifer.

The results of this study indicate that management activities that increase sub-canopy hardwoods may increase the quality of woodrat habitat while activities designed to suppress sub-canopy hardwoods including burning, pre-commercial thinning, and herbicidal control, may decrease the quality of woodrat habitat. Although pre-commercial thinning has been shown to decrease woodrat abundance (Whitaker 2003), in one timber management unit that we studied, pre-commercial thinning of tan oaks by manually cutting them off at the base, in addition to an approximately 30% mortality of overstory conifer trees from bears feeding on the cambium and "girdling" them, resulted in stump sprouting of the tan oaks which also resulted in an increase of subcanopy hardwood cover. Thus the influence of silvicultural management on woodrat habitat quality may not always be clear.

Thome et al. (1999; summarized below) found that the proportion of 21-40 year old timber management units was lower in northern spotted owl locations than in random locations. However, among NSO nest sites, those with the highest fecundity also had the highest proportions of 21-40 year class timber management units. Thome et al. (1999) proposed that increased fecundity of spotted owls was due to higher abundance and availability of woodrats in 21-40 year timber management units. However, we found the number of woodrats captured in this age class varied considerably (range = 0-20), suggesting that coarse classification of habitat based primarily on timber management unit age may not be sufficient to quantify spotted owl foraging habitat unless additional information regarding sub-canopy vegetative structure is considered.

Although some forest locations may contain high abundances of woodrats, the associated high density of understory shrubs in young regenerating forest timber management units would limit the ability of spotted owls and other aerial predators to feed on them. However, radio collared woodrats from high abundance "young" forest locations were documented straying into more mature forests where predated by spotted owls (Sakai and Noon 1997) suggesting that juxtaposition of those habitats where woodrats are plentiful to habitats where spotted owls can forage must be considered when evaluating habitat quality for spotted owls.

In this study we identified small refugia in mature timber management units where active woodrat houses were located in small patches of sub-canopy hardwoods surrounded by open or conifer dominated understories. Although rare, the woodrats that inhabit these refugia are more susceptible to predation when the surrounding forest contains little subcanopy cover. Conversely, some authors have observed that woodrats may fail to utilize assumed high quality habitats in some areas, presumably because such habitats are rare and isolated within the forests (Carey 1991). This difference likely occurred because the forests within the GD ownership are more intensively managed, with many younger stands in close proximity. Thus, areas with suitable habitat are more likely to be colonized from other source populations.

Summary of woodrat studies on GD land

Both woodrat studies indicated that in the redwood/Douglas-fir zone of GD ownership, woodrats are in greatest abundance in young stands <40 yrs of age. Use of uneven-aged silviculture techniques such as commercial thinning or selection is not likely to enhance woodrat abundance because these practices generally encourage the proliferation of understory sciophytes that are not palatable forage for woodrats. Silviculture practices that promote a dense and diverse shrub layer of heliophilic species that are more palatable should promote woodrat abundance. However, woodrats also require suitable substrate in the form of redwood or tanoak stump sprouts, trees with basal hollows, logs, and other down material for construction of their houses.

Because woodrats are the primary prey species of northern spotted owls in northern California, forest management practices that influence woodrat abundance have implications to management of populations of threatened spotted owls. Thinning of mature stands is not likely to enhance the primary prey base for spotted owls in this region. The management strategies for threatened populations of spotted owls must take into consideration the habitat needs of the species itself and that of its primary prey.

3.B.1.iii Woodrat monitoring on GD land

Dusky-footed woodrats are a vital component of the diet for spotted owls on GD ownership. GD and graduate students at Humboldt State University have conducted several projects on the abundance patterns and habitat associations of dusky-footed woodrats, but information is lacking on annual fluctuations in woodrat populations across the ownership. Information on annual variation in woodrat numbers may help to explain variation in annual survival and fecundity estimates for spotted owls. This information, in conjunction with various other habitat and weather covariates, may aid in the development of resource selection models used to assess impacts of forest management activities on populations of spotted owls. The objectives of this project are to: (1) estimate woodrat abundance at the landscape scale using trapping transects; (2) associate woodrat abundance with forest stand level habitat variables; and (3) estimate annual variation in woodrat numbers at a landscape scale and use these estimates as an index of prey abundance for modeling demographic parameters of spotted owls.

Methods

We divided GD ownership into logical units using topographic features, watershed boundaries and broad habitat types. Units varied in size from 6,000-10,000 ha (15,000 to 25,000 acres). Many of these units coincided with forest management areas already in place. The total number of transects was constrained by areas that could be trapped during a three month time period from September to November and the amount of available resources (i.e. traps and personnel). Twenty-four possible transects were identified from eleven units within GD ownership. Trapping transects were identified based on a minimum length of 16 km all-season road use (i.e., rock or other stable surface) as well as having a broad distribution across the ownership.

A random start for each transect was determined within the initial 0.32 km of length. Each transect was then partitioned into 0.32 km intervals totaling 50 trap intervals. At each interval, a coin flip was used to determine the side of the road where traps would be positioned. Prior to placing the stations it was determined which side of the road each side of a coin represented. If a trapping station fell in a position of the road that was inaccessible or off ownership it was moved to a safe location within fifty meters. If this was not possible, the trapping station was moved to the next 0.32 km interval. Two traps were placed at each trap station perpendicular to the road at ten-meter intervals. Many of the roads on GD ownership are cleared of roadside vegetation and brush to facilitate road maintenance and drying of the road surface. When roadside clearing was present on portions of selected transects, the perpendicular measurements started from the edge of the forest stand and not from the edge of the road.

In the field, trapping stations were permanently marked with a yellow tree tag (J.L. Darling Corporation, Tacoma, WA, Tag #P-1114) and white vinyl flagging. Tree tags were marked with the transect acronym, station location and azimuth to trap locations. If possible, tree tags were nailed to the nearest tree with aluminum nails. If no tree was within 2m of the start of the transect, a wooden stake was driven into ground at the start of the trap line. Two or three white vinyl flags were placed on trees or vegetation at each trap station and were identified with permanent marker. After the trapping stations were located on the ground, we documented the precise location on 2004 aerial photographs.

Initially traps were baited with rolled corn, oats and barley (COB). COB bait was used on the NF and MR transects in 2004. During this trapping session we had difficulty with bait falling out of the trap. This prompted a switch to Lab Diet 5001 rodent pellet bait for the remainder of the study. Four to six pellets were placed in each trap. Traps were covered with black visqueen that was held in place with two rubber bands. This covering on the top and sides provided shelter from inclement weather conditions and fog drip. Trapping was conducted on four consecutive nights. Captured woodrats were marked on the chest between the front legs with permanent marker for recapture identification purposes. After each capture, transect, trapping station and trap number were recorded on a data sheet. Age, gender, reproductive status, weight, parasite load and physical condition were recorded for each individual. We also recorded each trap that was closed but contained no captured animal.

We used Kodak imaging software to annotate digital images for trapping stations on each transect. The annotated scanned photos were used as base maps for future fieldwork. Road intersection location information for each trap station was transferred into the GIS database.

Trap locations were computed using ten and twenty offsets (trap locations) from intersection point and a compass bearing.

Results

In 2004 and 2005, eleven transects were live-trapped from September through November. A total of 8,484 trap nights resulted in the capture of 487 individual woodrats. These individual woodrats were recaptured 346 times. In 2004, 293 individuals were captured ($\bar{x}$ =26.6, SE = 6.9), and in 2005, 194 individuals were captured ($\bar{x}$ = 17.6, SE = 5.7).

Discussion

This work is anticipated to continue as a long-term monitoring study of woodrat abundance. The estimates obtained will be used as an index of primary prey abundance at a landscape scale for future modeling efforts of owl habitat selection and demographic parameters.

3.B.2 Summary of woodrat studies from nearby areas

The U.S. Forest Service Redwood Sciences Laboratory conducted two studies of dusky-footed woodrats on the Six Rivers National forest, which abuts GD land (Sakai and Noon 1993 and 1997). In the first study, woodrats abundance was estimated in each of 5 seral stages of Douglas fir/tanoak forest (Sakai and Noon 1993). Using a combination of transect sampling to estimate woodrat nest density and live-trapping, Sakai and Noon (1993) found woodrat density was highest in stands 15-40 yrs old (81/ha), and much lower in stands <15 yrs old (1/ha), and stands >180 yrs old (<1 ha). No woodrats were found in stands 41-80 yrs old nor in stands 81-180 yrs old.

In the second study, Sakai and Noon (1997) radio tracked woodrats of both sexes and three age classes and found that woodrats made short-term, temporary movements from the 15-40 yr-old stands in which they were trapped, into old growth (>180 yr old) stands. These two studies suggested that brushy/sapling stands adjacent to older forest may benefit spotted owls by increasing the availability of woodrats to the owls.

3.C Tree Vole Ecology

Taxonomists disagree about the genus of tree voles, with some placing it in the genus *Phenacomys* with the heather vole (*P. intermedius*), and with the white-footed vole (*P. albipes*) in the subgenus *Arborimus*, and others elevating the subgenus *Arborimus* to the genus level (Bellinger et al. 2005). Genetic studies have so far have not resolved this debate (Murray 1995, Bellinger et al. 2005). We use the genus *Arborimus*, following Johnson and George (1991), who first proposed the species *A. pomo* (the Sonoma tree vole) as distinct from *A. longicaudus* (the red tree vole).

Tree voles are small, arboreal rodents that are an important component of the diet of the northern spotted owl where the owls and voles co-occur (Forsman et al. 2004a, 2004b), including on GD land (see section 3A, above). The red tree vole occurs from the Klamath River in California north to northwestern Oregon, whereas the Sonoma tree vole occurs from the Klamath River south to Sonoma County, California (Johnson and George 1991). Both tree vole species are restricted to Douglas fir forests and feed only on conifer needles, primarily those of Douglas fir (Maser et al. 1981). After consuming the fleshy part of the needles, the voles discard the resin ducts (Benson and Borell 1931). Vole nests can be identified by the presence of these resin ducts in the nest or on the ground below the nests. Tree vole populations are patchily distributed (Carey et al. 1991) and are easily identified by the presence of nests. Nests are constructed of twigs, feces, conifer needles, lichens, and discarded resin ducts and are most common in the lowest third of the canopy (Carey 1991).

3.C.1 Tree Vole Ecology on GD Land

Tree voles (*Arborimus spp*) are small arboreal rodents found primarily in Douglas-fir (*Pseudosuga menziesii*) forests of the Pacific Northwest (Carey 1991). They are nocturnal and canopy dwelling, and are unique in feeding exclusively on conifer needles (Huff et al. 1992). Within GD ownership, the Klamath River is thought to be the demarcation between the red tree vole (*Arborimus longicaudus*), occurring north of the river and the Sonoma tree vole (*Arborimus pomo*) south of the river. Recent studies have suggested that these species could be vulnerable to local extirpations as a result of the loss or fragmentation of old-growth and mature Douglas-fir forests (Ruggiero et al. 1991, Gillesberg and Carey 1991, Meiselman 1992). Tree voles were identified by the California Department of Fish and Game as a "Species of Special Concern" because "declining population levels, limited ranges and/or continuing threats have made them vulnerable to extinction" (DFG, 2005).

3.C.1.i. Abundance, nest characteristics, and nest dynamics

We studied the abundance, nest characteristics, and nest dynamics of Sonoma tree voles on GD land (Thompson and Diller 2002). To estimate abundance of tree vole nests, we sampled 46 stands in the Mad River and Redwood Creek drainages, from 6 stand age classes (6-9 stands per age class; Table 3.9). We randomly selected the stands from GD's GIS database. Within each stand, we used line transect sampling to estimate the number of tree vole nests. Nests were deemed active by one or more of the following: the presence of freshly discarded (green) resin ducts in or below the nest, small, fresh conifer boughs on top of the nest (Benson and Borell 1931), or sighting a tree vole at the nest. To evaluate the characteristics of vole nest trees, we randomly selected vole nests in each of the sampled stands, and measured the dbh of all trees >7.5 cm dbh within a 0.04-ha circular plot centered on the nest tree. To estimate nest occupancy over time, we intensively surveyed 100-m x 100-m grids for tree vole nests, with 6 sampling periods: in the fall of 1994; winter, spring, and fall 1995; and winter and fall of 1996. For estimating nest occupancy, we non-randomly selected 2 stands each within the 5 oldest stand age classes known to have high densities of tree vole nests.

We found 185 Sonoma tree vole nests in the five oldest stand age classes sampled (Table 3.9), and no nests in the 10-19 yr old age class, although we had occasionally observed vole nests in 10-19 yr-old stands elsewhere on GD land. Density of active tree vole nests increased with stand age among the 5 oldest age classes (ANOVA, $F_{4,34} = 2.904, P = 0.036$) , ranging from 1.00 nests/ha in 20-29 yr-old stands to 6.21/ha in 60 yr-old stands. It is unknown whether the number of vole nests accurately reflects the number of voles, because tree voles may have multiple nests. However, assuming the number of nests used does not vary with nest density or stand age, we believe that the density of active nests indicates the relative abundance of tree voles in different aged stands.

We found vole nests in 8 species of tree and one nest on the ground. Eighty percent of nests were in Douglas fir trees; tanoak was the next most common tree species used for nesting by voles. Most of the nests found in tanoaks appeared to have been constructed initially by squirrels. As stand age increased, vole nests were located in larger trees ($F_{4,179} = 9.56$, $P < 0.001$), higher in trees ($F_{4,179} = 8.30$, $P < 0.001$), and farther from the bole of the tree ($X^2_4 = 9.75$, $P < 0.05$). Nest trees were similar in size to surrounding trees in younger stands, but became disproportionately larger than surrounding trees as stand age increased.

Nest persistence did not differ among stand age classes ($X^2_{12} = 16.9$, $P = 0.154$). Estimated median persistence time for vole nests was 28.6 mo (95% CI = 25.8 to 34.8 mo). We found unusually high proportions of destroyed nests during different sampling periods among different aged stands. We hypothesized that this observed pattern was consistent with predation, wherein a predator that discovered 1 nest would likely discover other nests in the area.

3.C.1.ii. Distribution and abundance of tree voles

Tree vole populations have been found to be patchily distributed in the forest (Carey et al. 1991). This combined with their arboreal existence and unique food habits make the species difficult to study (Huff et al. 1992). Areas of activity are most easily evidenced by the presence of nests, which are constructed of fine twigs, feces, conifer needles, lichen and discarded resin ducts (Carey 1991). These resin ducts remain after voles consume the fleshy part of conifer needles (Benson and Borell 1931).

In this region, tree voles have the potential to provide an important food source for several forest predators including the northern saw-whet owl (*Aegolius acadicus*) (Forsman and Maser 1970) and the threatened northern spotted owl (Forsman et al. 1984). Tree voles constitute an important component of the diet of northern spotted owls within GD's ownership. An analysis of regurgitated spotted owl pellets collected from 1989-2004 indicated that tree voles comprised approximately 16% of the owl's diet in frequency and 3% in biomass. Tree voles are also an important component in the Central and South Coast regions of Oregon where some owl territories have >20% of the prey numbers represented by this species (Forsman 2004).

The primary objective of this study was to investigate the distribution and abundance of Sonoma tree vole nests within Douglas-fir forests on GD ownership in northwestern California. We also investigated forest habitat and other landscape attributes associated with areas used and not used by Sonoma tree voles.

Methods

The population of forested areas within GD ownership was identified based on forest age (>20 yrs.) and basal area of Douglas-fir (>30%). Forested areas meeting these criteria in the Korbel Operations area and Klamath Operations area south of the Klamath River were identified using GIS. To select sample plots, a grid pattern with 10 ha cells was randomly placed on GD ownership. Each 10ha cell that intersected a forested area meeting the age and basal area criteria entered into the population from which samples were selected. Forest age was classified into one of four strata. Age classes were: 20-29, 30-39, 40-49, and 50+. A systematic random sample of 100 10 ha quadrats was selected. Each 10 ha quadrat was the sampling unit.

Quadrats were located in the field using aerial photographs and handheld global positioning system. Line transects were established within each 10 ha quadrat. Sixteen transects with 20 m spacing were established in the 20-29 yr age class and 12 transects with 26 m spacing were established in all other age classes. A narrow strip width was necessary to effectively census the quadrat area. Two to four observers walked transects within each quadrat. Observers started at one edge of the 10 ha quadrat and systematically complete all transects within the quadrat. Transects were traversed using a compass and distance was measured using a hip chain. Observers visually searched all trees for the presence of vole nests. When a nest was detected, observers visually inspected the structure from the ground and used a time-constrained search limited to 5 minutes to identify discarded resin ducts at the base of the tree in which the nest is located. When resin ducts were found, the nest was considered as that of a tree vole. When resin ducts were not located, the nest was not counted as a vole nest. Upon confirmation as a vole nest, observers measured the perpendicular distance to the nest tree, marked the approximate location on a topographic map with a 1:2,400 scale and continued with the transect. After all transects were completed, observers randomly selected one transect completed by other observers and then re-sampled these transects for vole nests. Observers had no prior knowledge of the number or location of vole nests detected by the other observer. The purpose of re-sampling transects was to approximate g (0) in the detection function.

After completion of transect sampling, observers systematically numbered all vole nests plotted on the topographic maps and habitat sampling occurred at all vole nests located on the grid. The nest tree was identified to species, and measurements were taken on diameter at breast height (dbh) and nest height. The placement of the nest on the tree was recorded as limb or bole. Observers made a determination if the vole nest was inhabited or uninhabited based on the presence of fresh (green) conifer clippings on the top of the nest. A 0.042 ha plot (23.4 m radius) was centered on the nest tree. A 20 basal area factor prism was used to assess tree species composition and basal area. All trees ≥10 cm were measured and identified to species. All snags >2 m in height were measured and identified to species where possible. Overstory canopy was measured with a spherical densiometer at four locations 5 m from plot center in each of the cardinal directions. The number of stumps (natural and man-made <2 m in height) within the fixed plot was recorded. The amount of large wood within the plot was estimated by measuring logs at both end diameters (minimum end diameter of ≥24 cm) and total length. Understory vegetation (<2 m in height) was quantified using a line intercept approach along one randomly chosen 23.4 m orientation line on the fixed plot. A minimum of four random plots were selected within each 10-ha grid. The same habitat information was gathered on random plots.

Results

From September to January 2001-2004, 68 10-ha square grids were sampled and 32 of these areas were found to be inhabited by tree voles. A total of 129 vole nests were located with a range of one to 19 per grid. Of the vole nests located, 46.5% were assessed as inhabited and 83.7% were located at the bole of the tree. Nests were located in seven species of tree and five different deformities or structures on the tree (Table 3.10). Nests were found in a wide range of tree sizes ($\bar{x}$ = 53 cm, SE = 15 cm) and heights ($\bar{x}$ = 11.9 m SE = 0.5 m).

The age of forest stands sampled ranged from 23 to 129 years. Mean dbh of trees on nest plots were not different from random plots ($t = 0.17$, $P = 0.86$). Log volume was greater on random plots than nest plots ($t = -2.7$, $P = 0.007$) and random plots contained more stumps than nest plots ($t = -4.0$, $P = 0.000$). There was no difference in slope ($t = 0.78$, $P = 0.44$) or canopy closure ($t = -0.04$, $P = 0.97$) in nest versus random plots. We observed a positive relationship between vole abundance and forest age ($F = 18.7$, $P < 0.000$) and distance from coast ($F = 32.6$, $P < 0.000$). Abundance appeared to be greatest toward the southern interior of the study area (Fig. 3.4).

Discussion

Our study and analysis indicates that tree voles are rare or absent from the coastal portions of the study area and increase in abundance with increasing distance from the coast. This phenomenon is most likely linked to the increasing presence of Douglas-fir, their primary forage, in the more interior areas. In an examination of vole abundance and distribution from regurgitated owl pellets, Forsman (2004) found that tree voles (*A. longicaudus*) were widely distributed in Oregon, but were more abundant in the southern and central coast regions of their study. These regions of their study area were out of the coastal redwood zone and dominated by Douglas-fir and grand fir. We found that tree voles were present in a wide range of forest ages but abundance of nests was positively related to forest age. These results are consistent with those of Thompson and Diller (2003), a study conducted within the same ownership.

3.C.2. Summary of Tree Vole Studies from Nearby Areas

Meiselman and Doyle (1996) studied Sonoma tree voles in young (<100 yr old), mature (100-200 yr old), and old-growth (> 200 yr old) Douglas fir forests, in Mendocino County, California. Vole nests were most abundant in old-growth forest ($G = 9.02$, $P < 0.01$, df = 2). Tree diameter was greater for nest trees than for unoccupied trees, and nests were patchily distributed. All vole nests found were in Douglas fir trees ($n = 79$). In contrast to our results, vole nests were most frequently located adjacent to the trunk, as opposed to farther from the tree bole (Meiselman and Doyle 1996).

Jones (2005) compared tree vole abundance among stands of three size classes on Pacific Lumber Company land in Humboldt County, California, in 2000. Mature stands (>61 cm dbh) contained approximately 6 times the number of nests found in either pole stands (15-28 cm dbh) or unthinned young stands (28-61 cm dbh; $F_{2,9} = 11.88$, $P = 0.003$). In 2001-2002, Jones (2005) studied habitat associations of Sonoma tree voles in Redwood National and State Parks, Humboldt Redwoods State Park, and Angelo Coast Range Reserve, in Humboldt and Mendocino counties, California. Using transect sampling, Jones (2005) found 531 nests; 93% of nest trees were Douglas fir.

In Oregon, Swingle and Forsman (2005) fitted 61 red tree voles with radio-transmitters and followed the voles for 3-307 days ($\bar{x} = 76$, SE = 8 days) to observe daily and seasonal movements. Based on 95% fixed kernel estimates, vole home range sizes averaged 0.11 ha (SE = 8 ha). By following voles equipped with radio-transmitters, Swingle and Forsman (2005) located 56 vole nests and determined that 31 of the nests were not detectible from the ground.

3.D Early Green Diamond Resource Company and Outside Definitions of Spotted Owl Habitat

In the following section we summarized spotted owl nest and nest tree characteristics on GD land and reviewed two early studies designed to quantify the vegetation conditions associated with spotted owl nesting habitat and the influence that those conditions had on spotted owl reproductive output. In addition, we reviewed studies conducted outside GD's ownership that were relevant to understanding definitions of spotted owl habitat.

3.D.1 Spotted Owl Nest Tree Species, Nest Types and Nest Locations

We located 273 nests at 126 spotted owl territories in 1992-2004. Because many of the nests were used in multiple years, the 273 nests represent 726 nesting attempts. The majority (52%) of nests were located in platforms, including mammal nests (nests of flying squirrels, tree voles, and dusky-footed woodrats), bird nests, and debris platforms (Table 3.11). The remaining nests were in cavities (23%), broken-top "chimneys" (17%) or unknown (8%). Douglas-fir, redwood, and tanoak accounted for > 75% of nest tree species. Mean percent slope at nest locations was 39% (range 4-90%; Fig. 3.5). Nest trees were well distributed across slope aspects (Fig. 3.5). Mean nest tree diameter at breast height was 129 cm (SE = 5 cm). Mean nest tree height was 18.4 m (SE = 0.5 m).

Of 46 nests measured by Folliard (1993), mean length and width was 57 x 47 cm. Nest structures were similar in size across nest types. Mean canopy closure directly above the nest was 96% (SD = 5, range = 78-100). See Section 4.B.2 for an analysis of the factors related to fecundity rates including nesting success.

3.D.2. Vegetation and Landscape Characteristics of Spotted Owl Habitat

In the first study of spotted owl habitat characteristics, we characterized nesting habitat at 3 scales (nest microsite, nest stand, and landscape) for 60 spotted owl pairs (Folliard 1993, Folliard et al. 2000). For nest microsite-level comparisons, we measured vegetation characteristics (tree basal area by size class and conifer/hardwood, canopy cover, canopy height, log volume, ground cover, and slope) in 0.07 ha plots centered on nest trees and at 4-5 random locations within each nest stand. For nest stand-level comparisons, we measured the same characteristics in random locations. For landscape-level comparisons, we used GD GIS data in combination with 1:12,000 color aerial photos, to classify stands within 0.8 km (0.5 mi) radius (203 ha) circles around owl activity centers and random locations. In addition to quantifying the area of stand age classes, within each 203 ha circle we measured slope position of the nest, length of roads, the amount of edge between different age classes, the amount of high-contrast edge, distance from the nest to the nearest forest opening, distance to water, the number of cover type polygons, and the area of the largest cover type polygon. For stand- and landscape-level analyses, random locations were in stands at least 30 yrs old and thought to be unused by spotted owls (>1.6 km from known owl spotted owl activity centers).

Nest microsites
Ninety-five percent of nest microhabitat plots were not different than random plots within the same stand, based on separate multivariate linear models for each plot (this was not a powerful test). Multivariate analysis of variance (MANOVA) indicated that all nest sites combined differed from all random points within nest stands combined (Wilks' $F = 2.586$, $P < 0.001$). Univariate *t*-tests revealed that 5 of 20 variables contributed to these differences ($P < 0.05$): spotted owl nest sites had greater basal area of large conifers (> 90 cm dbh), greater canopy height, lower basal area of small hardwood trees (13-27 cm dbh), lower canopy closure, and greater log volume. Very few snags were present at nest sites, and 82% of nest sites contained no snags >52 cm dbh. Mean basal area of small (9-52 cm dbh) and large (>52 cm dbh) snags in nest stands was 0.99 and 0.92 m^2, respectively.

We compared basal area of large conifers, basal area of small hardwood trees, canopy height, and log volume at successful ($n = 47$) and unsuccessful ($n = 10$) nests using *t*-tests. We found no significant differences (all $P > 0.28$).

Nest stands
Stand cover types used by spotted owls for nesting were Redwood/Hardwood (17%), Redwood/Douglas fir/Hardwood (25%), Douglas fir/Hardwood (23%), and Hardwood/Conifer (35%). The distribution of nest stands did not differ from random stands ($\chi^2 = 4.365$, df = 3, $P = 0.225$). Eighteen percent of nests occurred in stands 31-45 yrs old, 35% in stands 46-60 yrs old, 30% in stands 61-80 yrs old, 7% in stands 81-200 yrs old, and 10% in stands >200 yrs old. Sixty-two percent of owl pairs nested in stands with residual, older trees present; 38% nested in even-aged stands. Among stands dominated by hardwoods, 90% contained residual trees. Snag density was low in both nest and random stands.

We compared nest stands to random stands separately for conifer- and hardwood-dominated stand types (hardwood-dominated stands were those in which hardwood tree species accounted for > 50% of total basal area). MANOVA indicated that conifer-dominated nest stands differed from conifer-dominated random stands (Wilks' $F = 4.483$, $P < 0.001$). Univariate tests revealed that 9 of 20 variables contributed to these differences ($P < 0.05$): nest stands had greater basal area of large conifers (>90 cm dbh), lower basal area of small conifers (13-27 cm and 28-52 cm dbh), fewer conifer saplings, steeper slopes, and higher ground cover of shrubs, ferns, forbs, and tree seedlings. Similarly, hardwood-dominated nest stands differed from hardwood-dominated random stands (Wilks' $F = 2.875$, $P = 0.024$). Univariate tests revealed that nest stands had lower basal area of small conifers (13-27 cm), and higher ground cover of ferns, forbs, and tree seedlings (all $P < 0.05$).

We entered the variables that differed between nest and random stands into a stepwise discriminant analyses. For conifer-dominated stands, the discriminant function model correctly classified 69% of nest stands and 82% of random stands. Variables included in the model were ground cover of ferns, tree seedlings, conifer sapling density, and slope. For hardwood-dominated stands, the discriminant function model correctly classified 76% of nest stands and 86% of random stands. Variables included in the model were ground cover of ferns and tree seedlings.

Nesting landscape

Landscape composition of 203 ha circles centered on nests differed from circles centered on random locations (Wilds' $F = 6.073$, $P < 0.001$). Subsequent univariate *t*-tests indicated that 8 of 12 variables contributed to these differences ($P < 0.05$): Nest circles had more 31-45 yr old and 46-60-yr old forest (the age classes representing 53% of nest locations; see above), less 8-30-yr old forest (not used for nesting), and were similar to random stands in the amount of forest >60 yrs old and the amount of forest 0-7 yrs old (Table 3.12). Furthermore, nest circles had greater total edge (juxtaposition of different cover types or age class of the same cover type), were lower on the slope, were closer to water, had lower length of roads, and had a longer distance from the circle center to the nearest forest opening.

We entered variables significantly different between nest and random sites into a stopwise discriminant analysis. Four variables were selected in the final discriminant function model: position on slope, total edge, 31-45 yr old forest, and 46-60 yr old forest. The discriminant function model correctly classified 72% of nest landscapes and 73% of random landscapes. We tested for univariate differences in these four variables between successful ($n = 47$) and unsuccessful spotted owl nests ($n = 8$), and found none.

In the second study of spotted owl habitat characteristics, we used a longer span of spotted owl reproductive data (1991-1995) to compare landscape-level habitat characteristics between sites with high and low fecundity, at 5 spatial scales (Thome et al. 1999). We calculated reproductive success at each site as the proportion of years in which ≥1 owlet fledged. We also compared habitat characteristics of random and occupied sites (Thome et al. 1999). The spatial scales we used were 7, 50, 114, 203, and 398 ha. Stand age classes differed from those used by Folliard (1993) and Folliard et al. (2000), and were 0-5-yrs-old, 6-20-yrs-old, 21-40-yrs-old, 41-60-yrs-old, 61-80-yrs-old, and >80-yrs-old.

Using the same data, we compared landscape-level habitat characteristics (at the 398 ha scale) and reproductive output of sites with and without turnover (replacement of one owl by another owl following death or dispersal of the first owl). We recorded turnover as a binary variable (0 turnovers, ≥1 turnover; Thome et al. 2000).

Owl reproductive success

Sites with higher spotted owl reproductive success had a greater proportion of 21-40 yr old stands and lesser proportion of 0-5 yr old stands within the largest circles than sites with lower reproductive success (Mann-Whitney U-tests, $P < 0.10$). However, spotted owl sites had lower proportions of 21-40 yr old stands than random sites within the smallest four circles (Mann-Whitney U-tests, $P < 0.10$). Forward stepwise logistic regression found 4 of 55 landscape characteristics predicted spotted owl use sites: the proportion of 6-20 and 21-40 yr old stands within the 50 and 114 ha circles were negatively related to the presence of spotted owls. Forward stepwise logistic regression was unable to model reproductive success.

Owl turnover

Spotted owl sites with no turnover ($n = 21$) had higher proportions of 21-40 yr old stands ($\bar{x} = 0.36$, SE = 0.06) than did sites with at least one turnover in four annual intervals ($n = 30$, $\bar{x} = 0.23$, SE = 0.05). Sites without turnovers had higher reproductive output than sites with turnovers. However, 50% of the new recruits were subadults, which breed at lower rates and have lower productivity than adult owls. Therefore, reproductive output at sites with turnover was confounded by owl age class.

Discussion

Spotted owls on GD land nested in younger stands than reported elsewhere in the subspecies range (Courtney et al. 2004). Thomas et al. (1990) speculated that this may be due to young redwood stands developing structural attributes similar to those found in older forests throughout most of the range of the northern spotted owl. However, as noted above, a hardwood component and older residual trees within the stand may have contributed to the use of these young stands for nesting.

A lower proportion of spotted owl nests found on GD land were located on platforms (52%) than elsewhere in the Redwood Region of California. Four other studies found 65-88% of spotted owl nests on platforms; tree species used for nesting were similar to other studies in the region (Pious 1994, Tanner 1999, Chow 2001, Fehring et al. 2003; summarized in Courtney et al. 2004).

Spotted owl nest microsites on GD land had greater basal area of large conifers, greater canopy height, lower basal area of small hardwood trees, lower canopy closure, and greater log volume than random sites within nest stands. Similarly, nest stands had greater basal area of large conifers, lower basal area of small conifers, fewer conifer saplings, steeper slopes, and higher ground cover of shrubs, ferns, forbs, and tree seedlings than random stands. These findings are consistent with habitat associations of northern spotted owls at several spatial scales throughout the range of the subspecies (Courtney et al 2004:5-18):

> "Forest stand structural attributes positively associated with foraging, roosting and nesting included vertical canopy layering, tree height or diameter diversity, canopy volume, canopy closure, snag diameter, snag basal area or volume, tree diameter and log volume. These attributes correspond to those identified by Thomas et al. (1990) as important components of Northern Spotted Owl habitat."

Landscape composition around nests differed from random locations on GD land, with nest locations containing more 31-45 yr old and 46-60 yr old forest. The amount of clearcut area did not differ between nest and random sites on GD land; this was also found by Meyer et al. (1998) in Oregon. In contrast to all other studies of northern spotted owls except one in the eastern Cascades of Washington, landscapes surrounding nests did *not* contain more older forest (>60 yrs in our study) than random landscapes (summarized in Courtney et al. 2004).

Although we found associations between reproductive output and forest cover types, we did not evaluate spotted owl survival in relation to habitat variables in these studies.

Table 3.13 compares the results of Folliard et al. (2000), Thome et al. (1999), and the nocturnal and nesting resource selection functions from Chapter 2. Recall that nocturnal resource selection at a point was a positive function of the nearest stand being 6-20 or 21-40 yrs old, a negative function of the nearest stand being at least 40 yrs old, a (convex) quadratic function of the percent of the area within 250 m (820 ft) being at least 41 yrs old, a positive function of the percent a stand containing a point being composed of hardwoods, and a negative function of increasing position on a slope. Recall also that nesting resource selection was a negative function of a point being in 2nd growth, a (convex) quadratic function of the nocturnal resource selection function, a positive function of opening edge density within 600 m (1969 ft), and a (convex) quadratic function of the percent of the stand containing the point being composed of hardwoods. For second growth stands, additional variables were important in the probability of a stand being selected for nesting: the age of the stand containing a point was positively associated with selection, and the percent of residual trees within the stand had a (convex) quadratic relationship to selection of a site for nesting.

In summary, in comparing various age classes in the landscape, neither very young stands (0-5 yrs) nor older stands (>60 yrs) were good predictors of spotted owl nesting or nocturnal locations, except that a point located in second growth appeared (with a negative coefficient) in the nesting resource selection function (RSF). Stands 41-60 yrs old appeared in greater proportions in the vicinity of nests at several scales, whereas if the nearest stand were in this age class, a point was less likely to be selected for nocturnal activity. The proportion of stands 21-40 yrs old was lower around nests in one study (Thome et al. 1999), but the proportion of stands 31-45 yrs old was higher around nests in another study (Folliard et al. 2000). Nocturnal locations were more likely to occur at a point if the nearest adjacent stand was 21-40 yrs old. Locations lower on a slope were positively associated with both nesting and nocturnal locations.

3.D.3. Influence of Habitat Configuration on Spotted Owl Survival, Reproduction, and Habitat Fitness

Several recent studies modeled temporal and spatial variation in reproduction and survival of northern spotted owls with respect to habitat configuration and weather at the landscape scale (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005). On the Willow Creek study area, in the Klamath Province of California, Franklin et al. (2000) characterized suitable habitat as mature and old-growth conifer ≥ 53 cm dbh, percent of conifers ≥ 40%, and overstory canopy cover ≥ 70%. Suitable habitat and a single category termed "all other habitat" were mapped within 158 ha circles. From the best models of survival and reproduction, Franklin et al. (2000) estimated habitat fitness potential (λ_H) of spotted owl sites using modified Leslie projection matrix methods.

As summarized in Courtney et al. (2004), in the California Klamath province:

> "Survival was positively and non-linearly associated with the amount of interior older forest (>100 m from an edge), the amount of edge between older forest and other vegetation types, and showed a quadratic (convex) relationship to the distance between patches of older forest. Reproductive output was negatively and non-linearly associated with the amount of interior older forest, had a quadratic (concave) relationship to the number of older forest patches, and was positively associated with the amount of edge between older forest and other vegetation types. Thus, there appeared to be a trade-off between the benefits to survival conferred by interior older forest and benefits to reproduction conferred by less

interior older forest and more convoluted edge between the two habitat categories. Estimates of λ_H ranged from 0.438 to 1.178 (mean = 1.075). Based on 95% confidences intervals, 69% of owl territories had estimates of $\lambda_H > 1$, indicating owls at these territories more than replaced themselves. Franklin et al. (2000) suggested that habitat quality may determine the magnitude of λ (finite rate of population growth) and recruitment may determine variation around λ. In addition, owls in territories of higher habitat quality (i.e., $\lambda_H > 1$) had greater survival during inclement weather than those in poorer quality habitat."

Olson et al. (2004) and Dugger et al. (2005) generally followed the methods of Franklin et al. (2000) for northern spotted owls in the Oregon Coast Range, and Oregon Cascades (respectively). Olson et al. (2004) evaluated demographic relationships to habitat at three spatial scales, within 113, 707, and 1810 ha circles and classified vegetation as late-seral conifer, mid-seral conifer, non-habitat, and broadleaf.

As summarized in Courtney et al. (2004):

"In the central Oregon Coast Range, survival had a quadratic (convex) relationship to the amount of mid- and late-seral forest within 1500 m of owl site centers (707 ha circles; Olson et al. 2004). The best model explained only 16% of the variation in the data. Of the variation explained by the model, habitat accounted for 85%. Reproductive output was positively related to the amount of edge between mid- and late-seral forests and other habitat classes. The best model explained 84% of the total variability; however, the habitat variable accounted for only 3% of the variation explained by the model. Consitsent with results from the Klamath Province in California (Franklin et al. 2000), a mixture of older forests with younger forests and nonforested areas appeared to benefit owl life history traits. Estimates of λ_H ranged from 0.74 to 1.15 (mean = 1.05, variance = 0.005), with 95% confidence intervals around λ_H for all but one territory overlapping 1, indicating a potentially stable population based on habitat pattern (Olson et al. 2004)."

Dugger et al. (2004) evaluated demographic relationships to habitat at three spatial scales, within 167 and 1565 ha circles and within the 1388 ha annulus between the outer and inner circles. Dugger et al. (2005) classified vegetation as older forest, intermediate-aged forest, and non-habitat, with subcategories of the forested habitats.

In the southern Oregon Cascades spotted owl survival was positively associated with the amount of old growth forest within 167 ha of the territory center. For survival, this relationship was best described by a "pseudothreshold" model (increasing relationship that levels off at higher values of of the amount of old growth). In addition, there was a quadratic (convex) relationship between survival and the amount of non-habitat within the 1388 ha ring, indicating that survival was higher at intermediate levels of non-habitat within the ring. These two habitat covariates explained 54% of the spatial variation in survival whereas temporal variation was essentially zero. Owl reproduction was also positively associated with the amount of old growth forest within 167 ha of the territory center. The best model accounted for 25% of the total variance in reproductive output and the habitat variable only accounted for 7% of the model variance. Estimates of λ_H ranged from 0.29 to 1.09 (mean = 0.86, SE = 0.02, n = 97). In contrast to Franklin et al. (2000) and Olson et al. (2004), Dugger et al. (2005) did not find a positive lationship between the amount of edge and spotted owl reproduction.

Based on geographic proximity, the Franklin et al. (2000) results would likely be the most applicable to the GD study area. The Willow Creek study area is immediately to the east of the GD study area, and at one point, the two study areas are only approximately 3 miles apart. However, the Willow Creek study area is located on US Forest Service land with a different past mangement history, which may have influenced the results obtained.

3.D.4. Influence of Weather on Spotted Owl Survival and Reproduction

In each of the three studies described above (3.D.3), researchers modeled spotted owl survival and reproduction as a function of weather variables (temperature and precipitation during several biologically-defined periods: winter stress, early nesting, late nesting, dispersal, and heat stress periods).

As summarized in Courtney et al. (2004):

> "In the California Klamath Province, annual survival was negatively associated with precipitation and positively associated with temperature during the early nesting period (Franklin et al. 2000). Reproductive output was negatively related to precipitation during the late nesting period. This model explained essentially all of the estimable temporal process variation in reproductive output (Franklin et al. 2000).
>
> In the central Oregon Coast Range, survival was negatively related to early nesting season precipitation and positively related to late nesting season precipitation (Olson et al. 2004). The best model explained only 16% of the variation in the data, and most of the variation was spatial; the precipitation covariates explained 15% of the model variation. Reproductive output was positively related to late nesting season precipitation. The best model explained 84% of the total variability; 38% of the model variation was explained by weather covariates."

In the southern Cascades, the best model of spotted owl survival did not include any effects of weather; temporal variation in survival was essentially zero (Dugger et al. 2005). Owl reproduction was negatively related to precipitation during winter. The best model accounted for 25% of the total variance in reproductive output, with the weather variable accounting for 19% of the variance in the model.
Seventy-four percent of the model variance was explained by a biannual pattern in reproduction

("even-odd year effect") and the experience of male owls on a territory (Dugger et al. 2005). Based on geographic proximity, the Franklin et al. (2000) results would likely be the most applicable to the GD study area. The Willow Creek study area is immediately to the east of the GD study area, and at one point, the two study areas are only approximately 3 miles apart. However, most of the GD study area is within the coastal influence, which results in mild winters and cool summers. The Willow Creek study area is mostly outside the coastal influence with greater temperature extremes particularly in summer when temperatures can exceed 100^0 F.

3.E Foraging Behavior of Spotted Owls on Green Diamond Resource Company Land

There has been extensive research on northern spotted owls (*Strix occidentalis caurina*) designed to understand the habitat requirements and population viability of this federally listed species (USDI 1990). The focus of habitat based studies has been to identify the structural characteristics and spatial requirements for nesting, roosting and foraging (Forsman et al. 1984, Carey et al. 1990, Solis and Gutiérrez 1990, Ripple et al. 1991 and 1997, Lehmkuhl and Raphael 1993, Hunter et al. 1995, Buchanan et al. 1993 and 1995, Zabel et al. 1995). The majority of these studies have been conducted in landscapes with significant areas composed of mature and old growth forests, the principal habitat for this subspecies throughout much of its range. Due to the influence spotted owls have on forest management, there has been considerable interest in identifying management practices which could accelerate development of suitable owl habitat in forested landscapes which currently lack the structural characteristics necessary to support owls. However, because most owl habitat took decades, or even centuries to develop, there have been few opportunities to elucidate the critical components of regenerating forest stands that are first being utilized by spotted owls as habitat.

The coastal region of northern California was recognized early in the 1990's as being somewhat unique for spotted owls (Thomas et al. 1990). In this area, spotted owls were frequently located nesting in relatively young managed stands, in contrast to what had been observed throughout most of the owl's range. Several factors contribute to the uniqueness of the region. Habitat structure develops more rapidly in the moist coastal region due to the rapid regeneration of redwoods (*Sequoia sempervirens*) and other conifers, but it is the coppice growth of a variety of hardwood species, including tanoak (*Lithocarpus densiflorus*), madrone, (*Arbutus menziesii*), and California bay (*Umbellularia californica*), that results in high structural diversity in managed even-aged stands. Dusky-footed woodrats are the primary prey for spotted owls in the study area (see section 3A, above). Dusky-footed woodrats are found in high abundance in young forest stands regenerating after timber harvest (Sakai and Noon 1993, Hamm 1995), so that a limited degree of harvesting of older stands may benefit owls through increased prey availability (Cary et al. 1992, Carey and Peeler 1995). All of these factors contribute to the early development of suitable habitat so that owls can be found occupying landscapes predominantly comprised of stands as young as 30 years of age (Folliard et al. 2000).

This suggests that an investigation of the key habitat elements utilized at night by spotted owls in a managed landscape would not only provide useful information for the coastal region, but may also provide insights that could be applied throughout the north coastal region of California.

Methods

Study Area

The study was conducted in three primary areas on Green Diamond Resource Company ownership (Fig. 2.1). All three areas were heavily roaded which provided for excellent access throughout. The northern area is located north of the Klamath River, in the Terwer, Hunter and Wilson Creek drainages. This is an area of approximately 17,800 ha that was composed of redwood and Douglas fir stands that were mostly 15-30 years old with a few scattered stands of mature and old-growth timber.

The central area was in the Little River drainage, situated between McKinleyville and Big Lagoon, east of Highway 101. This area comprised approximately 30,350 ha, was highly fragmented, and had a mix of redwood and Douglas fir stands ranging from 0-80 yrs old. Silvicultural practices in this area resulted in a wide range of forest stand conditions, including lightly to heavily thinned stands, shelterwood stands, and even-aged stands.

The southern area was in the lower Mad River drainage and consisted of approximately 7,600 ha. The majority of stands in this region were from 0-15 yrs old, with isolated stands of 60-80 yr old second growth timber. The area was predominately redwood with some Douglas fir.

Visual Observations

Owls in this study were fitted with radio-transmitters as part of GD's study of nocturnal habitat use (see Chapter 2). From March-July 1999, we attempted to observe each transmittered owl once/week, and to alternate between early night and late night observations for each owl in subsequent occasions. After triangulating on an owl, we attempted to locate the bird visually with the aid of night vision scopes outfitted with small infrared lights (ITT Night Quest, Model 160 and 190). Our observations were limited to locations in which an owl was reasonably accessible from a road. We attempted to minimize the effect of observers on the owls' behavior by not approaching any closer than necessary to observe the owls through scope.

We followed individual owls for a minimum of 3 hours per night, with telemetry or visual locations recorded at intervals of 30 minutes or less. Because owls are sit-and-wait predators, 30 minute intervals allowed movement patterns to be established. The monitoring periods included both p.m. and a.m. nocturnal sessions. Data collected on foraging behavior included: time spent per perch, number of prey capture attempts/hour, number of prey captures/hour, and total time spent foraging. Data collected on habitat elements associated with foraging included foraging perch characteristics (tree species, size and location – e.g. stand interior versus edge, habitat retention area, watercourse protection zone, and characteristics – e.g. live tree, snag, stump), perch height, perch structure, percent slope, aspect, and ground cover.

Results

Visual observations often consisted of multiple perches used over a short time span in close proximity to one another. We collected the majority of observations during the early hours of the owls foraging (1800-2400; Fig. 3.6). We obtained visual observations for 18 of the 22 transmittered owls. However, 5 owls were excluded from comparisons among individuals because they were observed on fewer than 3 perches each. The remaining 13 individuals (6 males and 7 females) were observed on 204 perches over 41.25 observation hours.

We observed 22 attempts by owls to capture prey with an average of 1 prey capture attempt per 9.3 perches, or 1 prey capture attempt per 112.5 minutes of perch time. Overall mean time per perch was 15.7 minutes (SE = 2.75; range = 4.9-43.3). Males spent less time on each perch than females ($\bar{x}$ = 9.5 and 21.0 minutes, respectively; $t = 2.49$, $P = 0.030$; Fig. 3.7). Of the 22 attempts by owls to capture prey, we judged 3 to be successful. Two of the captures were observed and the third was inferred by the fact that the male owl being observed promptly flew back to the nest following the capture attempt and gave prey delivery calls.

Multiple estimates of perch height while foraging were only obtained for 5 individual owls. The mean perch height based on 47 observations from three males was 4 m (12.7 ft), which was significantly lower ($t = 3.83$, $P = 0.008$) than the mean of 6.5 m (21.2 ft) from 16 observations of three females.

There were biases associated with our ability to visually locate the owl in different types of habitats and with our ability to move at night through different habitats. We obtained the majority of visual observations when the owls were foraging near roads, which existed in most stand types. However, we were not able to quantify the number of foraging observations associated with roads because assigning an owl to this category was too arbitrary. The majority (57) of visual observations occurred in recent clearcuts (<10 years old) when the observer believed the owl was not near a road, followed by riparian buffer zones (4) and forested stands (2).

Approximately 50% of both triangulated and visual owl observations occurred in forest stands >40 yrs old, and 20-30% occurred in stands 10-20 yrs old (Fig. 3.8). In contrast, few observations occurred in the 5-9 or 21-40 year age classes (Fig. 3.8). Eight percent of visual and 13% of triangulated owl observations occurred in the 0-4 age class.

Discussion

The northern spotted owl has been described as a sit-and-wait predator that forages by flying from perch-to-perch to search for its prey (Forsman 1984). Our observations confirm this mode of hunting with an estimated overall mean perch time for both sexes of approximately 16 minutes. Our data also suggest that males tend to spend less time per foraging perch than females, which may suggest a slightly different foraging strategy between the sexes. There is moderate reversed sexual dimorphism in spotted owls with females averaging approximately 15% larger in body mass (Blakesley et al. 1990). Potentially, males may be better adapted to taking smaller more abundant prey and their more frequent movements reflect this foraging strategy. It is also possible that this phenomenon is related to behavioral differences between the sexes (Bull et al. 1989). During courtship, males offer food to their mate while the female often sits and emits begging calls (Forsman 1984). Also, during the early breeding season, females do all the incubating and brooding of the young, while the males forage. During the transition period when female behavior shifts from being fed to actively foraging on their own, there may be a tendency for females to wait to be fed by the male for a time before beginning active foraging. Our observations at this time of year may contribute to an estimate of significantly longer perch times for females.

Our data suggest that spotted owls capture prey at few (11%) of their hunting perches and that few (14%) of their attempts to capture prey are successful. This indicates that they successfully capture prey from <2% of their total hunting perches. We observed 3 successful capture attempts in 41.25 hours of foraging or 1 capture every 13.75 hours of foraging. During the shorter summer nights with only 8-9 hours of darkness, an owl would average a single capture approximately every 1.6 nights. This should be adequate to sustain an individual owl that is preying on larger prey such as dusky-footed woodrats (mean body mass = 210 g [Hughes 2005]), the primary prey in our study area (see Section 3A, above). However, a male spotted owl would be unlikely to be able to sustain his mate and several nestling owlets with this level of hunting success. As noted above, this estimate is based on a small sample size and may not accurately reflect average foraging success of spotted owls in our region. In addition, the presence of the observer, who was attempting to remain at a discrete distance while maintaining visual contact with the foraging owl, may have influenced the owl's hunting success, either by influencing the owl's prey or influencing the owl's hunting ability. In an observational study of diurnal foraging by northern spotted owls, capture success rate was 22% (Sovern et al. 1994).

Mean perch height while foraging of 4 and 6.5 m for males and females respectively, suggests that spotted owls in our study area are foraging primarily on the ground and understory. The observation is consistent with preying on dusky-footed woodrats, which primarily nest on the ground (Sakai and Noon 1993). Given the small sample size, the estimated differences between the sexes should be interpreted with caution.

As noted above, there were several inherent biases in this study associated with visual observations of foraging in spotted owls. As a result, we can not assess various aspects of their foraging ecology such as temporal patterns in foraging throughout their activity period and relative amounts of time they spend foraging in different habitats. However, nocturnal locations of spotted owls based on triangulations likely also had biases associated with them. To get a single location, three separate azimuths had to be obtained that converged on a single point. If an owl were actively moving, the probability of getting three converging azimuths was greatly reduced. Generally, it took approximately 15 minutes to travel to three points and get good compass bearings with the directional antennae in this study. As a result, triangulations were most likely biased to locations where owls spent >15 minutes in one location. Given the relatively short mean perch times (9.5 and 21.0 minutes, respectively for males for females) estimated from direct visual observations of foraging owls, nocturnal locations based on triangulation likely missed much of the active foraging, especially for males. Therefore, studies of nocturnal habitat use based on triangulations likely under estimate actual foraging habitat and tend to reflect habitat used for spotted owls when engaged in other behaviors at night (e.g. resting, grooming, vocalizations and others).

Despite the biases, it is apparent that spotted owls tended to spend the greatest time in older stands (>40 yrs) during their period of activity at night. Stands 10-20 yrs also received high use, and although not a high proportion (7.7% triangulation and 16.9% visual) of all the locations, spotted owls used recent clearcuts (0-4 yrs) more than we anticipated based on the majority of previous radio telemetry studies (Courtney et al. 2004). In addition, the foraging in recent clearcuts was not an aberrant behavior of just a few of the birds being monitored since 13 of 22 birds were recorded in these open areas on at least one occasion.

Presumably, the high use in the older stands relates to their ability to use these stands to forage for certain species of prey (e.g. flying squirrels, tree voles, birds and etc.) as well as engaging in other nocturnal behaviors as described above. In contrast, use of the younger stands were likely only associated with foraging for species such as dusky-footed woodrats, which are known to be abundant in young stands (Sakai and Noon 1993, Hamm 1995, Hughes 2005). We believe the high use in the 10-20 yr old stands occurs, because these stands had high densities of woodrats (Sakai and Noon 1993, Hamm 1995, Hughes 2005), and spotted owls were able to forage relatively well in stands of this age. We postulate that the rapid development of coastal forests results in sufficient stand development and canopy lift during the 10-20 age class that woodrats become more vulnerable to avian predators. In contrast, brushy clearcuts that are 5-9 yrs old may have relatively high numbers of woodrats, but they may be too dense to permit access by avian predators. The 0-4 yr old clearcuts may contain relatively few prey items, but those present should be quite vulnerable to an avian predator.

3.F Barred Owls

Barred owls (*Strix varia*) and Northern Spotted Owls are closely related, are similar in morphology (barred owls are approximately 15% larger), and have similar habitat associations where their ranges overlap (Courtney et al. 2004). Barred owls expanded their range from eastern to western North America in the latter part of the 20th century, arriving in Washington in 1965 (Rogers 1966), Oregon in 1974 (Taylor and Forsman 1976) and California in 1981(Evens and LeValley 1982). The barred owl's range now overlaps essentially all of the range of the northern spotted owl.

Most observations of barred owls in the range of the Northern Spotted Owl were detected incidental to spotted owl surveys and demographic studies (Courtney et al. 2004). Only one study has focused on home range and diet of sympatric barred and spotted owls, in the Washington Cascades (Hamer 1988, Hamer et al. 2001). Home ranges of barred owls were much smaller than spotted owls in Washington (Hamer et al. 1988). However, spotted owl home ranges in Oregon and California tend to be smaller than those in Washington; the relative sizes of the two species' home ranges in Oregon and California are unknown. Barred owls in Washington had a more diverse diet than sympatric spotted owls (Hamer et al. 2001). Again, dietary overlap between these two species has not been studied in Oregon or California.

In some regions, barred owl pairs occupy many territories formerly occupied by spotted owls (e.g., Olympic peninsula, Scott Gremel, *personal communication*; Washington Cascades, Pearson and Livezey 2003 & Herter and Hicks 2000). It is unknown whether barred owls directly displaced spotted owls in these cases, or whether spotted owls vacated their territories for some other reason, allowing the barred owls to colonize the vacant areas. Occupancy of former spotted owl territories by barred owls has occurred on many types of land ownership (National Parks, National Forests, BLM Districts, tribal land, state land, timber company land, etc.; Courtney et al. 2004), including those that experienced timber harvest and those not available for timber harvest.

Hybridization between spotted and barred owls occurs infrequently. Kelly and Forsman (2004) found records of 47 spotted-barred hybrids in Oregon and Washington, 1970-1999, out of all available spotted owl survey data, including >9000 observations of banded spotted owls. Of the 47 hybrids, 31 were F1 hybrids (a first generation offspring of a pure spotted owl and a pure barred owl) and 16 were F2 hybrids (a second generation offspring of an F1 hybrid with either a pure spotted owl or a pure barred owl; an F2 hybrid could also result from an F1xF1 crossings, but this has not been observed in the field).

Hybrid owls tend to arise from pairings between female barred owls and male spotted owls because both species exhibit reversed sexual size dimorphism (females are larger than males). Male barred owls are similar in size to female spotted owls (Courtney et al. 204), making this pairing less likely (Kelly and Forsman 2004). On 13 occasions at 6 territories, male spotted owls were paired with female barred owls. In no cases were female spotted owls paired with male barred owls (Kelly and Forsman 2004). In a different study, six of seven hybrid owls genetically sampled proved to have barred owl mothers, whereas only one had a spotted owl mother (Haig et al. 2004).

Eleven F1 hybrids of both sexes were observed paired with barred owls and seven F1 hybrids of both sexes were observed paired with spotted owls, although 15 of 16 F2 juveniles observed were produced by F1 hybrids that backcrossed with female barred owls. No pairings of F1 males with F1 females were observed. It may be difficult to distinguish hybrid backcrosses in the field (e.g., to distinguish and individual that ¾ spotted owl and ¼ barred owl from a spotted owl). However, these birds can be distinguished by genetic markers (Haig et al. 2004).

Hybridization appears not to be a threat to the spotted owl because it occurs when and where barred owls are relatively scarce, at the front of the barred owl range expansion (Kelly and Forsman 2004, Courtney et al. 2004). The real threat to spotted owls appears to arise from competition between barred owls for territories, at least in some areas. The 2004 scientific evaluation of the northern spotted owl (Courtney et al. 2004, Chapter 7, p. 43) concluded that "while we are convinced that barred owls are having a negative impact on spotted owls at least in some areas, the extent of this impact and its ultimate outcome is uncertain."

3.F.1 Number and Distribution of Barred Owls on Green Diamond Resource Company Land

Between 1993 and 2005, 43 barred owl sites were located on GD lands (Fig. 3.9). These sites were based on barred owl responses incidental to spotted owl surveys. Except for a few exceptions, follow ups were not done for barred owl responses and these sites do not necessarily represent activity centers or nest sites for resident barred owls. The potential exists that individual barred owls moved around during a given season and resulted in an over estimate in the number of sites. On the other hand, since the surveys were not designed to locate barred owls, there may have been resident barred owls that were not detected. Therefore, the total barred owl sites listed here probably does not accurately reflect the real number of barred owl sites on GD property.

Even though an estimate of the absolute number of barred owl sites is highly suspect, it is apparent that the number of sites has increased over time (Fig. 3.10). Spotted owl survey protocols and the level of survey effort have remained relatively constant over time, so that the increase in barred owl sites can most reasonably be attributed to more barred owls. It appears that the maximum number of sites peaked at 14 in 2003, but this should be viewed with caution. It is suspected that "floating" non-territorial barred owls may be more inclined to vocalize, while nesting individuals are relatively silent (B. Woodbridge, *personal communication*). It is possible that the apparent decline in barred owl sites was the result of more nesting pairs of barred owl rather than a real decrease

3.F.2 Summary of Barred and Hybrid Owl Numbers in Nearby Areas

In Redwood National and State Parks (RNSP), adjacent to GD land, the number of historic and current spotted owl activity centers in which barred owls were detected has risen gradually between 1993 and 2004, concurrent with a decline in the number of spotted owls in the activity centers (Schmidt 2005). For example, 24 spotted owl activity centers were surveyed in both 1995 and 2004. Of these 24 sites, 22 were occupied by spotted owls in 1995 (17 by owl pairs, 4 by single males, and 1 by a single female owl), and only 6 of these sites were occupied by spotted owls in 2004 (all by owl pairs). In 1995, two of the sites with spotted owl pairs each had a barred owl detection and no barred owls were detected in the remaining 22 surveyed sites. In 2005, one of the sites with spotted owl pairs had a barred owl detection and eight additional sites had barred owl detections. The remaining 10 sites had neither spotted owl nor barred owl detections (Schmidt 2005).

Among 36 sites surveyed from 1993-2004 (not all sites were surveyed each year), only one known hybrid spotted-barred owl was detected in Redwood National and State Parks. This was a hybrid female paired with a spotted owl male in 1998; the pair produced 2 fledglings.

3.F.3. Modeling Occupancy of Northern Spotted Owl sites with respect to Barred Owls in Oregon

Using data collected from 1990-2002 at three northern spotted owl demographic study areas in Oregon, Olson et al. (2005) modeled temporal variation in site occupancy, extinction and colonization probabilities. The effects of barred owls presence was also examined for these parameters. Barred owl presence was found to have a negative effect on spotted owl detection probabilities and either a positive effect on local extinction probabilities or a negative effect on colonization probabilities. The study concluded that because barred owl presence is increasing in the study area, further declines in the proportion of sites occupied by spotted owls was expected. This was one of the first attempts to quantify the impact of barred owls on spotted owl demographic parameters and it supports the growing concern about the potential impact of barred owls on spotted owl populations.

3.G West Nile Virus

West Nile Virus (WNV) is an arthropod-borne virus transmitted primarily by mosquitoes. Birds are the primary (reservoir) host of WNV although other mammals, including humans (incidental hosts), may be infected and develop disease. WNV first appeared in the U.S. in New York City in 1999. By the end of 2004, WNV had spread across the continental U.S. (except for Washington State), causing human, equine, and avian mortality (U. S. Centers for Disease Control and Prevention [CDC] webpage). By July 2005, WNV was found in the U.S. in dead wild birds of >200 species, including 8 owl species and 14 additional raptor species (CDC webpage). Mortality rates among infected birds vary by species, with Corvids especially susceptible. Birds can develop immunity to WNV following exposure.

It is unknown the extent to which northern spotted owls will be affected by WNV. The 2004 scientific evaluation of the northern spotted owl (Courtney et al. 2005, chapter 8, p. 36) stated:

> "It is undeniable that WNV is a new threat to Northern Spotted Owls. WNV also has the potential to reduce population viability throughout the owl's range. But the degree to which this potential will be realized is quite uncertain. It is not certain: (1) what proportion of owls that are infected will die from WNV; (2) how uniform infection will be throughout the range of the owl; (3) when, or if, owls will develop some immunity to the disease and therefore limit the duration of expected mortality; and (4) how the potential indirect benefits of reduced predation (e.g., loss of Northern Goshawks), the potential indirect detriments of increased competition (e.g., relative increases of less susceptible Barred Owls), or reduction in nest site availability by reductions in facilitating species (e.g., Northern Goshawks in eastern Washington, Tracy Flemming, NCASI, *personal communication*) will balance."

GD participated in research on West Nile Virus in conjunction with Dr. Alan Franklin of Colorado State University. We collected oral swabs from 1 adult and 46 juvenile spotted owls in 2004. Using Polymerase chain reaction (PCR) techniques, all 47 samples tested negative for WNV. In 2005, we collected oral swabs and blood from 1 adult and 29 juvenile spotted owls. Tests have not been completed for these samples.

In addition to the oral swabs and blood samples, GD participated in sampling small mammals and mosquitoes for West Nile Virus in 2005. The sampling on small mammals involved using a restricted random sampling design to trap and collect serological samples from small mammals on 8-10 spotted owl territories. Within each spotted owl territory, we placed two trap lines, one in older forest near a current roost or nest site of the owls, and one in an adjacent early seral stage area, where small mammals tend to be more abundant. Each trap line was 200m long with 21 trap stations spaced 10m apart. One Sherman and one Tomahawk live trap were placed at each station. Grids were trapped for 4 days with traps baited and set each evening and morning. Both diurnal and nocturnal species were trapped. We collected blood from small mammals using the retroorbital plexus technique (Mills et al. 1995). Animals were anesthetized with isoflurane just prior to collecting blood. Individuals were weighed, sexed, and ear-tagged to prevent sampling individuals more than once.

Mosquito sampling involved 6 trapping stations spaced equally along each of the 200m small mammal transects. At each mosquito trap station we placed one CO_2 baited Center for Disease Control (CDC) light traps (Anderson et al. 2004) and 2 CDC ovitraps to collect eggs and larvae

(Fay and Eliason 1966). Three of the mosquito trap stations were placed 7m above ground in trees and three were placed 2m above ground, with high and low stations being alternated along the line. The light traps were used to estimate relative abundance, by species, of mosquitos, and the ovitraps were used to estimate species presence and composition. Mosquitos from the collection were separated by trap, site, and date and then frozen. Samples were sent to the Arthropod-borne and Infectious Disease Laboratory at Colorado State University. Testing of these samples has not been completed.

Table 3.2. Forest stand and understory vegetation variables considered in regression model of woodrat abundance on Green Diamond Resource Company land (after Hamm 1995).

Forest stand variables	Metric
aspect	degrees
$\bar{x}$ slope	%
conifer stems >45.7 cm dbh	#/ha
conifer and hardwood stems >45.7 cm dbh	#/ha
basal area conifer stems >45.7 cm dbh	m^2/ha
basal area conifer and hardwood stems >45.7 cm dbh	m^2/ha

Forest understory variables	Metric
leaf litter ground cover	%
open dirt ground cover	%
small wood ground cover	%
large wood ground cover	%
moss ground cover	%
log volume ($\geq$ 9 cm on the small end)	m^3/ha
$\bar{x}$ understory cover board value	%
redwood (*Sequoia sempervirens*) coverboard value	%
rhododendron (*Rhododendron macrophylum)* coverboard value	%
tanoak (*Lithocarpus densiflorus*) coverboard value	%
huckleberry (*Vaccinium ovatum*) coverboard value	%
salal (*Gaultheria shallon*) coverboard value	%

Table 3.3. Estimated mean number ($\overline{x}$) and standard error (SE) of woodrats captured by live-trapping in 1992–93 and 1999 (after Hamm 1995). Means within columns followed by the same letter do not differ. *n* indicates the number of stands sampled for each age class/thinning treatment.

Age Class (yrs)/Thinning Treatment	$\overline{x}$	SE	*n*
1992–1993			
5–9	45.1 A	9.0	8
10–20	45.8 A	10.2	8
21–60	3.6 B	1.4	4
61–80	0.5 B	0.5	4
1999			
5–20	29.8 A	6.5	4
Heavy Thinning	2.5 B	0.3	3
Medium Thinning	0.6 B	0.5	4
Light Thinning	0.0 B	--	4

Table 3.4. Top ten models of woodrat abundance incorporating stand variables and top ten models of woodrat abundance incorporating understory variables on Green Diamond Resource Company land (after Hamm 1995). See Table 3.2 for definitions of variables.

Forest stand models	AIC_c	ΔAIC_c
– conifers >45.7 cm	31.53	0.00
– basal area conifers >45.7 cm	31.57	0.04
– basal area conifers and hardwoods >45.7 cm	32.83	1.30
– conifers and hardwoods >45.7 cm	33.37	1.85
+ slope – basal area conifers >45.7 cm	33.64	2.11
+ slope – conifers >45.7 cm	34.15	2.62
+ slope – basal area conifers and hardwoods >45.7 cm	34.94	3.41
+ slope – conifers and hardwoods >45.7 cm	35.99	4.46
+ slope + conifers >45.7 cm – conifers >45.7 cm:slope	35.99	4.47
– slope – basal area conifers >45.7 cm + basal area conifers >45.7 cm:slope	36.59	5.06

Forest understory models		
– logs + understory cover – rhododendron – salal	18.22	0.00
+ understory cover + redwood – rhododendron – salal	20.11	1.89
+ large wood – logs + understory cover + tanoak	23.36	5.14
+ understory cover – huckleberry – rhododendron – salal	23.38	5.16
– logs + understory cover – rhododendron + tanoak	25.59	7.37
– leaf litter – logs + understory cover + tanoak	25.72	7.52
+ understory cover + redwood –salal	25.79	7.57
+ understory cover + redwood	25.91	7.69
–logs + understory coverc + tanoak	26.80	8.58
–small wood + understory cover + redwood	26.83	8.60

Table 3.5. Daubenmier cover classes and "midpoint" values used for analysis of ground cover along woodrat trapping transects on Green Diamond Resource Company land (after Hughes 2005).

Class	Range	Analysis value
1	0 – 5 %	2.5 %
2	5 – 25 %	15.0 %
3	25 – 50%	37.5 %
4	50 – 75 %	62.5 %
5	75 – 95 %	85.0 %
6	95 – 100 %	97.5 %

Table 3.6. Variables used in Poisson regression models of woodrat abundance (after Hughes 2005).

Code	Definition
	Primary variables
GCTO	Ground Cover of Tan oak
GCDF	Ground Cover of Douglas-fir
GCCONIF	Ground Cover of Conifers
GCHW	Ground Cover of Hardwoods
SHW	Shrub Cover of Hardwoods
STO	Shrub Cover of Tan oak
SDF	Shrub Cover of Douglas-fir
SCONIF	Shrub Cover of Conifers
AGE	Stand Age (Years Post Harvest)
SALL	Shrub Cover of all Species Combined
SALW	Shrub Cover of all Live Woody Shrubs
USHW	Density of Understory Hardwoods
USTO	Density of Understory Tan oak
USDF	Density of Understory Douglas-fir
USCONIF	Density of Understory Conifers
USALL	Density of all Understory Tree Species Combined
USALLlive	Density of all Live Understory Tree Species Combined
	Secondary variables
GCSWD	Ground Cover of Small Woody Debris (logs and dead woody material <30cm across the narrowest width)
OSHWBA	Basal Area of Overstory Hardwoods
GCLWD	Ground Cover of Large Woody Debris (logs and dead woody material >30cm across the narrowest width)
OSCONIFBA	Basal Area of Overstory Conifers

Table 3.7. Top ten Poisson regression models of woodrat abundance (after Hughes 2005). See Table 3.6 for definitions of variables. Models are ranked by ΔQAICc.

Model (b1 + b2 + b3)	b1	b2	b3	ΔQAICc	w_i	Dev r^2
AGE+GCTO+GCLWD	-0.059 [a]	0.127 [a]	0.151 [c]	0.00	0.983	0.704
AGE +SHW+ GCLWD	-0.035 [a]	0.063 [b]	0.112 [d]	8.52	0.014	0.666
AGE + GCTO + SHW	-0.038 [a]	0.066 [b]	0.037 [d]	12.83	0.002	0.646
AGE+GCTO+GCSWD	-0.045 [a]	0.175 [b]	-0.037 [d]	15.42	0.000	0.635
AGE +SHW+ GCSWD	-0.036 [a]	0.055 [b]	0.020 [d]	15.49	0.000	0.635
SHW+OSCONIFBA	0.075 [a]	0.000 [d]	-	16.19	0.000	0.619
AGE+GCTO	-0.051 [a]	0.112 [b]	-	17.63	0.000	0.613
AGE+SHW	-0.030 [a]	0.064 [b]	-	17.78	0.000	0.612
SHW+GCLWD	0.095 [a]	0.109 [d]	-	19.10	0.000	0.606
AGE+ SHW + USHW	-0.032 [a]	0.069 [b]	-0.007 [d]	19.96	0.000	0.615

[a] $p < 0.001$, [b] $p < 0.01$, [c] $p < 0.05$, [d] $p \geq 0.05$

Table 3.8. Top ten logistic regression models of woodrat nest (n = 45) and random (n = 45) sites (after Hughes 2005). See Table 3.6 for definitions of variables. Models are ranked by ΔQAICc.

Model (b1 + b2 + b3)	b1	b2	b3	ΔAICc	w_i
USHW +USCONIF + OSCONIFBA	0.124 [b]	-0.890 [b]	0.000 [b]	0.00	0.76
STO +USCONIF + OSCONIFBA	4.985 [b]	-0.590 [c]	0.000 [b]	5.63	0.05
SHW +USCONIF + OSCONIFBA	3.983 [b]	-0.736 [c]	0.000 [b]	5.81	0.04
STO +USHW + OSCONIFBA	4.709 [c]	0.102 [b]	0.000 [c]	6.07	0.04
STO +USALL + OSCONIFBA	5.616 [b]	0.089 [c]	0.000 [c]	7.16	0.02
USHW +USCONIF	0.113 [b]	-0.654 [c]	-	7.61	0.02
STO +USCONIF + GCSWD	7.331 [a]	-0.554 [c]	-0.047 [c]	7.71	0.02
USHW +USCONIF + OSHWBA	0.122 [b]	-0.630 [c]	0.000 [d]	8.11	0.02
USHW +USCONIF + GCLWD	0.117 [b]	-0.670 [c]	-0.078 [d]	8.47	0.01
USHW +USCONIF + GCSWD	0.114 [b]	-0.686 [c]	-0.110 [d]	9.30	0.00

[a] $p < 0.001$, [b] $p < 0.01$, [c] $p < 0.05$, [d] $p \geq 0.05$

Table 3.9. Number and median density of active Sonoma tree vole nests by stand age class on Green Diamond Resource Company lands (after Thompson and Diller 2002).

Parameter	Stand age class 10-19	20-29	30-39	40-49	50-59	≥60
Number of stands searched	6	7	9	8	8	8
Number of stands with nests	0	4	9	6	7	7
Total transect distance (m)	3250	3850	4300	3900	3870	3550
Number of nests	0	11	40	45	44	45
Number of active nests	0	7	29	33	22	39
Median density of active nests (number/ha)	0	1.00	3.40	3.99	2.01	6.21

Table 3.10. Tree species containing tree vole nests and type of tree deformity in which the nest was located during sampling of 68 10-ha quadrats on Green Diamond Resource Company land, 2001-2005.

Tree species	*n*	Tree Deformity	*n*
Douglas-fir	117	Broken-top	19
Tanoak	1	Cavity	11
White Oak	1	None	33
Black Oak	6	Mistletoe broom	22
California Bay	1	Forked top	28
Redwood	1	Undetermined	16
Other	1		

Table 3.11. Tree species and nest types of Northern Spotted Owl nests on Green Diamond Resource Company land, 1992-2004.

Nest tree species	Nest type					
	Platform	Cavity	Chimney	Unknown	Total	Percent
Douglas-fir	55	13	11	10	89	33%
Redwood	35	27	15	7	84	31%
Tanoak	15	9	3	2	29	11%
Cedar	6	4	7	2	19	7%
Western hemlock	13	1	1	1	16	6%
Grand fir	8	0	0	0	8	3%
Maple	2	5	1	0	8	3%
Black oak	0	0	6	0	6	2%
California laurel	2	3	0	0	5	2%
Fir species	2	0	0	0	2	1%
Pacific madrone	0	2	0	0	2	1%
Red alder	1	0	1	0	2	1%
White fir	1	0	0	0	1	0%
Unknown	1	0	1	0	2	1%
Total	141	64	46	22	273	
Percent	52%	23%	17%	8%		

Table 3.12. Summary statistics for landscape characteristics measured within 203-ha circular plots centered on 60 Northern Spotted Owl nest sites and 60 random sites on Green Diamond Resource Company land, 1990-1991 (After Folliard et al. 2000: Table 1).

	Nest Landscapes	Random Landscapes	F	P
Variable	Mean ± SD	Mean ± SD		
0-7 yr old forest, ha	17 ± 26	23 ± 39	0.065	0.800
8-30 yr old forest, ha	24 ± 38	53 ± 69	4.376	0.039
31-45 yr old forest, ha	46 ± 60	29 ± 50	4.341	0.039
46-60 yr old forest, ha	55 ± 64	34 ± 56	5.314	0.023
>60 yr old forest, ha	42 ± 46	41 ± 49	0.122	0.728
Nonforest, ha	20 ± 19	22 ± 34	0.630	0.429
Total edge, km	8.1 ± 3.1	6.4 ± 2.9	9.273	0.003
High-contrast edge, km	4.2 ± 2.9	4.0 ± 3.2	0.172	0.679
Position on the slope	0.35 ± 0.23	0.52 ± 0.28	14.034	<0.001
Distance to water, m	137 ± 97	191 ± 141	4.711	0.032
Length of roads, km	3.7 ± 2.1	4.8 ± 2.7	5.067	0.026

Table 3.13. Landscape level characteristics important in distinguishing Northern Spotted Owl nesting, roosting, and/or foraging sites from random sites on Green Diamond Resource Company Lands.

Study:	Folliard 2000	Thome 1999	Nocturnal RSF, Chapter 2	Nesting RSF, Chapter 2
Comparison or Model:	Nest v. Random	Nest v. Random	Probability of selection	Probability of selection
Spatial scale:	203 ha circle	5 circles, 7-398 ha	20 ha circle	1 circle & 3 buffers
Landscape characteristic	Comparison	Comparison	Model	Model
Stand 0-5 yrs old	Not different	Not different		
Stand 6-20 yrs old	(8-30 yrs) Lower at nests	Lower at nests within 7 and 50 ha circles	Nearest stand, Positive	
Stand 21-40 yrs old	(31-45 yrs) Higher at nests	Lower at nests within 7, 50, 114, 203 ha circles	Nearest stand, Positive	
Stand 41-60 yrs old	(46-60 yrs) Higher at nests	Higher at nests within 50, 203, 398 ha circles	Nearest stand, Negative; % within 20 ha circle, convex quadratic	
Stand 61-80 yrs old	Not different	Not different	(Lumped with >40 yrs old)	
Stand >80 yrs old	(Lumped with >60 yrs old)	Not different	(Lumped with >40 yrs old)	
Stand age				Positive for 2nd growth
% hardwoods in stand			Positive	Convex quadratic - max selection at ~35%
% residual trees in stand		Positive with high reproductive success		Convex quadratic - max selection at ~55%
Nonforest area	Not different			
Total edge	Greater at nests			
Opening edge density				1312-1969 foot annulus, Positive
High contrast edge	Not different			
Position on the slope	Lower at nests		Negative (lower is better)	
Distance to water	Shorter at nests			
Length of roads	Lower at nests			
Second growth				Negative

Appendix I. Species of prey items found in 965 collections of regurgitated pellets from 245 Northern Spotted Owl territories or locations on Green Diamond Resource Company lands in northern California, 1989-2004.

Species	Species/Group	Mass (g)	N
Mammals			
Chiroptera			
Lasiurus spp. (unidentified hairy-tailed bat)	Other[1]	10	3
Myotis spp.	Other	10	1
Dipodidae			
Zapus spp. (unidentified jumping mouse)	OSRI[2]	24	2
Geomyidae			
Thomomys spp. (unidentified gopher)	OSRI	87	43
Heteromyidae --- Perognathinae			
Perognathus spp. (unidentified pocket mice)	OSRI	20	1
Leporidae			
Sylvilagus bachmani (Brush rabbit)	*Sylvilagus*	500	80
Lagomorph (unknown)	Other	500	2
Muridae --- Arvicolinae			
Arborimus spp. (Sonoma tree vole/red tree vole)	*Arborimus*	27	497
Clethrionomys spp.(unidentified red backed vole)	OSRI	23	29
Microtus spp. (unidentified vole)	OSRI	39	98
Microtinae (unidentified vole spp.)	OSRI	26	14
Muridae			
unidentified rat or mouse	OSRI	25	94
Muridae --- Murinae			
Rattus rattus (black rat)	OSRI	105	24
Muridae --- Sigmodontinae			
Neotoma fuscipes (dusky-footed woodrat)	*Neotoma*	230	1479
Peromyscus spp. (Deer/white footed mouse)	*Peromyscus*	25	154
Mustelidae			
Mustela spp. (Ermines, minks, weasels, ferrets)	Other	200	3
Sciuridae			
Glaucomys sabrinus (northern flying squirrel)	*Glaucomys*	115	307
Sciuridae (unidentified squirrel)	OSRI	265	8
Tamiasciurus douglasii (Douglas Squirrel)	OSRI	208	1
Soricidae			
Sorex spp. (unidentified shrews)	OSRI	5	14

(continued next page)

Appendix I, continued

Species	Species/Group	Mass (g)	N
Talpidae --- Talpinae			
Neurotrichus spp. (American Shrew-mole)	OSRI	9	5
Scapanus spp. (unidentified western mole)	OSRI	125	5
Talpidae spp. (unidentified desmans, moles)	OSRI	125	1
Birds			
Columbidae			
Columba fasciata (Band-tailed Pigeon)	Aves	340	11
Corvidae			
Aphelocoma spp. (unidentified scrub jays)	Aves	107	1
Cyanocitta stelleri (Steller's Jay)	Aves	74	11
Picidae			
Picoides villosus (Hairy Woodpecker)	Aves	50	1
Picidae spp. (unidentified woodpecker or wrynecks)	Aves	50	1
Sphyrapicus spp. (unidentified sapsucker)	Aves	40	1
Strigidae			
Aegolius acadicus (Northern Saw-whet Owl)	Aves	83	1
Aves (unidentified bird)	Aves	30	95
Insects			
Aeridiidae (grasshopper spp.)	Other	0.5	1
Arachnida			
Araneus spp. (Wheel weaving spiders)	Other	0.5	1
Coleoptera --- Scarabacidae (dung beetles)	Other	0.5	2
Coleoptera spp.(Sheath-winged beetles)	Other	0.5	30
Diptera spp. (Fly spp.)	Other	0.5	1
Insect (unidentified insect)	Other	0.5	6
Orthoptera --- Gryllacrididae			
Stenopelmatus spp. (Jerusalem Cricket)	Other	1	6
Fishes			
Cyprinidae spp. (minnows and carps)	Other	80	1
Reptiles and Amphibians			
Lower vertebrate (unknown)	Other	10	21

[1] Other (Insecta, Chiroptera, Mustelidae, Teleolstei, Reptilia).
[2] OSRI (Other Small Rodent or Insectivore).

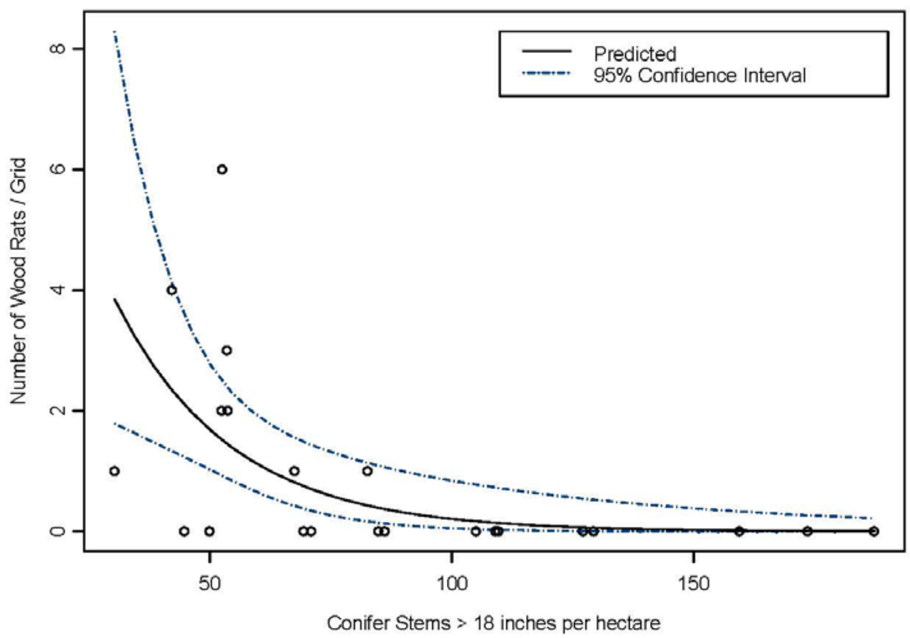


Figure 3.1. Poisson regression of woodrat captures and number of conifer stems >18 inches (≥45.7 cm) dbh per hectare (after Hamm 1995).

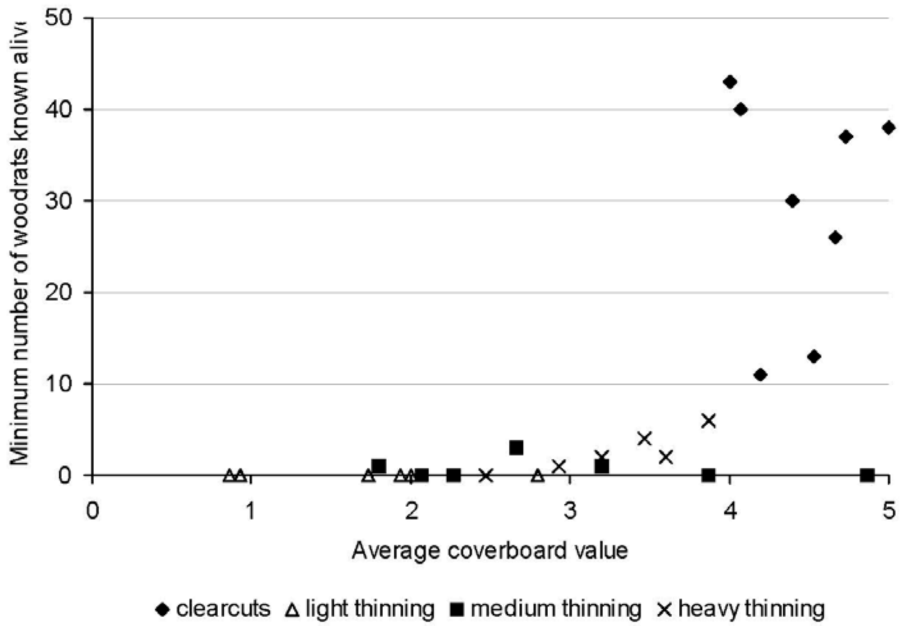


Figure 3.2. Number of dusky-footed woodrats captured on 1.2 ha live-trapping grids in coastal redwood forests during 1999 and associated average coverboard values representing density of shrub layer vegetation (0–2 m high) on each trapping grid (after Hamm 1995).

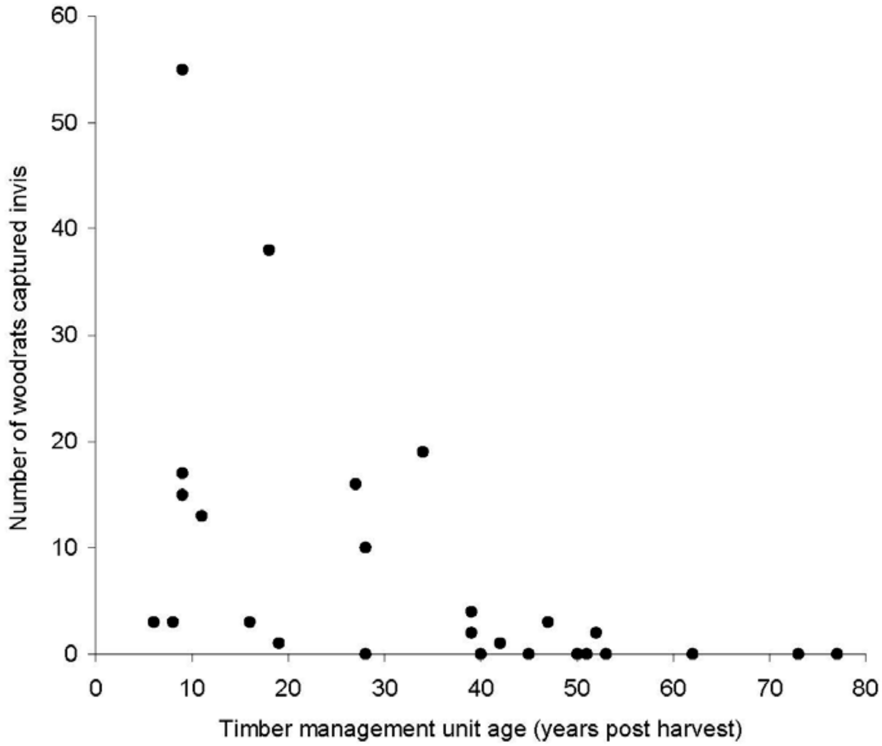


Figure 3.3. Scatter plot of the number of individual woodrats captured per timber management unit vs. years after harvest of timber management unit. $R^2 = 0.422$, $p < 0.001$ (after Hughes 2005).

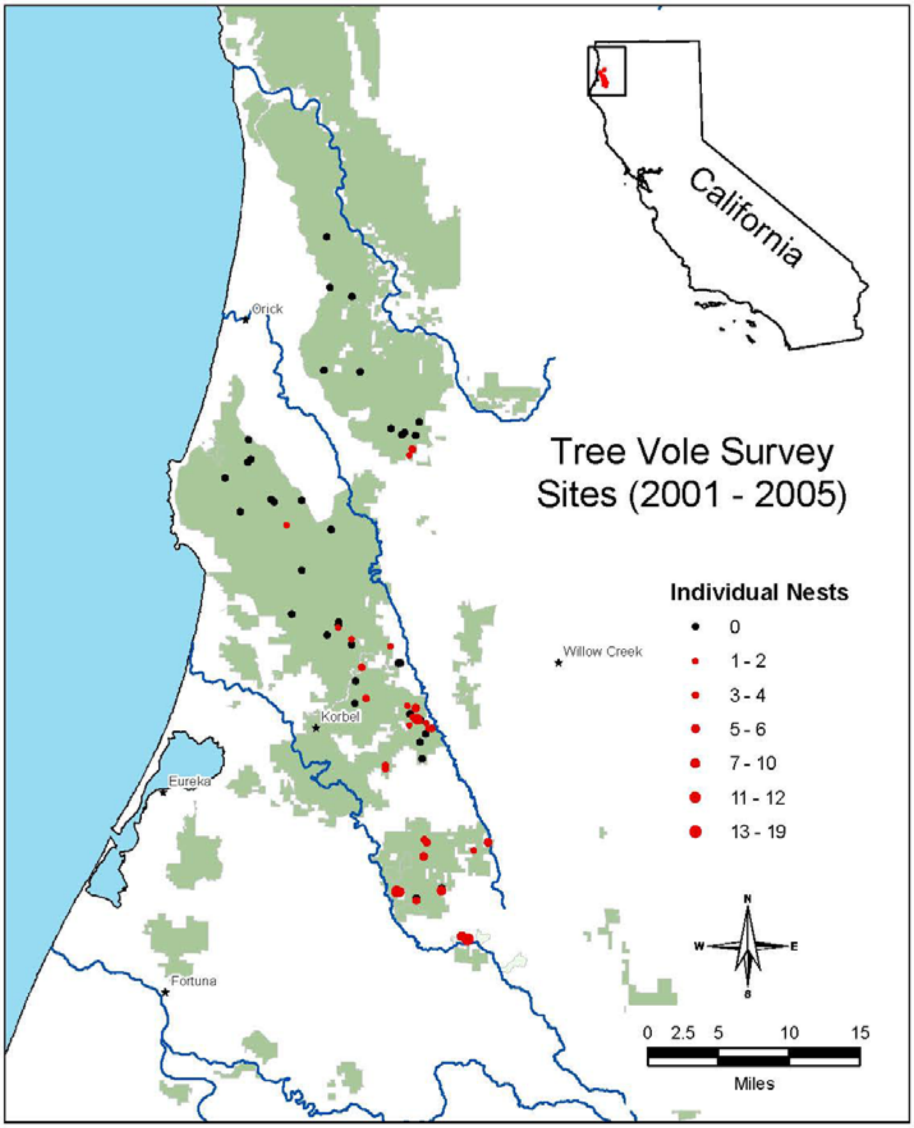


Figure 3.4. Abundance of tree vole nests on Green Diamond Resource Company land, 2001-2005.

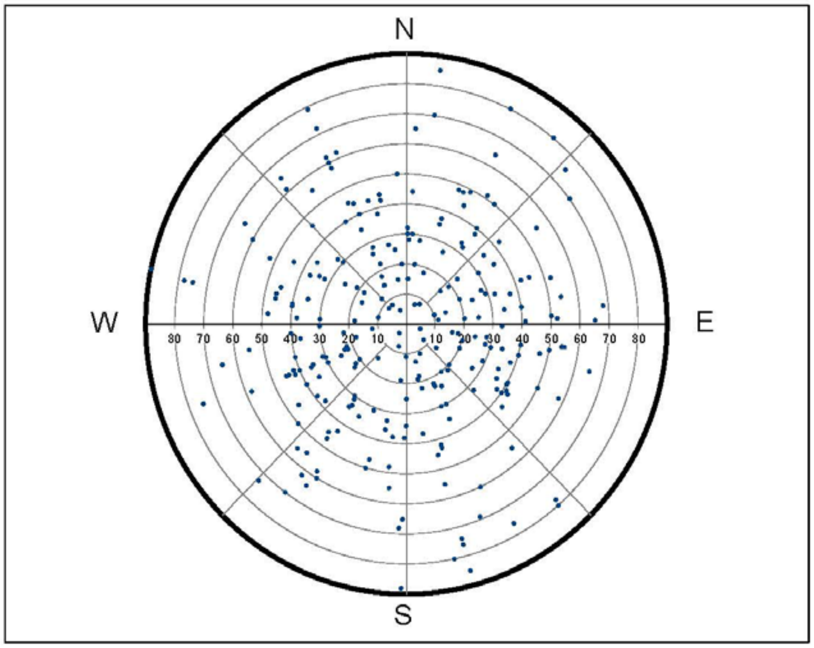


Figure 3.5. Location of 273 Northern Spotted Owl nest trees on Green Diamond Resource Company land in relation to aspect and percent slope.

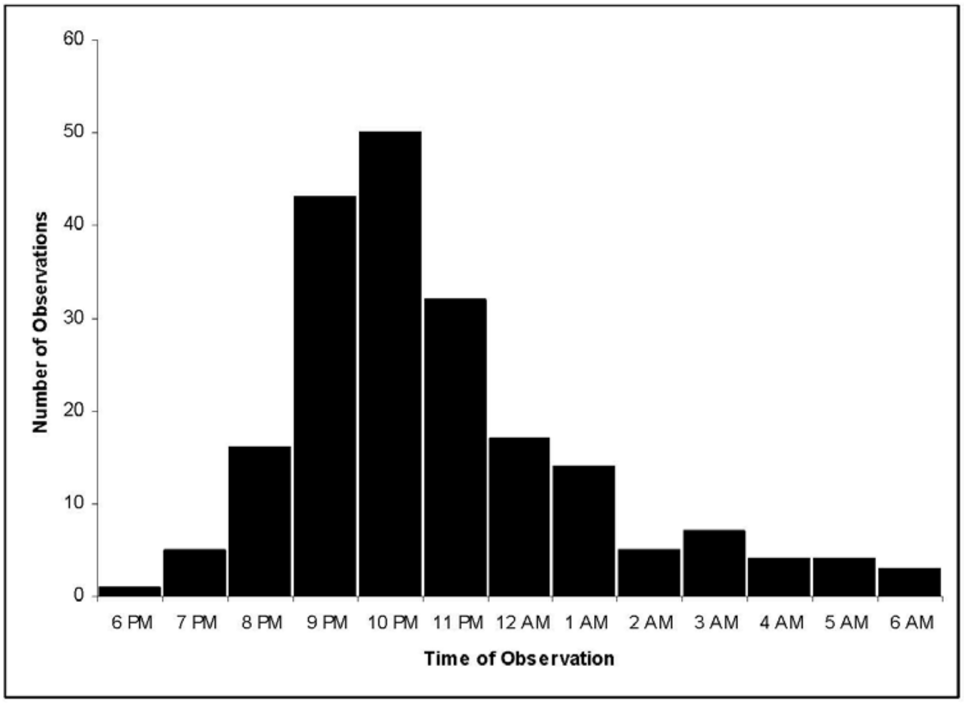


Figure 3.6. Time when foraging Northern Spotted Owls were visually observed on Green Diamond Resource Company land.

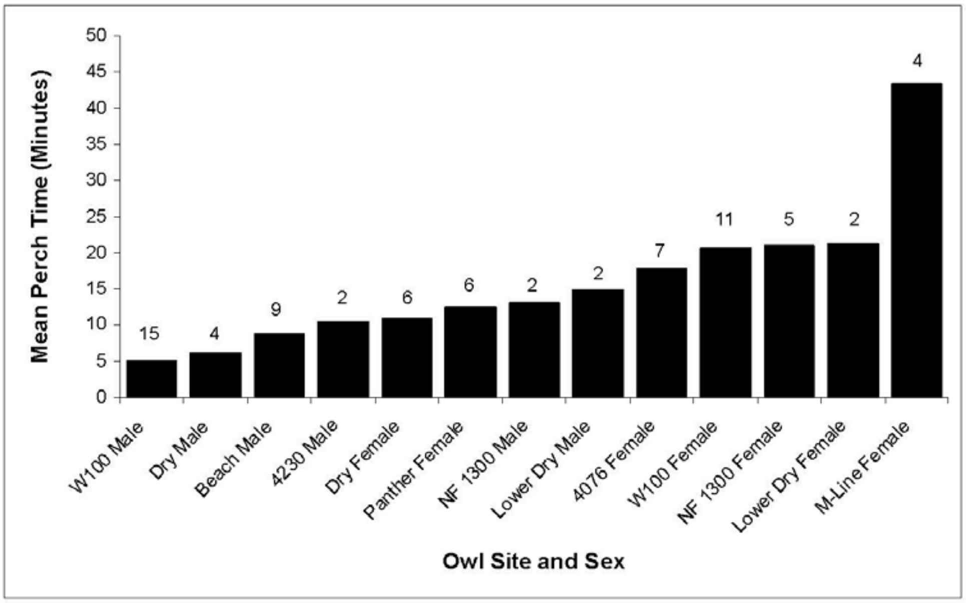


Figure 3.7. Mean time per perch for individual Northern Spotted Owls on Green Diamond Resource Company land.

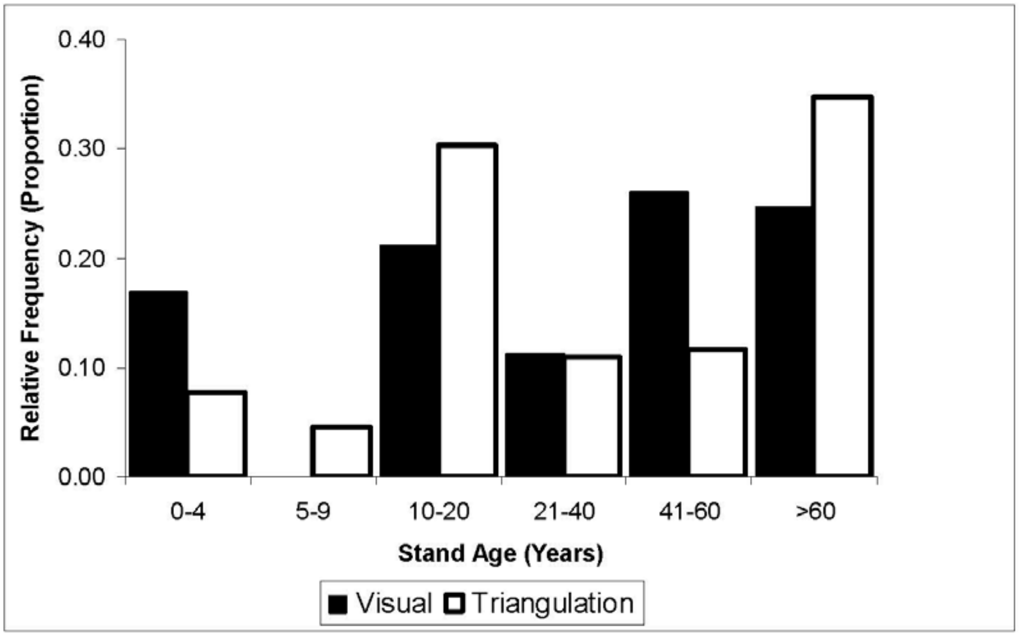
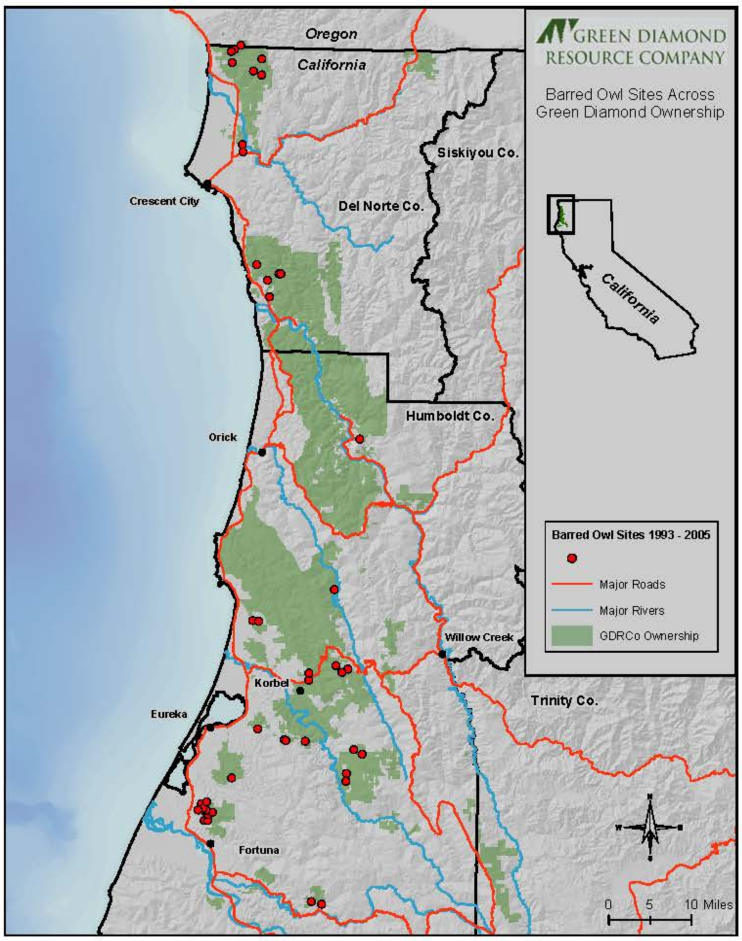


Figure 3.8. Age of forest stands used by Northern Spotted Owls at night on Green Diamond Resource Company land. Observations were based on radio-telemetry triangulation and direct visual sighting.

Figure 3.9. The distribution of barred owl sites across Green Diamond Resource Company lands, 1993-2005.



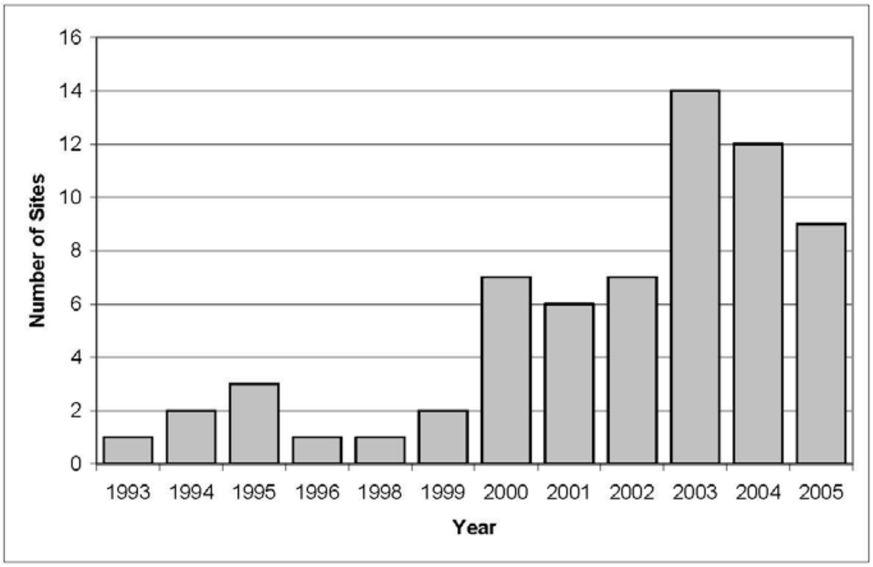


Figure 3.10. Annual numbers of sites with barred owls detected on Green Diamond Resource Company lands.

Chapter 4 – Northern Spotted Owl Viability and Set-asides

This chapter is based on the requirement for "a detailed analysis of the efficacy of and continued need for the set-asides and of the long-term viability of the owl population on Simpson's (now Green Diamond) property."

4. A. Long-Term Viability as Indicated by Population Demographic Rates

As stated in Chapter 2, a major premise of Green Diamond Resource Company's (GD) habitat conservation plan (HCP) for the Northern Spotted Owl was that habitat suitable for owls would remain constant or increase throughout the 30-year period of the plan. Although not explicitly stated as a goal, it was expected that if suitable habitat was stable or increasing through time, the owl population should also be stable. Mark-recapture studies were initiated throughout GD's ownership in 1990 to estimate key demographic parameters and trends in the population.

Along with other range-wide demographic studies of Northern Spotted Owls, GD participated in three previous meta-analyses of Northern Spotted Owl demographic data in December 1998, January 2004 and January 2009 (Franklin et al. 1999; Anthony et al. 2006 and Forsman et al. *In Review*, respectively). The objectives of each meta-analysis included estimation of survival, fecundity, and the finite rate of population change (lambda, λ) for each study area. In addition, participants examined regional and other trends across study areas. Each analysis includes data from all years of each study; therefore, results from later analyses supersede earlier analyses.

2004 Meta-analysis

Except for data relevant to the ten-year view, the full details of the 2004 meta-analysis are included in Anthony et al. (2006) and will not be repeated in this document. GD demographic data were collected from 1990-2003, which included survival estimates based on 1,344 total banded owls and 4,087 combined captures and recaptures (totals include 708 juveniles). Fecundity was based on 1332 total determinations of the number of young produced per female. Although intermediate in study area size and duration, the GD capture-recapture and fecundity dataset was the single largest of any of the 14 demographic study areas scattered throughout the range of the Northern Spotted Owls. Salient results from the most recent Northern Spotted Owl meta-analyses are summarized in Tables 4.1 to 4.3. Estimated mean apparent survival probability of adult spotted owls on GD land was 0.850 (SE = 0.010), similar to estimates from the nearby Willow Creek (NW California) and Hoopa study areas (Table 4.1). The conclusion of the meta-analysis was that GD and Hoopa showed no evidence for a decline in survival, but there was evidence for a decline for Willow Creek (Anthony et al. 2006). Estimated mean annual fecundity for adult spotted owls on GD land was 0.326 (SE = 0.037), which was similar to the estimate from Willow Creek and higher than the estimate from Hoopa (Table 4.2). However, there was some evidence for a declining trend in fecundity for GD and Willow Creek, but Hoopa showed an increasing trend. Estimated rate of spotted owl population change (λ_{RJS}) on GD land was 0.97 (SE = 0.012), similar but slightly lower than the two nearby study areas. The 95% confidence interval for λ_{RJS} did not include 1.0 for GD providing evidence that the population was declining from 1990-2003. This was not the case for 9 of the other 14 study areas either because of a larger SE for λ_{RJS} (the GD SE was among the lowest for any study area), or a higher estimate of λ_{RJS} combined with a larger SE.

Estimates of realized population change represented the trend in owl numbers over the entire period of study. The trend represents the ratio of the population size in each year, expressed relative to the initial population in the first year. Fig. 4.1 indicated that the population of spotted owls on the GD study area was apparently stable or increasing until the late 1990's when the population appeared to begin a downward trend. During this time, apparent non-juvenile survival remained constant (Fig. 4.2), but there were three years in a row with below average fecundity (Fig. 4.3) from 1998-2000.

2009 Meta-analysis

The following data that are relevant to the ten-year view were excerpted from the most recent 2009 meta-analysis that is not yet available to the public. The full details of the meta-analysis have been submitted for publication to Studies in Avian Biology (Forsman et al. *In review*). GD demographic data were collected from 1990-2008, which included survival estimates based on 836 total banded owls and 3,777 combined captures and recaptures (totals do not include almost 900 juvenile owls captured during this time). Fecundity was based on 1,653 total determinations of the number of young produced per female. Although intermediate in study area size, the GD capture-recapture and fecundity datasets were the largest of any of the 11 demographic study areas scattered throughout the range of the Northern Spotted Owls. Estimated mean apparent survival probabilities of adult spotted owls on GD land were 0.851 (SE = 0.007) and 0.853 (SE = 0.007) for males and females, respectively. These estimates were similar to adult survival estimates from the nearby Willow Creek (NW California) and Hoopa study areas. The analysis indicated that all three areas showed evidence of decline in survival, although survival rates have only been in decline in Hoopa since 2004. Estimated mean annual fecundity for adult spotted owls on GD land was 0.305 (SE = 0.030), which was similar to the estimate from Willow Creek and higher than the estimate from Hoopa. However, there was evidence for a declining trend in fecundity for GD and Willow Creek, but Hoopa showed a stable trend. Estimated rate of spotted owl population change (λ_{RJS}) on GD land was 0.972 (SE = 0.012), similar but slightly lower than the two nearby study areas. The 95% confidence interval for λ_{RJS} did not include 1.0 for GD providing evidence that the population was declining from 1990-2008. The Willow Creek study area was also determined to be declining, but the Hoopa study area was one of only four study areas throughout the range of the Northern Spotted Owl that had evidence for a stationary population.

Estimates of realized population change represented the trend in owl numbers over the entire period of study. The trend represents the ratio of the population size in each year, expressed relative to the initial population in the first year. As noted above (2004 meta-analysis), Fig. 4.1 indicated that the population of spotted owls on the GD study area was apparently stable or increasing until the late 1990's when the population appeared to begin a downward trend. The 2008 meta-analysis indicated that this downward trend had fluctuated, but was still in an overall downward trend since 2003.

The 2004 meta-analysis described in Anthony et al. (2006) did not attempt to determine the factors that may have been responsible for any observed population changes. In the most recent 2009 meta-analysis (Forsman et al. *In review*), additional covariates such as barred owls, weather and habitat were included in the analysis in the hopes that they could provide some insights into spotted owl demographic trends. The barred owl covariate was included in the top GD model for fecundity and it was one of four study areas where barred owls showed a negative relationship with fecundity. The same was also true for apparent survival where the top GD model included the barred owl covariate with a strong negative coefficient. It also should be noted that the jump in barred owl numbers on GD's ownership (see Fig. 3.10) approximately coincided with the apparent decline in spotted owls (Fig. 4.1). However, caution should be used when attempting to interpret past barred owl numbers, because all of these barred owls were located incidental to doing spotted owl surveys. Recently, it has been documented that spotted owl surveys are very inefficient at finding barred owls and the actual abundance of barred owls in an area may be over twice that estimated through incidental spotted owl surveys (D. Wiens, pers. comm.).

Various other factors, such as the rate of emigration versus immigration may have influenced the population trend, and although we have documented that spotted owls move into and out of the study area, we have no comprehensive data on movement rates of spotted owls over time that would suggest any recent trends. Although, weather or climate did not enter any of the models in the 2009 meta-analysis for the GD study area, it did for other demographic study areas and it entered the analysis of factors influencing survival, fecundity and habitat fitness (see Section 4.B. below). Temperature in the early nesting season was shown to influence survival and precipitation in the early nesting season was shown to influence both survival and fecundity. This indicated that weather or climate change could have driven changes in spotted owl numbers on GD's ownership, but the weather data available to us and/or the manner in which it was summarized did not provide support for this hypothesis. At this time, the only hypothesis for the decline in the spotted owl population on GD's ownership with any analytical support is the increase in barred owls. This is a hypothesis that we believe is in urgent need of additional testing.

There was an important footnote to this apparent decline observed using data collected from 1990 to 2008. From 2008 to 2009 (i.e., data not available for the 2009 meta-analysis), we observed a 26.6% increase in the number of occupied owl sites within GD's density study area (Green Diamond 2010 NSO HCP Annual Report). All of the reasons for this apparent dramatic increase in the spotted owl population are not known, but pilot work doing limited barred owl removal, modifications of the survey protocol to increase spotted owl detection rates and newly colonized owl sites are all potential factors.

4. A.1. Influence of "take" on demographic parameters

In Chapter 1, we described GD's incidental take permit that covers all take of spotted owls incidental to timber harvest operations. The federal Endangered Species Act (ESA) describes a variety of ways in which listed species can be taken, but the primary form of incidental take anticipated in the HCP was the displacement of individual birds due to modification of spotted owl habitat (i.e., the owls were caused to abandon their territory due to a loss of habitat). As further described in Chapter 1, we estimated when a potential owl displacement resulted in an actual take as defined by the ESA by recording occupancy and nesting at a given owl site for 3-5 years following the timber harvest that triggered the potential displacement. In Chapter 1 (Section 1.B), we also investigated the factors associated with abandonment of owl sites to help understand the mechanisms that caused potential displacements to become takes. During review of an earlier draft of the Ten-Year Review Report, reviewers at the US Fish and Wildlife Service (FWS) requested that we investigate the impact of take on demographic parameters of spotted owls on GD's ownership by adding take as a covariate to the 2009 meta-analysis results (Forsman et al. *In Review*). Here we report the results of adding take as a covariate to the top models for survival, fecundity and lambda that were generated as part of the meta-analysis. A more complete and thorough analysis of the factors, including take, that influence survival, fecundity and lambda of spotted owls on GD's ownership are described below in Section 4.B.

Survival

To investigate the effects of take on survival, we constructed a *take* covariate from the capture histories we used in the Northern Spotted Owl 2009 meta-analysis. The *take* covariate was an individual-time varying covariate constructed as follows:

1. If a resident owl occupied a "take site" (i.e., owl site in which timber harvest reduced habitat below a critical threshold and the resident owls were displaced) in the year it was taken, or in the 2 previous years, its *take* covariate was assigned a value of 1 for the remainder of the study, regardless of whether it was subsequently seen at another site. This was based on the assumption that displacement of a resident owl from its territory has the potential to affect its survival for the remainder of its life.

2. If a resident owl was not associated with a take site within 3 years of harvest at the site, its *take* covariate was 0.

3. An owl that occupied a site after the year the site was taken was assigned a 0 for its *take* covariate. This was based on the assumption that an owl would not colonize a site if it were not adequate to meet that particular individual's habitat needs. This is feasible in GD's highly dynamic landscape, because timber harvest that caused the take of an owl site could have resulted in increased prey habitat (i.e., dusky-footed woodrats) within as little as 5 years post-harvest.

To avoid confounding the analysis with other covariates entering the top model, we did not run through another model selection process, but instead we simply fitted *take* into the top survival model resulting from analysis conducted as part of the 2009 meta-analysis (Forsman et al. *In Review*).

The top survival model from the 2009 meta-analysis included the effect of being a S1 (1^{st} year sub-adult) and the effect of barred owl density. This model yielded an estimate of mean apparent adult female survival of 0.853. The same model including *take* as a covariate increased QAICc from 6427.9 to 6428.3. The Wald *t*-ratio (coefficient / standard error) for *take* was -1.31 and not near statistical significance ($p = 0.19$). Both of these measures (QAICc and the Wald *t*-ratio) indicate that *take* did not have a statistically significant effect on survival. To further support the lack of statistical significance, the effect of *take* was estimated to change survival of adults (the age group with the greatest change) by only 0.11%. Overall, 140 of 836 (17%) owls were associated with a *take* site at some point in their lives.

Fecundity

To investigate the effects of take on fecundity, we constructed a *take* covariate for the fecundity dataset that we used in the 2009 meta-analysis. The *take* covariate used in the fecundity analysis was constructed using the value of the *take* covariate from the survival analysis (described above). If a female owl was associated with a *take* site, all fecundity (nesting) records for the female were associated with a 1 from the time of the take until the end of the study. If a female was never associated with a take site, its fecundity covariate was set to 0. As in previous analyses, nest records with missing female band numbers or unknown or missing female ages were discarded for this analysis.

The statistical methodology used to analyze fecundity during the 2009 meta-analysis was unknown at the time of this writing, because it was still in review. We therefore replicated model estimation methods used in the 2004 meta-analysis (Anthony et al. 2006). These methods fitted all possible mixed-effects linear models containing fixed effect terms for *age* of the female, *year*, and an *even-odd* year effect. The number of female young fledged at a site was assumed to be independent across sites. Consequently, all error structures in the mixed effects model used *site* as the grouping factor. The best fitting statistical error structure was chosen from among the compound symmetric, autoregressive order 1, exponential, and Gaussian forms using AIC and REML estimation. The best fitting fixed effect model was chosen using AIC and maximum likelihood estimation. The effects of *take* were estimated by including *take* as a fixed effect in the best fitting mixed effect model (Anthony et al. 2006)
.

The best fitting mixed effects model for fecundity (i.e., number of female young fledged per female) contained effects for *age* and *year*. From this model, average fecundity was estimated to be 0.077, 0.100, and 0.305 for S1 (1st year sub-adult), S2 (2nd year sub-adult), and adult owls ($\geq$3 years old), respectively. Inclusion of *take* lowered fecundity of females associated with take sites was reduced by 63.6, 49.2 and 15.2% for S1, S2, and adult owls, respectively. Wald *t*-ratio for the coefficient of *take* was -1.83, (p =0.067), which suggests near statistical significance. AIC of the model with *take* was 1.3 units below AIC of the model without *take,* suggesting that *take* had some but not a great deal of predictive ability. Generally, models with AICs less than ~2 units apart are considered functionally equivalent.

Lambda

To investigate the effects of take on lambda, we estimated lambda using a 4-age Leslie projection matrix as described in Franklin et al. (1999). Introducing the *take* covariate into the estimation of lambda using the same methodology as the 2009 meta-analysis (λ_{RJS} or re-parameterized Jolly-Seber model) was more complicated and deemed unnecessary for these purposes, since our goal was to estimate the impact of take on lambda and not to derive the most accurate estimate of the rate of population change. Lambda was estimated using age-specific survival and fecundity values both with and without considering take. Juvenile survival in the 4-age projection matrix was set to 0.365. This value was the average of the latest estimates of survival for GD's juvenile owls that were available to us (Franklin et al. 1999), since juvenile survival was not estimated in the last two Northern Spotted Owl meta-analyses (Anthony et al. 2006; Forsman et al. *In Review*).

The original lambda estimate based on the projection matrix approach and values of age-specific survival and fecundity from models that did not consider *take* was 0.951. When *take* was included, lambda decreased by 1.4% to 0.938. This drop in lambda was almost entirely attributable to the reduction in fecundity of birds associated with a take site at some point in their lives. We interpret this reduction to mean that lambda would have been approximately 1.4% higher if take sites had not been present.

4. A.2. Influence of "set-asides" on demographic parameters

In the original 1992 Northern Spotted Owl HCP, GD (formerly Simpson) created 39 set-asides totaling 13,242 acres. Timber harvesting was not allowed in these set-asides and they were designed to protect existing owl sites in selected areas and to promote development of suitable owl habitat following timber harvest in other areas. One of the key goals of Chapter 4 was to assess the value of set-asides to spotted owls to determine the continued need for set-asides in future conservation planning efforts. During review of an earlier draft of the Ten-Year Review Report, reviewers at the FWS requested that we investigate the impact of set-asides on demographic parameters of spotted owls on GD's ownership by adding set-asides as a covariate to the 2009 meta-analysis results (Forsman et al. *In Review*). Here we report the results of adding set-asides as a covariate to the top models for survival, fecundity and lambda that were generated as part of the meta-analysis. A more complete and thorough analysis of the factors, including set-asides, that influence survival, fecundity and lambda of spotted owls on GD's ownership are described below in Section 4.B.

Survival

To investigate the effect of set-aside on survival, we constructed a *set-aside* covariate from the capture histories that we used in the 2009 meta-analysis. The *set-aside* covariate was an individual-time varying covariate constructed as follows:

1. If a bird was seen in a set-aside, or within 0.5 mile of a set-aside, its *set-aside* covariate was assigned a value of 1 for the remainder of the study. Rarely, a bird formerly associated with set-aside was subsequently resighted at another site. When this happened, we did not attempt to change the bird's set-aside status. This was a pragmatic decision, because spotted owls are commonly not resighted in a given year and there is no way to know if a bird was at a site and unobserved or at a different site. With these gaps in capture histories, there was no way to accurately assess when a bird should have been assigned to a new owl site.
2. If a resident owl was not associated with a set-aside, its *set-aside* covariate was 0.

To avoid confounding the analysis with other covariates entering the top model, we did not run through another model selection process, but instead we simply fitted *set-aside* into the top survival model that resulted from analysis that we did as part of the 2009 meta-analysis (Forsman et al. *In review*).

The top survival model from the 2009 meta-analysis included the effect of being a S1 and the effect of barred owl density. This model yielded an estimate of mean apparent adult survival of 0.853. When *set-aside* entered the top model from the 2009 meta-analysis, QAICc increased from 6427.9 to 6429.9. The Wald *t*-ratio for *set-aside* was −0.257 and not near statistical significance ($p = 0.797$). Both of these measures (QAICc and the Wald *t*-ratio) indicate that *set-aside* did not have a statistically significant effect on survival. The effect of *set-aside* was slightly negative (coefficient = −0.0232), which estimates that survival of birds associated with set-asides was slightly lower than that of other birds. This slight decrease in estimated survival of set-aside birds was due to randomness in the non-significant coefficient. Adopting a one-sided *a priori* hypothesis approach, we would conclude there was no evidence of an increase in survival when birds were associated with a set-aside. Overall, 340 of 836 (41%) owls were associated with a set-aside at some point in their lives.

Fecundity

To investigate the effects of set-asides on fecundity, we constructed a *set-aside* covariate for the fecundity dataset that we used in the 2009 meta-analysis. The *set-aside* covariate was constructed in a parallel manner to the *take* covariate for fecundity. When a female owl was associated with a set-aside, its *set-aside* covariate was set to 1 for all its subsequent nest records. Otherwise, a female's nest records were associated with *set-aside* values of 0.

We estimated fecundity of birds associated with set-asides parallel to the way we estimated fecundity of birds associated with take as describe above. We re-used the mixed effects linear model containing terms for *age* of the female and *year* that was derived for estimation of take effects. The *set-aside* covariate was added to this model to estimate fecundity of birds associated with set-asides.

Inclusion of the *set-aside* covariate in the best fitting mixed effect model resulted in a coefficient of -0.0065 and Wald *t*-ratio of -0.3133 ($p = 0.7541$). Although negative, the small coefficient and large *p* value indicated that there was no evidence in our data that birds associated with set-asides had lower fecundity than other birds. AIC of the model containing *set-aside* was 1.9 units higher than AIC of the model without *set-aside*. The increase in AIC of 1.9 is near the maximum possible and indicates that *set-aside* had predictive abilities roughly equivalent to random variation.

Lambda

Using the 4-age projection matrix approach as described above, lambda computed with survival and fecundity values associated with set-asides was 0.950. This lambda was for all practical purposed identical to the original lambda that did not consider set-asides as a covariate. We interpret this to imply that growth of the population would have been identical to observed growth if set-asides had not been present on the landscape.

4. B. Factors Influencing Survival, Fecundity and Habitat fitness

Previous chapters provided descriptions and quantified characteristics of habitat selected by spotted owls for nocturnal activities and nesting on a managed landscape. However, these habitat models do not necessarily provide direct insight into the relationship between forest management and long term viability of spotted owls. Previous studies have generally concluded that timber harvesting, particularly large clearcuts, was detrimental to spotted owl populations (Courtney et al. 2004). However, many of these studies were in the northern portion of the spotted owl's range where flying squirrels are the primary prey of spotted owls (Courtney et al. 2004). In addition, these earlier studies did not incorporate a spatial component to habitat analysis as seen in several more recent studies (Franklin et al. 2000; Olson et al 2004; Dugger et al. 2005). Two of these studies (Franklin et al. 2000; Olson et al 2004) that were conducted within the range of the dusky-footed woodrat indicated that habitat heterogeneity may increase overall habitat fitness for spotted owls. This observation leads to a testable hypothesis that timber management could be used to increase the habitat fitness potential of some forest stands currently lacking in habitat heterogeneity. Currently, such experiments have not been done, but spotted owl studies on GD's ownership, provides an opportunity to further investigate this relationship between habitat heterogeneity and fitness of owls. In particular, this study provides a unique opportunity, because the timber harvesting occurred within the context of an approved Habitat Conservation Plan with provisions for incidental take. In addition, the timber harvesting resulting in selected take of spotted owl habitat was done within a demographic study that has been ongoing since 1990. As a result, this study provides the unique opportunity to assess the impacts of timber harvesting, including harvest that exceeded thresholds expected to result in take, within the context of a long term demographic study. Furthermore, the combination of geographically referenced and relatively detailed forest stand information on all parts of GD's ownership made it possible for us to directly relate habitat characteristics with survival and fecundity to estimate habitat fitness for spotted owls (Franklin et al. 2000). This "fitness" measure which integrated the ability of habitat to sustain both survival and fecundity, potentially provides the most complete picture of overall habitat quality for owls.

In this section, we utilized capture-resight data from 1990-2003 to estimate survival, while fecundity was estimated from nesting information over the same time frame. Finally, we estimated fitness as a function of average survival and fecundity at a location through a site-specific projection matrix. From these projection matrices, the growth rate or largest eigenvalue of the projection matrix was computed and defined to be the fitness of the site. Mapping fitness values provided a way to assess the characteristics of locations that contribute to high fitness, as well as the relative fitness of all location at a single point in time and changes in fitness as a function of future harvest regimes.

We have organized this chapter into 3 distinct subsections corresponding to survival, fecundity, and fitness value. In the fecundity section, we describe methods and results of an analysis to assess factors influencing fecundity. This analysis related fecundity to life history of the owls, habitat, weather and timber harvest covariates. In the fitness section, location specific survival and fecundity values were composed in a Leslie matrix and habitat fitness computed. The final section contains a discussion of all analyses, focusing on the implications of forest practices on spotted owl habitat fitness.

4. B.1 Factors Influencing Survival Rates

Our objective in this section was to relate owl survival to life history of the owls, habitat features, weather patterns and timber harvest in order to obtain survival models that provided insight into the primary factors that were influencing owl survival. In addition, these models could be used to predict the relative quality of habitat across the study area in terms of its contribution of survival for spotted owls.

Methods

Field methods

Each year from 1990-2003, we attempted to located all individual territorial spotted owls within the entire study area. Surveys were initiated each year beginning 1 March using protocols initially adapted from Forsman (1983) and further modified to support GD's approved spotted owl habitat conservation plan. Owls were initially located primarily at night using vocal imitations or recordings of their calls. Daytime surveys were used primarily to locate roosts and determine the status of owls at sites where they had been previously located or where nighttime responses had been heard. Once an owl was located, it was typically offered live mice to determine its identity (if previously captured and marked), paired and reproductive status (Forsman 1983). Most owls were captured with a snare pole, but occasionally they were captured by hand or with several other capture techniques (e.g. nets and foot snares). Captured owls were weighed, a variety of physical measures were taken and any apparent reproductive status (e.g. brood patch) noted. A unique numbered locking Fish and Wildlife Service (FWS) band was attached to one tarsus and a plastic color band was attached to the other tarsus using a pop-rivet. The color band consisted of the same color/pattern for all juvenile owls banded in a given year (cohort color band), but each territorial owl was given a plastic band with a unique color/pattern that was not repeated for any other owls within a minimum of approximately 12-15 miles. The color band allowed individuals to be resighted without the need to recapture the owl. On rare occasions, a territorial owl moved to a new location that created the need to recapture the owl and identify it by the unique number on the FWS band.

Analytical methods – Covariates

Data used to estimate annual survival of Northern Spotted Owls consisted of individual owl capture histories collected on the GD study area from 1990 to 2003. These same data were analyzed along with all the other Northern Spotted Owl demographic studies at a meta-analysis workshop in 2004 (Anthony et al. 2006). GD data included capture-resight histories for 835 banded, territorial spotted owls. Birds banded as juveniles but never resighted as territorial non-juveniles did not appear in our data set.
Territorial owls were typically located several times throughout the field season in a given year and the associated nest or primary roosting area was given a name and its location was recorded in GD's Geographic Information System (GIS). Hereafter, we refer to the location associated with a nest or primary roost as the activity center for a given year. In order to model survival as a

function of habitat features, the activity center associated with each year was used as either a single point or as an anchor point for a polygon to determine habitat covariates associated with the activity center. For example, nighttime activity (NTA) and nesting habitat suitability index (HSI) values (hereafter, NTA or nesting HSI values) (Chapter 2) within a 600 m radius circle centered on the activity center's location were averaged. Because we believed it was important to potentially include NTA and nesting HSI values as explanatory variables in the survival model, our analysis was restricted to owls located in areas where it was possible to compute the NTA and nest site HSI models. In addition to habitat variables, covariates related to temperature, precipitation, age class of trees, sex of the bird, age of the bird, year, take status as defined by GD's habitat conservation plan (HCP), proximity to set-asides identified in the HCP, and net property-wide reproduction were computed. A full list of the variables considered, and their definitions, appears in Table 4.4.

Raw NTA and nesting HSI values computed from the final RSF models that appear in Chapter 2 were scaled so that the maximum value in 1992 was 10,000. These scaled NTA HSI values were calculated on a 10 m X 10 m grid of points covering the entire study area. Scaled nest HSI values, however, were calculated on a 400 m x 400 m grid of points covering the entire study area. Ideally, nest HSI values would have been computed on the same 10 m x 10 m grid of points as the NTA values, but that computation was not feasible due to its complexity and length. Instead, we centered a 600 m-radius circle on each activity center and averaged any nesting HSI values from the 400 m grid that fell inside the circle. Depending on the activity center's location relative to points in the 400 m grid, this average contained from 4 to 9 values. To obtain NTA HSI values whose variation was comparable to that of the nest HSI values, we calculated average NTA values on a 400 m radius circle around each nest site and every point on the same 400 m x 400 m grid using values with 10 m spacing. Then, the same 600 m-radius circle was centered on every activity center and the average of the 4 to 9 average NTA values within the 600 m-radius circle was calculated. Finally, average NTA and nesting HSI values on the 600 m-radius circles were centered by subtracting their long-term mean, and dividing by their long-term standard deviation, to put their variation on a par with variation of other variables and thereby increase stability of the estimated model.

We defined an opening to be any forest stand <6 years old plus all non-forest areas such as prairies and highways. Open edge density was calculated by amalgamating all contiguous openings in a 600 m buffer centered on the nest site, computing the amount of opening edge in the buffer (m), and dividing by area of the buffer. Open edge density was calculated using a customized version of Fragstats.

The suite of percent age class variables appearing in Table 4.4 (i.e., *%_0-5yrs_600m, ...*, *%_NF_921m*) were calculated on 2 different sized buffers centered on the activity location. The smaller buffer (600 m in radius) was considered because variables calculated on 600 m buffers were previously identified as important predictor variables for nest site selection probability (Chapter 2). Following Franklin et al. (2000), the second buffer size was set equal to ½ the nearest neighbor distance between activity centers on GD property (921 m). We also computed the percent age class variables in annuli surrounding the activity center, where the inner radius of the annulus was 600 m and outer radius was 921 m.

To compute the weather and climate related variables appearing in Table 4.4, hourly temperature values were obtained from 3 remote-activated-weather-stations (RAWS) located in or near the study area (Fig. 4.4). One RAWS station was located at Hoopa (40° 17′ North, 123° 40′ West; COOP ID 044089); another at the Arcata Airport (40° 58′ North, 124° 6′ West); and the final one at Crescent City McNamara (41° 46′ North, 124° 14′ West). Because the RAWS record from the Hoopa station did not cover the entire study period, we followed Franklin et al. (2000) and modeled hourly temperature as a function of daily minimum and maximum temperatures for the period without hourly values. We assumed intra-day hourly temperatures followed a cosine model. Hourly temperature values at the Hoopa RAWS were available from the initiation of the station, 19 April 1997, through 2 February 2005, and daily minimum and maximum temperature values were available for the entire study period at a nearby station, Hoopa Trinity River. Hourly temperature values were available for the entire study period (1990 – 2003) at the other 2 stations, so no modeling was necessary for those stations. The cosine model we assumed at Hoopa was

$$\text{Hourly temperature} = T_{\min} + \left(\frac{T_{\max} - T_{\min}}{2}\right)\left[1 - \cos\left(\frac{\gamma\pi}{24}h - \frac{\delta\pi}{24}\right)\right]$$

where T_{max} and T_{min} were daily maximum and minimum temperatures measured at the Hoopa Trinity River station, h was the hour of the day, and γ and δ were estimated parameters for the phase angle and width, respectively (Franklin et al., 2000). Proc NLIN (SAS Institute 2000) was used to obtain least-squares estimates of γ and δ for 3 seasonal periods; winter stress (November – February), early nesting (March – April), and late nesting (May). We applied this model to the complete record from the Hoopa Trinity River station to obtain estimated hourly temperatures for all days from 1 January 1990 to 31 December 2003. Hourly temperature values, whether measured or modeled, for a particular day were summed to obtain a degree-hour value. These daily degree-hour values were then averaged during winter stress (Nov-Feb) or early nesting (Mar – Apr) to obtain the temperature covariates listed in Table 4.4 (i.e., *temp_winter* and *temp_nesting*) (Franklin et al. 2000).

Activity centers were associated with data from a particular RAWS based on proximity and similarity of gross weather patterns. For example, all activity centers in the Eel River region were associated with temperature values measured at the Arcata airport, while all activity centers north of the Klamath River were associated with the Crescent City RAWS.

Precipitation covariates (*precip_winter* and *precip_nesting*) were the total number of days with measurable precipitation ($\geq 0.3\,\text{cm}$) during the winter stress and early nesting periods. Daily precipitation records were obtained from the University of California Integrated Pest Management Program web page (URL: http://www.ipm.ucdavis.edu/WEATHER/wxretrieve.html). Records were obtained for stations located at Eureka WSO, Woodley Island (NAD 83: 40° 48′ North, 124° 09′ West; NCDC# 2910); Crescent City 3 NNW (41° 45′ North, 124° 12′ West; NCDC# 2147); and Hoopa Trinity River (41° 02′ North, 123° 40′ West; NCDC# 4089). As with temperature, all activity centers in a particular region were associated with data from a precipitation stations based on proximity to the station and similarity of gross weather patterns (Figure 4.4).

Individual territorial owls were not always resighted at the same location every year due to shifts in the activity center and occasional dispersal and new pair formations. Even if an owl was resighted on the same territory for several years, it was possible for timber harvest activities to change habitat in the surrounding area. For these reasons, and because we required covariates every year after the initial capture regardless of subsequent resighting, we were forced to make assumptions about the location of owls when they were not seen. When an owl was not resighted, we assumed its territory had not changed from its last known location. This assumption had the effect of perpetuating a past location's covariates forward into years when owls were not resighted. For example, if an owl was resighted at activity center A in 1992, went undetected in 1993 and 1994, and was resighted at activity center B during 1995, we computed 1993 and 1994 habitat covariates for this owl at the 1992 location of activity center A. Activity center locations can change annually for a variety of reasons, and we choose to associate a non-resighted bird with the last known habitat that may have caused the bird to go missing. If this same owl disappeared completely after 1995, its habitat covariates for 1996 to 2003 were computed at the 1995 location of activity center B using underlying habitat values from each year.

Because we used buffers around activity centers to compute certain covariates (e.g., *NTA_HSI, nest_HSI, open_edge_density, %_0-5_600m,* and etc.), we could not compute these covariates near the edge of GD's property boundary, because the associated circle extended well beyond the GIS coverage. Locations were defined to be "near the edge" if they were ≤250 m from any GD boundary or if >25% of a 600 m or 921 m circle centered on the location was off GD property. These 2 conditions were referred to as the "edge 250" and "R75" rules. When an owl was resighted at a location meeting either the "edge 250" or "R75" rules, its location was defined to be an edge location and we ignored that resighting event. In this case, habitat covariates for individual owls with edge locations were computed at the location associated with their last interior resighting.

Estimation

Once covariates were computed, open population capture-recapture models (Nichols 2005) were used to relate those covariates to survival and capture probabilities. The regression approach of McDonald et al. (2005), whereby covariates were 2-D matrices of values, was followed, and model estimation was carried out using S-Plus and R software (package MRA, www.west-inc.com). Over-dispersion ($\hat{c}$) was estimated by fitting the most general model and running Test 2 and Test 3 of program Release (Version 3.0 for Win 95, Sep 1997). All subsequently computed AIC statistics were adjusted by $\hat{c}$ into QAIC values. Samples sizes were large enough that the small sample correction to QAIC, i.e., QAICc, was not deemed necessary.

Model Development

In all, 374 models were fitted to our capture-resight information (Table 4.5) that included various combinations of the covariates in Table 4.4 and interaction terms deemed potentially important to spotted owls. Although our model selection process was similar to the most recent Northern Spotted Owl meta-analysis (Anthony et al. 2006), we used a more exploratory and comprehensive approach that was required in order to completely extract the predictive power of the more comprehensive set of covariates that was available to us. Model selection proceeded in a quasi-stepwise fashion by fitting a set of models, picking the best approximating model from that set, and adopting this best model in subsequent fits. The first set of models paired each of 3 plausible survival models with each of 32 plausible capture models (Models 1 to 96, Table 4.5). These initial models were ranked according to QAIC and the capture structure from the model with lowest QAIC was used as the "best" capture model during most subsequent steps. The "best" capture model was then paired with 8 survival models containing temperature and precipitation covariates (models 97-104), 56 survival models containing habitat covariates (models 105 – 160), and 44 survival models interacting with the best 2 weather models and 11 habitat models (models 161 – 204). Models 161 – 204 were fitted under the assumption that habitat either ameliorates or exacerbates adverse weather effects on survival. Following this, a series of 81 survival models containing time, sex, age, set-aside, and take effects were fitted with the "best" capture model (models 205 – 285). Then, the best 5 survival models amongst models 97 – 204 were fitted with the best 5 survival models amongst models 205 – 285 to produce 25 models (models 286 – 310). From models 97 – 310, the 2 best survival models were determined, and the same set of 32 capture models previously fit were paired with each to produce the final set of 64 models (models 311 – 374). Following estimation of all models, the full set of 374 models was ordered according to QAIC and the model with lowest QAIC was selected as the best approximating model.

During model selection, logarithmic (ln) trends in selected continuous variables were considered, but quadratic trends were not. All possible quadratics effects were not considered because doing so would have increased the number of fitted models beyond what was reasonable. To assure us that non-linear effects outside the logarithmic effects already considered were not present in our top models, we fitted quadratic trends for all continuous covariates in the top 10 models. By adding quadratic trends to each of the top 10 models and noting changes in QAIC, we were able to determine whether inclusion of quadratic trends improved the model. To investigate the effects of birds moving into and out of edge areas where their capture probabilities may differ, we conducted a sensitivity analysis to gauge the effects of temporary emigration on estimated over-dispersion ($\hat{c}$) on the top models. During this sensitivity analysis, we identified all birds sighted in the interior that were later sighted exclusively in the edge (i.e., 1 interior-edge border crossing). We also identified birds that were sighted in the interior of the study area, then in the edge for a period of time, then back in the interior (i.e., 2 interior-edge border crossings). Other birds that crossed the boundary between interior and edge more than 2 times were present and also identified. Recall that initial (and all other) sightings in the edge were ignored for estimation of the models and $\hat{c}$. We investigated the sensitivity of $\hat{c}$ to presence of edge birds by re-estimating $\hat{c}$ after eliminating all birds that were known to cross the interior-edge boundary ≥1 and ≥2 times. We also re-ran model selection using data from the subset of birds that did not cross the interior-edge boundary and compared top models with and without these so-called "edge" birds.

Results

Among the 374 fitted models, no model clearly fit better than all others, resulting in little difference in QAIC among our 374 fitted models (Table 4.6). Delta QAIC weight was 0.02899 for the top model. Our top capture-resight model contained constant probability of capture for all birds and time periods. The top survival model estimated negative effects on survival for increased days of precipitation during early nesting and for locations > ½ mile from a designated set-aside (relative to locations inside a set-aside). Positive effects on survival were associated with increased temperatures during early nesting, increased nest site HSI and for locations near (< ½ mile) to a set-aside (relative to locations inside a set-aside). Parameter estimates for the top model appear in Table 4.7. The model ranked second by QAIC, which differed in QAIC from the top model by only 0.03, was similar but included the logarithm of nest HSI in the survival model (Table 4.6). Inclusion of quadratic effects for continuous variables in the top 10 models did not result in lower QAIC values.

The estimated value of over-dispersion for all model fitting runs was $\hat{c} = 1.234 = 169.1458 / 137$, based on the total 'Test 2 + Test 3' goodness of fit results computed by program RELEASE. In the data, 18 birds (5.4%) were known to have crossed the interior-edge boundary 2 or more times during their capture histories. When these birds were eliminated from the analysis, $\hat{c}$ decreased to 1.01 = 115.1665 / 114. When an additional 37 (11.1%) birds that were known to cross the interior-edge boundary 1 time were eliminated from the analysis (i.e., a total of 55, 16.5%, were eliminated from the 332 used for model fitting), $\hat{c}$ decreased to 0.85 = 86.73 / 102. In the subsequent sensitivity analysis investigating the effects of edge birds, $\hat{c}$ was set equal to 1.0, because $\hat{c} < 1.0$ was theoretically very unlikely and it would have been inappropriate to try to develop a post hoc "*edge bird*" covariate that would adequately model the variation associated with these birds.

When 55 birds that crossed the interior-edge boundary at least once were eliminated from the analysis (hereon known as "edge" birds), and all 374 models were re-estimated, the set of top models were different from the previous run in 2 primary ways. First, the top 2 models had greater separation in QAIC from the remaining models. During the first round of model selection, the difference in QAIC between model 1 (top model) and model 3 was 0.29. When edge birds were eliminated, the difference in QAIC between model 1 and 3 was 2.66. Second, one covariate in the top 2 models was replaced by another covariate that previously did not occur in any of the top 20 models; otherwise, the top 2 models contained the same covariates when fitted with and without edge birds. Upon eliminating 55 edge birds, the top model of survival contained the variables *precip_nesting, temp_nesting, %_0-5yrs_921m, set_aside_out* , and *set_aside_near* . The second-ranked model contained the variables *ln_precip_nesting, temp_nesting, ln_nest_HSI, set_aside_out* , and *set_aside_near* . Thus, the only difference between the top 2 models relative to the variables included was that the variable *nest_HSI* was replaced by the variable *%_0-5yrs_921m* in the top model. Coefficient estimates for non-intercept variables (i.e., all the variables that were not related to set-asides) in the top 2 models were similar with and without edge birds.

Discussion

The negative impact we reported on survival of colder, wetter weather during the early nesting season was consistent with the findings of Franklin et al. (2000) whose study area was immediately to the east of this study. Studies done in Oregon within different physiographic provinces provided somewhat different results. Olson et al. (2004) had a similar relationship with the amount of precipitation during the nesting season, but Dugger et al. 2005 found no relationship between any weather covariates and survival.

We also found a positive relationship between survival and nesting HSI, which is similar to Franklin et al. (2000) who found survival was positively associated with interior forest and edge between older and younger forests. Olson et al. (2004) showed a quadratic relationship between survival and the amount of late and mid-seral forests, while Dugger et al. (2005) found a strong positive relationship between older forests and survival.

The relationship between survival and set-asides (i.e., designated stands where harvest was not allowed under the provisions of GD's spotted owl HCP) was more complicated to understand. Owls in or near set-asides might be expected to have higher survival relative to non-set-aside (i.e., matrix) birds, because more owl sites in the matrix were taken on a regular basis as provided for by the incidental take provision of the HCP. However, it is not clear why owls near (< ½ mile) the set-aside should have had higher survival relative those owls in the set-asides. This phenomenon needs further investigation to determine if autocorrelation with some unmeasured variable was creating a spurious relationship or if being near a set-aside truly did provide some biological benefit that increased survival in spotted owls.

To gage the effects of temporary emigration on the top survival models, we conducted a sensitivity analysis that first identified all birds that were known to cross the interior-edge boundary at least once, then re-estimated $\hat{c}$ and re-performed model selection after eliminating these birds. Birds crossing the interior-edge boundary were called "edge birds", and were postulated to be those most susceptible to temporarily emigrate off the study area. Eliminating 55 edge birds had a large effect on $\hat{c}$, but less of an effect on the top survival estimated models. The estimated $\hat{c}$ changed from 1.234 to 0.85 after eliminating edge birds, and implies that nearly all over-dispersion in the original data was associated with birds near the boundary. During re-performance of model selection, the reduced $\hat{c}$ of models without edge birds allowed additional terms to enter the capture probability model, because lowering $\hat{c}$ effectively reduced the penalty term inherent in the QAIC statistic. Besides the different capture probability model, the only change in the top 2 survival models was replacement of *Nest_HSI* with *%_0-5_921m*, and replacement of *ln_precip_nesting* by *precip_nesting* in the top model. The second ranked survival models both with and without edge birds contained identical covariates and nearly identical estimated coefficients for non-intercept parameters (range of change = 2% – 20%). The QAIC difference between the top 2 models without edge birds was 2.66. Below, we discuss changes in the second-ranked model first, followed by discussion of changes in the top ranked model.

Comparing the identical second-ranked models both with and without edge birds revealed little change in non–intercept coefficients (i.e., coefficients of variables not related to set-asides), but a substantial change in the intercept parameter. The intercept parameters increased by 855% when edge birds were removed. The relative stability of non–intercept effects implies that these effects were probably appropriate for both edge and non–edge birds. An increase of 855% in the intercept seems large, but in fact only resulted in increases of between 3% and 7% in real survival estimates over the range of estimates in this study (i.e., ~ 0.7-0.9). The observed increase in survival when edge birds were eliminated implies one of the following: (1) that true survival of edge birds was lower than interior birds due to some unknown factor(s), or (2) that edge birds had lower *apparent* survival than interior birds due to emigration off the study area. The latter hypothesis is both plausible and predictable since field crews were not able to search for birds that may have moved outside the study area boundaries. However, to further investigate this analytically, we added an "edge bird" covariate (i.e., covariate equaled 1 for all occasions if bird was one of the 55 edge birds, 0 otherwise) to the second-ranked model fit to all data. The second-ranked survival model was used for this analysis, because during both runs (with and without edge birds) it had identical covariates in the models and nearly identical estimated coefficients. This simplified interpretation of the changes that occurred in the coefficient with and without the *edge* covariate. In addition, the intercept in the second-ranked model fit to interior birds was larger, implying higher average survival of interior birds (i.e., adding the covariate for "edge birds" would be more likely improve the model fit for survival in the second-ranked model if "edge birds" were statistically different relative interior birds). This new model had a QAIC of 1587.2, an increase of 3.32 over the original model's QAIC of 1583.9. This increase was near the maximum possible when a single variable was added, implying near zero predictive strength for the covariate. The edge bird coefficient was –0.17849 (SE = 0.21488). We interpret this to mean that there was not enough evidence in our data to suggest that the reduced apparent survival of edge birds was statistically real. We postulate that the reduced apparent survival of edge birds was due to increased emigration off the study area and is not a reduction in true survival.

The top-ranking survival model fit to data without edge birds contained two different covariates (*%_0-5_921m* and *precip_nesting*). While it was not surprising that the ln of precipitation was replaced by its linear version, it was not immediately apparent why *%_0-5yrs_921m* entered the top model with a strong positive coefficient (coefficient = 0.01958, se = 0.00929, t-ratio = 2.11). Inspection of intermediate steps in the model building process reveals that *%_0-5yrs_921m* did not drastically improve its predictive abilities when edge birds were removed, rather *nest_HSI* lost some of its predictive abilities and failed to rank higher than models with *%_0-5yrs_921m*. *Nest_HSI* lost some of its predictive abilities because edge birds were, generally, associated with poorer nesting habitat than interior birds (Fig 4.5). The proportion of larger *Nest_HSI* values (i.e., the right-hand tail of the distribution in Fig 4.5) among edge birds was much lower than that of interior birds. In fact, the average *Nest_HSI* for interior birds was 0.0525, while the average *Nest_HSI* for edge birds was -0.2239. Thus, because *nest_HSI* was more uniform for interior birds, it explains less *variation* in survival when edge birds were eliminated.

Poor nesting HSI values, however, do not fully explain why *%_0-5yrs_921m* appeared in the top model once edge birds were removed. Based on prior studies, we might have expected a different covariate to take the place of *nest_HSI*, or that *%_0-5yrs_921m* would have entered the model with a negative coefficient. However, the distribution of stand ages and harvesting practices on GD's ownership provides a potential explanation that is consistent with spotted owl ecology in this region. The initial harvest of the old growth forests was generally done in a systematic continuous even-age harvest within a given sub-basin, which created large areas of even-aged second growth. Harvest of the second growth within these areas typically was initiated when stands reached 45-50 years in age. Harvesting was regulated by the California Forest Practice rules, which requires small clearcuts (currently averages approximately 8 ha) and forces the harvesting to be dispersed within a sub-basin. As a result, the maximum percentage of 0-5 year old stands (i.e., recent clearcuts) within a sub-basin typically did not exceed about 15%. Furthermore, the presence of clearcuts indicates that the region was composed of stands within the 41-60 year old age class – the most abundant older age class on the landscape. Therefore, we conclude that the positive association with 0-5 year old age class was really a surrogate for landscapes with high levels of heterogeneity within the older age classes on GD's managed forests.

4. B.2 Factors Influencing Fecundity Rates

Our objective in this section was to relate owl fecundity, defined as the number of fledged females produced per adult female, to life history of the owls, habitat features, weather patterns and timber harvest in order to obtain fecundity models that provided insight into the primary factors that were influencing the fecundity of owls. In addition, these models could be used to predict the relative quality of habitat across the study area in terms of its contribution to fecundity for spotted owls.

Methods

Field methods

The study area for analysis of fecundity was the same area of GD lands as those chosen for inclusion in a previous analysis of nesting habitat (see Chapter 2, Section B.3, Fig. 2.1). Fecundity information was collected from 92 owl sites in the study area during 1990-2003. Fecundity information was collected by identifying the number of fledged young (i.e., 0, 1, 2, and 3) for each resident female each year. Identity and age class of the resident male and female owls at each owl site was also collected whenever possible. The specific field methods were the same as described in Chapter 2, Section B.2.

Analytical Methods – Covariates

Following previous fecundity analyses conducted as part of spotted owl demography workshops (Forsman et al. 1996, Franklin et al. 1999, Franklin et al. 2004, Anthony et al. 2006), we analyzed the (approximate) number of female young fledged per resident female by assuming a 1:1 sex ratio and dividing the number of fledged young by 2. The number of female young fledged per resident female took on values of 0, 0.5, 1, and 1.5. A total of 496 observations were available for analysis. The number of females fledged per resident female was analyzed using a linear mixed model (Littell et al. 1996, Franklin et al. 2000, Franklin et al. 2004) to estimate average fecundity for each adult age class. The response, number of female young fledged per resident female, was not normally distributed, but we applied a normal mixed linear model anyway for 3 reasons. First, mixed linear models are known to be robust to non-normality under sufficient sample sizes (Neter et al. 1996, White and Bennetts 1996) and proper model specification (Littell et al. 1996). Second, the mixed model analysis allowed us to identify the proper error covariance structure which in turn allowed us to properly account for the lack of independence in repeated observations at the same nest site. Third, all previous spotted owl demography workshops (Franklin et al. 2000; 2004, Anthony et al. 2006; Forsman et al. *In Review*) have applied similar mixed linear models for the same reasons. Finally, McDonald and White (2010) specifically looked at the robustness of mixed models for the California Spotted Owl fecundity data.

Covariates considered for estimating fecundity included linear and quadratic time trends, an even-odd year effect, age of the resident female (first-year sub-adult, second-year sub-adult, adult), whether the site was considered to have been "taken" during the study period, proximity of the nest to a "set-aside" area, and various climate and habitat related variables. Natural log transformations of several covariates were also considered (Table 4.8). Climate covariates considered in the analysis were similar to those investigated by Franklin et al. (2000). Hourly temperature information was the same as that used to model survival (see *Survival* section above). Precipitation information was also the same as that used to model survival. Seasonal climate conditions at each site were estimated for the winter stress period (November-February), early nesting period (March-April), and the late nesting period (May). Data from the weather stations was again assigned to nest sites based on distance and similarity in climate (see *Survival* section above).

Habitat variables included in the fecundity analysis were the same as those used in the survival analysis, only centered on nest trees instead of activity centers (see Table 4.8 for descriptions). There were only two minor differences between variables used in the survival and fecundity analyses. The first was that *take* was calculated and associated with a nest for the fecundity analysis, rather than calculated on an activity center and associated with an individual. Second, temperature and precipitation values during the late nesting period (May), and their natural log, were added to the pool of variables considered during fecundity modeling (Table 4.8).

Estimation and Model Development

We selected covariates to include in the linear model using using Proc MIXED (SAS Institute, 2000) and a two-stage model selection approach. The first stage of model selection involved selecting an appropriate model for the error covariance matrix, while the second stage involved selecting an appropriate model for the fixed effects. To select an appropriate error covariance structure, the restricted maximum likelihood (REML) (Verbeke and Molenbergs 2000, Littell et al. 1996) technique was used to estimate the model

$$fecundity = \beta_0 + \beta_1(age) + \beta_2(year),$$

where *age* was a categorical variable representing the age of the female owl at the nest site, and year was continuous. This model was fit four times, each with a different covariance structure. The four candidate covariance structures were: compound symmetric; first-order autoregressive (AR1), heterogeneous first-order autoregressive (ARH1); and a log-linear variance structure. REML estimation is based on *n-p* error contrasts, where *n* is the number of observations and *p* is the number of fixed effects plus the intercept term (Verbeke and Molenbergs 2000). For appropriate comparison of covariance structures the same mean model (formula above involving age and year) was fitted using each covariance structure, and AICc (Burnham and Anderson 2002) values were compared across models, where an effective sample size of $n^* = n\text{-}p$ was used to calculate AICc. AICc values were calculated as

$$AICc = -2\ln(likelihood) + 2k\left(\frac{n^*}{n^*-k-1}\right),$$

where k is the number of covariance parameters. The covariance structure with the lowest AICc was chosen as the most appropriate covariance structure, and was utilized during the second stage of modeling.

Once the most appropriate covariance structure was identified, we fit mean models to fecundity data and selected the most appropriate. Full maximum likelihood (ML) estimation was used to fit mean models using the most appropriate covariance structure identified during the previous stage of modeling, and AICc values were again used to rank the appropriateness of mean models. AICc values for models estimated via maximum likelihood do not account for the number of covariance parameters used to fit the model. For this reason, we fit all mean models using both ML and REML, used AICc values from the ML approach to compare and rank models, but used parameter estimates produced by the REML method because REML generally produces better coefficient and standard error estimates (Verbeke and Molenbergs 2000).

The mean models fit to data were categorized into six sets of models (Fig. 4.6): elementary models; climate models, habitat models; a take model; a set-aside model; and age class models. A pre-analysis correlation screening revealed that average daily degrees hours in the early nesting period was highly correlated with the average daily degree hours in the late nesting period (Pearson's correlation coefficient = 0.81), so these two variables were not considered in the same model. Because it was impractical to fit all possible combinations of models from each category, we combined the top models from 3 categories in a stepwise fashion to reduce the overall number of fitted models (Fig. 4.6). Following estimation of all models in each category, the top 5 age class and habitat models were "crossed" and fitted. "Crossing" the top 5 models from each category entailed estimating 25 models combining models from each category as follows: the #1 age class model was combined with the #1 habitat model, the #1 age class model was combined with the #2 habitat model, …, the #5 age class model was combined with the #5 habitat model. Once these 25 models were estimated and ranked amongst the 116 pure age class and 14 pure habitat models, the top 3 model in the entire group of 116 + 14 + 25 = 155 models were identified and crossed with the top 3 climate models. This produced 9 additional models combining climate, age class, and habitat effects. Finally, all possible "crossed" models amongst the top 3 elementary models, the take model, the set-aside model, and the top 3 climate X age class X habitat models were estimated. The entire set of estimated models was then ranked according to each model's AICc weight (Burnham and Anderson 2002). AICc weights quantify the plausibility of each model as being the actual best model in the set considered, and allow for comparisons of the relative differences between models. The bigger the AICc difference, the smaller the weight, and "the less plausible is [the] model as being the actual best model… based on the [study] design and sample size used," (Burnham and Anderson, 2002, p75). To conserve space we report all models satisfying $\sum_i (\text{AICc weight})_i < 0.9$, where the sum is over all models with AICc less than model *i*. We consider our top fecundity model to be the one with largest AICc weight.

Model Validation

Following model ranking and selection, we verified fit and assumptions of the top model by visually inspecting scatter plots of predicted values and residuals. We examined residual plots of all variables, particularly those that were log (ln) transformed, to identify whether or not quadratic relationships existed in the data. Fit of the top model was also assessed using the $PRESS_p$ (prediction sum of squares) (Neter et al. 1996) criterion and compared to that of model averaged predictions (Burnham and Anderson 2002). The $PRESS_p$ criterion was obtained by summing squared prediction errors that were in turn obtained by dropping the *i*th nest site and all its data collected through time from the dataset, re-fitting all models in the reported set containing 90% of AICc weight using the remaining *n*-1 sites, and then predicting all responses for the *i*th case. Models with smaller $PRESS_p$ values necessarily have smaller prediction errors and so are considered better models. Each time a site was dropped during the $PRESS_p$ procedure, model averaged predictions were computed over the same set of models containing 90% of all AICc weight in the original set of models.

Results

REML estimation of 4 different covariance structures under the same mean model produced 2 models that converged with positive definite covariance matrices (AR(1) and ARH(1)), 1 model that converged but failed to arrive at a positive definite covariance (CS), and 1 model that did not converge (EXP(*AGE YR*)). Failure of a mixed linear model to converge is common and was taken as evidence against that particular covariance model. Therefore, among the models that fully converge and produced valid covariance matrix estimates, the AR(1) model had the lowest AICc and was selected as the most appropriate among the 4 models that were investigated. At the end of model selection, 26 mean models accounted for 90% of all AICc weight. The top fecundity model estimated negative effects on fecundity for locations inside a set-aside, sites where take had occurred and for increased precipitation in the early nesting season. Positive effects were estimated for locations < ½ mile from a set-aside (relative to locations outside a set-aside), even number years, adult females relative to S2 females, ln of the percent of 41-60 old stands in a 600 m radius buffer, ln of the percent of 21-40 year old stands in a 600-921 m annulus, average nighttime activity *HSI* in a 600 m radius buffer and average open edge density in a 600 m buffer. Coefficients and AICc weights of 5 the top 26 models appear in Table 4.9.

The top model had a $PRESS_p$ value of 69.66, the model averaging method of prediction using the top twenty-six models had a $PRESS_p$ value of 69.12, and the null model (i.e., intercept term only) had a $PRESS_p$ value of 77.46. Thus, using the top model to predict fecundity rather than the mean fecundity value during the study period reduced the error sums of squares for the predictions by (1-69.66/77.46)*100% =10.1%. Using model averaging rather than the top model reduced the error sums of squares only by an additional 0.7%, suggesting that nearly all the predictive abilities of the average model were also contained in the top model. Dividing each $PRESS_p$ value by n = 496 and taking the square root results in an estimate of the average prediction error for new observations. The average fecundity prediction error for the top model was 0.375, and the average prediction error for the model average approach was 0.373. This implies that, on average, $PRESS_p$ predictions of fecundity were 0.375 and 0.373 units away from observed fecundity values using the top and average model respectively.

Discussion

The negative impact we reported on fecundity of wetter weather during the nesting season has been consistently observed in all studies that have attempted to quantify this phenomenon (Franklin et al. 2000, Olson et al. 2004 and Dugger et al. 2005). We also have empirical observations of high nest failures during extended rainy periods in the spring. The specific mechanisms have not been quantified, but presumably rainy weather inhibits foraging along with making thermoregulation more difficult. The negative impact of take on fecundity was also expected since individuals subjected to take were typically displaced and forced to find a new territory before they could attempt nesting. Two other variables that entered our top model, the even-odd year effect and increased fecundity of adult females, has been reported in many demographic study areas (Anthony et al. 2006).

The habitat variables associated with higher fecundity were less consistent across different studies. Franklin et al. (2000) reported that fecundity was negatively associated with interior forest, but positively associated with edge between older and younger forests. Olson et al. (2004) did not report a negative association with interior forests, but they did find a similar positive association between fecundity and edge. Similar to what they reported for survival, Dugger et al. (2005) did not report any type of positive relationship between edge and fecundity. Instead, they found a positive relationship between fecundity and the proportion of old growth forests near the owl territory center.

Our results indicated that edge along with older-aged (41-60 years) stands near the territory center and younger (21-40 years) stands in an annulus around the territory center contributed to higher fecundity. Fecundity also increased with higher average *HSI* values of nighttime activity, which included an integration of variables for edge and stand heterogeneity. In general, our habitat variables associated with higher fecundity were most closely associated with the results of Franklin et al. (2000) and Olson et al. (2004).

The relationship between fecundity and set-asides was more complicated to understand. The highest fecundity was found in owls near (< ½ mile) set-asides followed by those outside set-asides with the lowest fecundity for owls within set-asides. It was possible that the lower fecundity within set-asides was related to lower fecundity within interior forests as reported by Franklin et al. (2000). However, set-asides averaged 137.4 ha, which seems too small to act as interior forests. We believe there may be another explanation that was related to how fecundity estimates were obtained. Fecundity was assigned for each female observed by dividing the number of fledged young by two. However, if a female was not observed in a territory during a given year, no value was assigned for fecundity (Anthony et al. 2006). (We will call this later situation a "null value."). We hypothesize that this "null value" creates a positive bias to fecundity estimates, because it has been our observation that non-nesting females were more difficult to locate. Although it was possible that some females that could not be found in given years had moved to new locations and successfully nested, it was much more likely that females were not detected in a given year, because they were not nesting and did not show strong affinity to any particular activity center/nest site. This was particularly true since much of our study area was in a "density study area" (Anthony et al. 2006) in which 100% of the habitat was surveyed every year. We investigated this phenomenon relative to set-asides and discovered that null fecundity values occurred at 15.9, 24.1 and 32.1 percent of perennial owl sites within, near and outside set-asides, respectively. Our interpretation of this trend was that owls in set-asides with no harvest had greater habitat stability relative to those owls in the matrix where take displaced selected owl pairs. Presumably, we were more likely to find females in set-asides relative to the matrix regardless of their reproductive status, which would have biased the fecundity estimates. Assuming all null fecundity values were actually "0" fledged, mean fecundity estimates for all owls (includes territories too close to the study edge to be included in the fecundity analysis) were 0.264, 0.266 and 0.199 for owls within, near and outside set-asides, respectively. This would suggest that owls within or near set-asides have the highest fecundity and the matrix owls have the lowest fecundity. As with the survival analysis, impact of set-asides on owls requires further investigation to determine the true biological impact of set-asides on fecundity.

4. B.3 Factors Influencing Habitat Fitness Potential

In previous sections, survival and fecundity of spotted owls were estimated from separate data sets by using common habitat and weather information. While several variables associated with high survival were also associated with high fecundity (e.g., precipitation in the early nesting season and sites near set-asides), most variables were not in common making interpretation of these separate models difficult. Ultimately, the true understanding of the factors influencing spotted owl demographics is derived through the integration of survival and fecundity. In this section, we bring survival and fecundity information together into a single measure of owl fitness based on habitat quality called "habitat fitness" (λ_H).

Methods

There is a long history in population ecology of bringing survival and fecundity information together to project a population's trajectory (McGraw and Caswell 1996, Caswell 1989). Many methods for doing so exist, but one of the most popular and intuitive uses Leslie or population projection matrices. In general, these Leslie-type methods postulate an age structured population in an initial state, and then age the population to the next generation by applying age-specific survival and fecundity estimates. This aging and resultant population change is usually written as a matrix equation of the form,

$$\mathbf{N}_{t+1} = \mathbf{L}\mathbf{N}_t$$

$$\begin{bmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \end{bmatrix} = \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \end{bmatrix}$$

were $N_{i,t}$ is the number of animals in age class j at time t, and all l_{ij} are multipliers that are functions of survival and fecundity. The matrix **L** in this context is called the Leslie matrix, and the ultimate growth or decline of the population is determined by the largest eigenvalue of **L.** If the largest eigenvalue of **L** is >1.0, the population grows, <1.0, the population declines and when the largest eigenvalue of **L** equals 1.0, births equal deaths and the population's level is constant. In fact, the largest eigenvalue of **L** exactly quantifies the population's growth rate, and is often denoted λ.

In a similar way, site specific survival and fecundity information can produce a measure of fitness (or habitat quality) using the same Leslie matrix approach (Franklin et al. 2000). Here, we postulate a theoretical "micro-population" of owls living on or near a specific location having specific habitat characteristics. Assuming survival and fecundity of this "micro-population" are accurately estimated by our models, this theoretical population's growth rate can be computed. We define this site-specific growth rate of the "micro-population" to be the fitness of the site's habitat. We postulate that if this measure of habitat fitness is >1.0, owls living in the area will generally prosper (survive and reproduce) long term. If this measure of habitat fitness is <1.0, we postulate that owls living in the area will generally not prosper long term.

For our study, site specific habitat fitness (λ_H) was computed as the largest eigenvalue of the 3 age Leslie matrix,

$$L = \begin{bmatrix} \phi_{S1} b_{S2} & \phi_{S2} b_A & \phi_A b_A \\ \phi_{S1} & 0 & 0 \\ 0 & \phi_{S2} & \phi_A \end{bmatrix}$$

where ϕ_a denotes the estimated survival of age class a at the site, b_a denotes the estimated fecundity of age class a at the site (e.g., b_{S2} is estimated fecundity for age class S2 birds, which would have been calculated using habitat and other covariates from a specific location on the study area).

By taking the determinant of L analytically and solving the equation $det(L - \lambda I) = 0$ for the largest value of λ that makes it true, we obtained the following formula for site specific λ_H. The largest eigenvalue of L is:

$$\lambda = \frac{\phi_A + \phi_{S1} b_{S2} + \sqrt{(\phi_A + \phi_{S1} b_{S2})^2 + 4(\phi_{S2}\phi_{S1} b_A - \phi_A \phi_{S1} b_{S2})}}{2}.$$

Note that fecundity of S1 birds does not appear in L.

Aside from its intuitive appeal and precedence, our measure of site fitness can be considered a special case of a large class of estimators that have seen a large amount of research in the recent past. Because λ_H is a function of survival and fecundity, which are in turn functions of covariates like habitat and weather conditions, λ_H can be considered a structural equation (Bollen 1989) estimate of site fitness. A diagram of the structural equation appears in Fig. 4.7. In the language of structural equation modeling, ϕ (survival), b (fecundity), *NTA HSI* values, and *nest HSI* values are all latent variables (ovals in Fig. 4.7). Variables such as set-aside, % hard wood, % age class, edge density, temperature, etc. are measured or direct variables in the structural equation modeling language (rectangles in Fig. 4.7).

To calculate fitness of a site, all habitat covariates were computed at the site, or on a circle surrounding the site, from information in GD's GIS. Non-habitat variables, such as those varying over time (e.g., weather) or birds (e.g., age class), were either fixed at a certain level or averaged. For prediction of λ_H, temperature and precipitation were set to the mean value computed over the period of record from the station associated with the site. The average even-odd year effect on fecundity was computed by averaging the *EO* coefficient from that model. Age class of the bird was set to either S2 or Adult.

Estimating take on future landscapes created a significant challenge, because take depends upon the proximity of owl pairs to harvest units and the owl's post-harvest occupancy and nesting behavior. We had no method to predict site-specific future timber harvest, owl locations or the response of the owls to the timber harvest. The variable *take* was approximated in each of four target years (1992, 2002, 2012, and 2022) as follows:

1. A ½ mile buffer was placed around all harvest units that were clearcut during a target year. The ½ mile buffer around clearcuts was applied, because the original HCP assessed timber harvest in a ½ mile radius around owl sites to determine if a potential displacement (take) had occurred.
2. We determined the past percentage of owls that had been subjected to take at some point in their life (17%) and set 20% as a liberal estimation for future levels of take.
3. Then we calculated 20% of the total study area that was common among all four of the target years (i.e., 1992, 2002, 2012 and 2022).
4. Finally, in each of the four target years, we summed all the ½ mile buffers surrounding harvest units and pixels were selected at random until the area of selected pixels summed to 20% of the study area. Because *take* was originally assessed at points (i.e., pixels), this random selection of pixels near current harvest units approximated a take scenario whereby 20% of the study area was "taken".

It should be noted that this algorithm produced an approximation to reality, because our random sampling of pixels allowed "non-take pixels" to be interspersed with "take pixels." In reality, take and non-take pixels could only occur in proximity along the boundary of an actual take.

Following estimation of the structured model for λ_H, the sensitivity of λ_H to changes in each variable was investigated by approximating the derivative (gradient) of λ_H with respect to all measured and latent variables. Let λ_1 be the value of λ_H computed using typical values (medians) of every variable in the model. Let λ_2 be the value of λ_H computed after 1 variable was increased by ½ its standard deviation. The sensitivity of λ_H to changes in this variable was defined as the change in λ_H (i.e., $\lambda_2 - \lambda_1$) divided by the change in the variable (i.e., ½ its standard deviation). For example, λ_1 was computed for areas > ½ mile from a set-aside, in *2nd Growth*, with the nearest stand being of age 41+ yrs, for adult non-take females, using median values for the remaining variables. λ_2 was then computed using the same values of all covariates except that the typical value of slope position (36%) was increased by ½ its standard deviation (SD = 29.49%) to 50.74% (i.e., 36% + [29.49 ÷ 2] = 50.74%). The sensitivity of λ_H to this change in slope position was calculated as $(\lambda_2 - \lambda_1) / (29.49 \div 2)$.

Due to the structured nature of the site fitness model, it was possible for changes in measured variables to cause changes in latent variables which in turn caused changes in other latent variables and finally in λ_H. To compute sensitivity, all changes in measured variables were propagated forward to allow for changes in associated latent variables. To continue the example above, an increase in the value of slope position was associated with a decrease in the predicted NTA HSI. Since NTA HSI was input into the Nest HSI and fecundity models, the decrease in the predicted NTA HSI decreased the nest HSI value and predicted fecundity. The decrease in nest HSI in turn caused a decrease in survival. Thus, changes in both measured and latent variables could have had multiple effects expressed on site-specific fitness.

Due to their different natures, sensitivity was computed separately for categorical variables, continuous variables, and latent variables. As a result, sensitivity values should not be compared across groups due to the different scales involved in the changes. For example, a sensitivity value of 100 that occurs when age class of the nearest stand changes from 1 to 2 does not mean the same thing as a sensitivity value of 100 that occurs when opening edge density changes by ½ its standard deviation. Similarly, a change in nest HSI (a latent variable) of ½ its standard deviation could be caused by many different changes in its input variables, and sensitivity values for nest HSI should not be compared to, say, sensitivity values for opening edge density.

When computing sensitivity of λ_H to changes in the second growth and set-aside variables, typical values of the other variables were set to their respective medians in each area to better represent realistic changes in habitat. For example, when λ_1 was computed for second growth habitat, the medians of all continuous variables in second growth areas were used in the model. When λ_2 was computed for old growth habitat, the medians of all continuous variables in old growth were used in the model. This method prevented λ_1 and λ_2 being computed in unrealistic combinations of variables that would never occur in nature. For example, the median % hardwood value computed over all second growth areas is not a typical value of % hardwood in old growth areas. A summary of all the measured and latent variables used in the sensitivity analysis are listing in Table 4.10.

Results: Sensitivity of λ_H

Relative to other categorical variables, λ_H was most sensitive to the location of the nest site/activity center relative to a set-aside (Table 4.11). Site fitness decreased when a nest theoretically moved from the ½ mile buffer surrounding a set-aside to inside the set-aside, but increased when a nest moved from outside the ½ mile buffer to inside the ½ mile buffer. This means site fitness values were highest in the ½ mile buffer surrounding a set-aside, all else being realistically equal. While considerably lower relative to the magnitude of the effect, sites that went from non-take to take were the second most important categorical variable relative to λ_H.

Relative to measured continuous variables, λ_H was most sensitive to changes in precipitation during the early nesting period (Table 4.12). Decreases in λ_H were associated with increases in the total number of days of measurable precipitation within the early nesting period. The second most important continuous variable was open edge density, where increases in this variable resulted in higher values of λ_H. Relative to latent variables, λ_H was most sensitive to changes in survival, followed by changes in fecundity and nesting habitat (Table 4.13).

Discussion

Our study was patterned after Franklin et al. (2000), and as noted above with the analysis of survival and fecundity, we found similar results relative to the importance of habitat heterogeneity and climate that were obtained by Franklin et al. (2000) in northern California as well as Olson et al. (2004) in the central coast range of Oregon. Working in the south Cascades of Oregon, Dugger et al. (2005) did not find a benefit relative to habitat heterogeneity, but found the highest habitat fitness at sites with more contiguous old forest near the core of the owl site.

There were unique aspects to our study that can not be compared to any other published study. In particular, our study occurred on a managed landscape with designated set-asides and the authorization to take (i.e., harvest the habitat) a selected number of owl sites each year. Clearly, set-asides were important to both survival and fecundity, but the greatest benefit to habitat fitness appeared to be conferred on those owls residing near, but not in the set-asides. As noted above in the discussion of the fecundity results, this may be in part a bias created by the protocol used to estimate fecundity. Resident female owls that could not be found in a given year, and most likely were not nesting, were not included in the estimate of fecundity. A higher proportion of resident females were not found in the matrix followed by the buffer around the set-aside with the lowest proportion not found in the set-asides. This had the potential to have biased the estimates of fecundity so that the true impact of set-asides on fecundity was greater than estimated by the model. However, being in the buffer near a set-aside also increased survival, for which there was no obvious explanation. We believe our habitat fitness model should be regarded as a testable hypothesis with particular emphasis on the relationship between set-asides and owl demographic rates on managed timberlands.

4. C. Viability of the Northern Spotted Owl population based on future projections of habitat

Following modeling of Northern Spotted Owl survival, fecundity, and habitat fitness potential on GD's current study area, we investigated the trend in future habitat with the landscape in 1992 (year the HCP was approved) as the baseline. Using projections of future landscapes that will result from timber harvest and re-growth of harvested stands, we predicted the proportion of GD's future ownership that will fall within various habitat categories.

Methods

Using anticipated harvest plans in the near term (next 10 years) and projected harvests derived through a harvest schedule model, we compared habitat on GD's study area at 10 year intervals from 1992 to 2022 with respect to the three demographic measures of survival, fecundity, and fitness. We predicted these parameters for every location on the landscape from their respective models (Fig. 4.7) for the years 1992, 2002, 2012, and 2022. We then scaled all predictions by 10,000/ (maximum in 1992), then defined five categories of survival, fecundity, or habitat fitness potential (low to high) using the 1992 data as the baseline. These five categories of habitat were defined by the 20^{th}, 40^{th}, 60^{th}, and 80^{th} percentiles of the respective habitat distributions such that each category contained 20% of the landscape in 1992. We considered the top 20% of the relative probabilities from 1992 to be the "best" habitat in 1992. Because the same cut-points were used at each time interval, we could estimate the relative amount of GD's study area that would be included in each of the classification categories in subsequent years. Using these categories, we created maps and tabulated the percent of GD's ownership that fell within the five categories for potential survival, fecundity, and habitat fitness in 1992, 2002, 2012, and 2022 landscapes.

Results

The total area in the best survival habitat as predicted by the top model increased from 17,000 ha in 1992 to 21,000 ha in 2002, an increase from 20% to 25% of the study area (Table 4.14). That is, approximately 4000 ha of habitat with lower survival potential was converted into the "high" survival category between 1992 and 2002. The "best" survival habitat category was projected to increase to 32% of GD study area by 2012 and 37% of GD study area by 2022. Fig. 4.8 illustrates how the land base GD's study area was projected to change in relative habitat survival potential from 1992 through 2022.

The total area in the best fecundity habitat increased from 17,000 ha in 1992 to 25,000 ha in 2002, an increase from 20 to 29% of the ownership (Table 4.15). The "best" fecundity habitat was projected to increase to 41% of GD study area by 2012 and 57% by 2022. Fig. 4.9 illustrates how the land base changed in relative habitat fecundity potential from 1992 to 2022.

Due to the increases in survival and fecundity observed between 1992 and 2002, the total area in the best habitat fitness potential category increased from 17,000 ha in 1992 to 22,000 ha in 2002, an increase from 20% to 26% of the study area (Table 4.16). The "best" fitness potential habitat was projected to increase to 35% by 2012 and 45% by 2022. Fig. 4.10 illustrates how the study area changed in relative habitat fitness potential from 1992 to 2022, and how the land base is projected to change through 2022.

Discussion

Habitat that was estimated to promote high survival and fecundity was projected to increase through time. Habitat fitness estimates were calculated by integrating survival and fecundity, so it was also projected to increase through time. Since non-habitat variables (e.g., climate variables, take and even-odd year effect) were set at constant median values throughout the future projections, they did not contribute to the changes. Set-asides were also retained at a constant level, so this variable did not contribute to the future projections of habitat quality. Based on the sensitivity analysis above, the habitat variable that would most likely have contributed the most to the trend was open edge density. The proportion of older stands (41-60 yrs) adjacent to younger stands (6-20 and 21-40 yrs) could have also contributed to the trend.

Assuming that factors related to habitat heterogeneity were responsible for projections of increasing habitat quality through time, it is relatively easy to provide an explanation for the trend. The initial harvest of the old growth forests in this region was generally done in a systematic continuous even-age harvest within a given sub-basin, which created large areas of even-aged second growth. Harvest of the second growth within these areas typically was initiated when stands reached 50-60 years in age. Beginning in 1974, harvesting was regulated by the

California Forest Practice Rules (FPR), which created decreasing maximum clearcut sizes of approximately 32 ha, followed by 16 ha to the current maximum size of 8 ha. Reduced clearcut size has and will continue to create higher open edge density and overall more habitat heterogeneity. In addition, riparian protection measures have also been modified through time. Initially, the riparian reserves required under the FPR did not require sufficient forest structure to be retained to create forest edge between the stream buffer and the adjacent harvested region. Beginning in 1992, when GD (formerly Simpson Timber Company), implemented a HCP for Northern Spotted Owls, the riparian standards were increased so that the riparian buffers began taking on the character of linear stands of habitat. These stream protection standards have continued to increase due to changes in the FPR and the signing of an aquatic HCP by GD in 2007. In addition to the riparian reserves mandated by the aquatic HCP, protection of geolnically unstable areas will create a future landscape in which an estimated 20% or more of the landscape will be in some type of protected reserve. The net affect will be much greater overall open edge density and a higher overall level of habitat heterogeneity.

4. D. Potential future impacts of barred owls or West Nile virus on long-term viability of Northern Spotted Owls

It is impossible to predict the future impacts of barred owls or West Nile Virus on Northern Spotted Owls within the GD ownership. A recent review of the status of the Northern Spotted Owl (Courtney et al. 2004) provided a thorough evaluation of these two potential threats to the Northern Spotted Owl. Following is a summary of these topics from Courtney et al. (2004).

The panel of scientists conducting the Northern Spotted Owl status review ultimately did not agree on the severity of the threat of barred owls to spotted owls (Courtney et al. 2004). Barred owls now occupy many areas previously occupied by spotted owls, especially in the northern portion of the spotted owl's range. Many assume this situation to be the result of competitive displacement, although displacement has not been demonstrated. Although spotted owl numbers have declined within both GD land and Redwood National Park, barred owls are currently more prevalent in Redwood National Park. "This suggests that something other than Barred Owls is negatively affecting these adjacent Spotted Owl populations" (Courtney et al. 2004:7-30).

Courtney et al. (2004) outlined 9 alternative hypotheses about the consequences of the barred owl invading the range of the Northern Spotted Owl. Among the "clearly plausible" hypotheses was that the barred owl would displace the spotted owl throughout the spotted owl's range. Other hypotheses predicted that the two species would persist in some equilibrium or that spotted owls would maintain a competitive advantage in some habitats (e.g., in areas with diverse and abundant prey).

As noted in Section 3.F.1, barred owl numbers have increased from the early 1990's until 2003 on GD ownership, but since then, the number of barred owls sites appear to have stabilized at least temporarily. Additionally, the maximum number of barred owls sites still only represents 10% or less of the total *Strix spp.* owl sites. While this suggested that the barred owl was not a major threat over the period monitored, it does not preclude that barred owl numbers may rapidly expand at some future time as documented in Washington and Oregon (Pearson and Livezey, 2003, Kelly et al. 2003).

At the time of this writing, West Nile Virus (WNV) has not been reported in spotted owls. Courtney et al. (2004) expected WNV to result in increased mortality of owls within 1-2 years of the virus appearing in the region, with adult owls developing disease resistance during this time. Juvenile owls were expected to experienced mortality for a longer period. Because spotted owls are long-lived and exhibit low reproductive rates, population trend is highly sensitive to adult survival rate. It is unknown whether a short-term reduction in adult survival coupled with a longer reduction in juvenile survival will threaten spotted owl population viability. It is expected that the impact of WNV on spotted owls will be highly variable spatially. "Coastal areas in northern California may be at even higher risk (*Boyce et al. 2004*)" (Courtney et al. 2004:8-35).

TABLES

Table 4.1. Estimated apparent mean survival probability (ϕ), with standard error (SE) and trend in ϕ for adult ($\geq$ 3 yrs old) Northern Spotted Owls (after Anthony et al. 2006, Tables 13 and 21).

Study Area	ϕ	SE	Trend
Washington			
Wenatchee	0.750	0.026	Declining
Cle Elum	0.860	0.017	Declining?[a]
Rainier	0.832	0.020	Declining
Olympic	0.855	0.011	Declining
Oregon			
Coast Ranges	0.886	0.010	Stable
H. J. Andrews	0.883	0.010	Stable
Warm Springs	0.823	0.015	Stable
Tyee	0.878	0.011	Stable
Klamath	0.849	0.009	Stable
South Cascades	0.854	0.014	Stable
California			
NW California	0.869	0.011	Declining
Hoopa	0.853	0.014	Stable
Green Diamond	0.850	0.010	Stable
Marin – females	0.824	0.045	Stable
Marin – males	0.913	0.035	Stable

[a] Variable among years, but with a declining trend.

Table 4.2. Estimated mean annual fecundity (female young produced per adult female), (ϕ), with standard error (SE) and trend in fecundity for adult ($\geq$ 3 yrs old) Northern Spotted Owls (after Anthony et al. 2006, Tables 5 and 21).

Study Area	Mean	SE	Trend
Washington			
Wenatchee	0.491	0.058	Declining
Cle Elum	0.574	0.069	Declining?[a]
Rainier	0.253	0.061	Stable
Olympic	0.293	0.057	Stable
Oregon			
Coast Ranges	0.260	0.050	Declining?[a]
H. J. Andrews	0.321	0.045	Stable?[a]
Warm Springs	0.424	0.070	Stable
Tyee	0.319	0.040	Increasing
Klamath	0.445	0.040	Stable
South Cascades	0.377	0.059	Declining
California			
NW California	0.333	0.032	Declining
Hoopa	0.216	0.043	Increasing
Green Diamond	0.326	0.037	Declining?[a]
Marin	0.530	0.056	Stable

[a] Best model included age and even-odd year effects, but a competing model had a negative time trend.

Table 4.3. Estimated rate of population change (λ_{RJS}) for Northern Spotted Owls, with standard error and 95% confidence interval (after Anthony et al. 2006, Table 19).

			95% CI	
Study Area	λ_{RJS}	SE	Lower	Upper
Washington				
Wenatchee	0.917	0.018	0.882	0.952
Cle Elum	0.938	0.019	0.901	0.976
Rainier	0.896	0.055	0.788	1.003
Olympic	0.956	0.032	0.893	1.018
Oregon				
Coast Ranges	0.968	0.018	0.932	1.004
H. J. Andrews	0.978	0.014	0.950	1.005
Warm Springs	0.908	0.022	0.866	0.951
Tyee	1.005	0.019	0.967	1.043
Klamath	0.997	0.034	0.930	1.063
South Cascades	0.974	0.035	0.906	1.042
California				
NW California	0.985	0.013	0.959	1.011
Hoopa	0.980	0.019	0.943	1.017
Green Diamond	0.970	0.012	0.947	0.993

Table 4.4. Variables considered in modeling survival of Northern Spotted Owls on Green Diamond Resource Company's study area.

Variable	Description	Ln Value
1	Intercept = 1 for all occasions and individuals (i.e., constant time or mean model).	N
t	Discrete (annual) time effect.	N
lin.T	Linear time, parameterized as -6, -5, …, 5, 6, 7	Y
lin.TT	Quadratic time, parameterized as 36, 25, …, 25, 36, 49	N
EO	Indicator for even numbered year. Odd year was reference level.	N
sex	Sex, 0 = Male, 1=Female	N
age_S1, _S2 or_A	Age class: S1 = 1 yr old sub-adult, S2 = 2 yr old sub-adult, A = adult (3 yrs or older)	N
NTA_HSI	Night time activity habitat suitability index: Raw values were scaled so that maximum in 1992 was 10,000. Then, HSI values were averaged over 600 m circle centered on a location. Finally, HSI values were standardized by scaling (i.e., mean NTA_HIS over all years/std NTA_HSI = NTA_HSI - 3044.4848280640558) / 775.12740508571801).	Y
Nest_HSI	Nesting habitat suitability index: Raw values were scaled so that the maximum value in 1992 was 10,000. Then, HSI values were averaged over a 600 m circle centered on a location. Finally, HSI values were standardized by scaling (i.e., mean nest_HSI over all years / std nest_HSI = nest_HSI - 468.60323816352155 / 561.79945510222251).	Y
open_edge_density	Open edge density: Opening defined as non-forest or forest < 6 years old. Open edge (m) inside 600 m buffer, divided by area of 600 m buffer; then standardized (i.e., mean open_edge_density overall all years / std open_edge_density = open_edge_desnity - 29.265382328934116) / 20.897930306503781	Y
Ln_NTA_HSI	Ln NTA HSI: = ln(*NTA_HSI* - min(*NTA_HSI*) + 1) = ln(NTA_HSI + 4)	
Ln_nest_HSI	Ln Nest HSI: = ln(*nest_HSI* - min(*nest_HSI*) + 1) = ln(*nest_HSI* + 4)	N
Ln_open_edge_density	Ln open edge density: = ln(*open_edge_density* - min(*open_edge_density*) + 1) = ln(*open_edge_density* + 4)	
%_0-5yrs_600m	% age class 0-5 years old in a 600 m buffer (ac600.1 in Table 4.5)	
%_6-20yrs_600m	% age class 6-20 years old in a 600 m buffer (ac600.2 in Table 4.5)	
%_21-40yrs_600m	% age class 21-40 years old in a 600 m buffer (ac600.3 in Table 4.5)	
%_41-60yrs_600m	% age class 41-60 years old in a 600 m buffer (ac600.4 in Table 4.5)	
%_61-80yrs_600m	% age class 61-80 years old in a 600 m buffer (ac600.5 in Table 4.5)	
%_80+yrs_600m	% age class 80+ years old in a 600 m buffer (ac600.6 in Table 4.5)	
%_NF_600m	% non-forest in a 600 m buffer (ac600.7 in Table 4.5)	

Table 4.4 (continued).

Variable	Description	Ln Value[1]
%_0-5yrs_921m	% age class 0-5 years old in a 921 m buffer (ac921.1 in Table 4.5)	
%_6-20yrs_921m	% age class 6-20 years old in a 921 m buffer (ac921.2 in Table 4.5)	
%_21-40yrs_921m	% age class 21-40 years old in a 921 m buffer (ac921.3 in Table 4.5)	
%_41-60yrs_921m	% age class 41-60 years old in a 921 m buffer (ac921.4 in Table 4.5)	
%_61-80yrs_921m	% age class 61-80 years old in a 921 m buffer (ac921.5 in Table 4.5)	
%_80+yrs_921m	% age class 80+ years old in a 921 m buffer (ac921.6 in Table 4.5)	
%_NF_921m	% non-forest in a 921 m buffer (ac921.7 in Table 4.5)	
%_0-5yrs_ann	% age class 0-5 years old in a 600-921m annulus (ann.ac1 in Table 4.5)	
%_6-20yrs_ann	% age class 6-20 years old in a 600-921m annulus (ann.ac2 in Table 4.5)	
%_21-40yrs_ann	% age class 21-40 years old in a 600-921m annulus (ann.ac3 in Table 4.5)	
%_41-60yrs_ann	% age class 41-60 years old in a 600-921m annulus (ann.ac4 in Table 4.5)	
%_61-80yrs_ann	% age class 61-80 years old in a 600-921m annulus (ann.ac5 in Table 4.5)	
%_80+yrs_ann	% age class 80+ years old in a 600-921m annulus (ann.ac6 in Table 4.5)	
%_NF_ann	% non-forest in a 600-921m annulus (ann.ac7 in Table 4.5)	
Set_aside	Stands mostly occupied by owls where timber harvest was not allowed. Categorical variable: *set_aside_out* (not near set-aside; reference level); *set_aside_in* (within set-aside); *set_aside_near* (within 0.8 km buffer of set-aside).	
%_nesters	Percent birds nesting: = 100 * (# pairs nesting that year) / (# pairs). From Table 17 of GD annual reports.	
#_fledged_pair	# Fledged per pair: average # fledglings per nesting pair * 100. From Table 17 of GD annual reports.	
Temp_winter	Heating degree days during winter: Integral under daily temperature graph, measured at associated weather station during winter season (Nov-Feb)	N
Temp_nesting	Heating degree days during early nesting: Integral under daily temperature graph, measured at associated weather station during early nesting season (Mar – Apr)	N
Precip_winter	Number of days with measurable precipitation (>0.03 cm) during winter stress period (Nov – Feb)	Y
Precip_nesting	Number of days with measurable precipitation (>0.03 cm) during early nesting period (Mar – Apr)	Y
Ln_precip_winter	Ln precipitation in winter	
Ln_precip_nesting	Ln precipitation in early nesting	

Table 4.5. All 374 capture-recapture models fit to Green Diamond Resource Company Northern Spotted Owl data for estimating survival. See Table 4.4 for definitions of variables.

Model #	Capture Model	Survival Model
001	capture=~1,	survival=~1
002	capture=~t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~1
003	capture=~lin.T,	survival=~1
004	capture=~ln.T,	survival=~1
005	capture=~sex,	survival=~1
006	capture=~precip nesting,	survival=~1
007	capture=~fl.per.pair,	survival=~1
008	capture=~eo,	survival=~1
009	capture=~precip nesting+eo,	survival=~1
010	capture=~sex+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~1
011	capture=~sex+lin.T,	survival=~1
012	capture=~sex+lin.T+sex.by.linT,	survival=~1
013	capture=~sex+lin.T+lin.TT+sex.by.linT+sex.by.linTT,	survival=~1
014	capture=~sex+ln.T,	survival=~1
015	capture=~sex+ln.T+sex.by.lnT,	survival=~1
016	capture=~sex+precip nesting,	survival=~1
017	capture=~sex+fl.per.pair,	survival=~1
018	capture=~sex+eo,	survival=~1
019	capture=~sex+precip nesting+eo,	survival=~1
020	capture=~sex+fl.per.pair+sex.by.fl.per.pair,	survival=~1
021	capture=~age.s2,	survival=~1
022	capture=~age.s2+sex,	survival=~1
023	capture=~age.s2+lin.T,	survival=~1
024	capture=~age.s2+lin.T+ages2.by.linT,	survival=~1
025	capture=~age.s2+ln.T,	survival=~1
026	capture=~age.s2+ln.T+ages2.by.lnT,	survival=~1
027	capture=~age.s2+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~1
028	capture=~age.s2+precip nesting,	survival=~1
029	capture=~age.s2+fl.per.pair,	survival=~1
030	capture=~age.s2+eo,	survival=~1
031	capture=~age.s2+precip nesting+eo,	survival=~1
032	capture=~age.s2+sex+fl.per.pair+sex.by.fl.per.pair,	survival=~1
033	capture=~1,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
034	capture=~t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
035	capture=~lin.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
036	capture=~ln.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
037	capture=~sex,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
038	capture=~precip nesting,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
039	capture=~fl.per.pair,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
040	capture=~eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
041	capture=~precip nesting+eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
042	capture=~sex+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
043	capture=~sex+lin.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
044	capture=~sex+lin.T+sex.by.linT,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
045	capture=~sex+lin.T+lin.TT+sex.by.linT+sex.by.linTT,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
046	capture=~sex+ln.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
047	capture=~sex+ln.T+sex.by.lnT,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
048	capture=~sex+precip nesting,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
049	capture=~sex+fl.per.pair,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
050	capture=~sex+eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
051	capture=~sex+precip nesting+eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
052	capture=~sex+fl.per.pair+sex.by.fl.per.pair,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
053	capture=~age.s2,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
054	capture=~age.s2+sex,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12

055	capture=~age.s2+lin.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
056	capture=~age.s2+lin.T+ages2.by.linT,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
057	capture=~age.s2+ln.T,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
058	capture=~age.s2+ln.T+ages2.by.lnT,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
059	capture=~age.s2+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
060	capture=~age.s2+precip_nesting,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
061	capture=~age.s2+fl.per.pair,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
062	capture=~age.s2+eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
063	capture=~age.s2+precip_nesting+eo,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
064	capture=~age.s2+sex+fl.per.pair+sex.by.fl.per.pair,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12
065	capture=~1,	survival=~lin.T
066	capture=~t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~lin.T
067	capture=~lin.T,	survival=~lin.T
068	capture=~ln.T,	survival=~lin.T
069	capture=~sex,	survival=~lin.T
070	capture=~precip_nesting,	survival=~lin.T
071	capture=~fl.per.pair,	survival=~lin.T
072	capture=~eo,	survival=~lin.T
073	capture=~precip_nesting+eo,	survival=~lin.T
074	capture=~sex+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~lin.T
075	capture=~sex+lin.T,	survival=~lin.T
076	capture=~sex+lin.T+sex.by.linT,	survival=~lin.T
077	capture=~sex+lin.T+lin.TT+sex.by.linT+sex.by.linTT,	survival=~lin.T
078	capture=~sex+ln.T,	survival=~lin.T
079	capture=~sex+ln.T+sex.by.lnT,	survival=~lin.T
080	capture=~sex+precip_nesting,	survival=~lin.T
081	capture=~sex+fl.per.pair,	survival=~lin.T
082	capture=~sex+eo,	survival=~lin.T
083	capture=~sex+precip_nesting+eo,	survival=~lin.T
084	capture=~sex+fl.per.pair+sex.by.fl.per.pair,	survival=~lin.T
085	capture=~age.s2,	survival=~lin.T
086	capture=~age.s2+sex,	survival=~lin.T
087	capture=~age.s2+lin.T,	survival=~lin.T
088	capture=~age.s2+lin.T+ages2.by.linT,	survival=~lin.T
089	capture=~age.s2+ln.T,	survival=~lin.T
090	capture=~age.s2+ln.T+ages2.by.lnT,	survival=~lin.T
091	capture=~age.s2+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=~lin.T
092	capture=~age.s2+precip_nesting,	survival=~lin.T
093	capture=~age.s2+fl.per.pair,	survival=~lin.T
094	capture=~age.s2+eo,	survival=~lin.T
095	capture=~age.s2+precip_nesting+eo,	survival=~lin.T
096	capture=~age.s2+sex+fl.per.pair+sex.by.fl.per.pair,	survival=~lin.T
097	capture=best.capmodel,	survival=~precip.a+temp.a
098	capture=best.capmodel,	survival=~precip_nesting+temp_nesting
099	capture=best.capmodel,	survival=~precip.a+precip_nesting
100	capture=best.capmodel,	survival=~precip.a+temp.a+precip_nesting+temp_nesting
101	capture=best.capmodel,	survival=~ln.precip.a+temp.a
102	capture=best.capmodel,	survival=~ln.precip_nesting+temp_nesting
103	capture=best.capmodel,	survival=~ln.precip.a+ln.precip_nesting
104	capture=best.capmodel,	survival=~ln.precip.a+temp.a+ln.precip_nesting+temp_nesting
105	capture=best.capmodel,	survival=~ac600.1
106	capture=best.capmodel,	survival=~ac600.2
107	capture=best.capmodel,	survival=~ac600.3
108	capture=best.capmodel,	survival=~ac600.4
109	capture=best.capmodel,	survival=~ac600.5
110	capture=best.capmodel,	survival=~ac600.6
111	capture=best.capmodel,	survival=~ac600.7
112	capture=best.capmodel,	survival=~ac600.2+ac600.4
113	capture=best.capmodel,	survival=~ac600.2+ac600.5

114	capture=best.capmodel,	survival=~ac600.2+ac600.6
115	capture=best.capmodel,	survival=~ac600.3+ac600.4
116	capture=best.capmodel,	survival=~ac600.3+ac600.5
117	capture=best.capmodel,	survival=~ac600.3+ac600.6
118	capture=best.capmodel,	survival=~ac600.1+ac600.2+ac600.4
119	capture=best.capmodel,	survival=~ac600.1+ac600.2+ac600.5
120	capture=best.capmodel,	survival=~ac600.1+ac600.2+ac600.6
121	capture=best.capmodel,	survival=~ac600.1+ac600.3+ac600.4
122	capture=best.capmodel,	survival=~ac600.1+ac600.3+ac600.5
123	capture=best.capmodel,	survival=~ac600.1+ac600.3+ac600.6
124	capture=best.capmodel,	survival=~%_0-5yrs_921m
125	capture=best.capmodel,	survival=~ac921.2
126	capture=best.capmodel,	survival=~ac921.3
127	capture=best.capmodel,	survival=~ac921.4
128	capture=best.capmodel,	survival=~ac921.5
129	capture=best.capmodel,	survival=~ac921.6
130	capture=best.capmodel,	survival=~ac921.7
131	capture=best.capmodel,	survival=~ac921.2+ac921.4
132	capture=best.capmodel,	survival=~ac921.2+ac921.5
133	capture=best.capmodel,	survival=~ac921.2+ac921.6
134	capture=best.capmodel,	survival=~ac921.3+ac921.4
135	capture=best.capmodel,	survival=~ac921.3+ac921.5
136	capture=best.capmodel,	survival=~ac921.3+ac921.6
137	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.2+ac921.4
138	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.2+ac921.5
139	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.2+ac921.6
140	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.3+ac921.4
141	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.3+ac921.5
142	capture=best.capmodel,	survival=~%_0-5yrs_921m+ac921.3+ac921.6
143	capture=best.capmodel,	survival=~ann.ac2+ac600.4
144	capture=best.capmodel,	survival=~ann.ac2+ac600.5
145	capture=best.capmodel,	survival=~ann.ac2+ac600.6
146	capture=best.capmodel,	survival=~ann.ac3+ac600.4
147	capture=best.capmodel,	survival=~ann.ac3+ac600.5
148	capture=best.capmodel,	survival=~ann.ac3+ac600.6
149	capture=best.capmodel,	survival=~ann.ac1+ann.ac2+ac600.4
150	capture=best.capmodel,	survival=~ann.ac1+ann.ac2+ac600.5
151	capture=best.capmodel,	survival=~ann.ac1+ann.ac2+ac600.6
152	capture=best.capmodel,	survival=~ann.ac1+ann.ac3+ac600.4
153	capture=best.capmodel,	survival=~ann.ac1+ann.ac3+ac600.5
154	capture=best.capmodel,	survival=~ann.ac1+ann.ac3+ac600.6
155	capture=best.capmodel,	survival=~nta.hsi.centered
156	capture=best.capmodel,	survival=~Nest_HSI
157	capture=best.capmodel,	survival=~ln.nta.hsi
158	capture=best.capmodel,	survival=~ln_nest_HSI
159	capture=best.capmodel,	survival=~opn.ed
160	capture=best.capmodel,	survival=~ln.opn.ed
161	capture=best.capmodel,	survival=paste(best.weather.1,best.ac.1)
162	capture=best.capmodel,	survival=paste(best.weather.1,best.ac.2)
163	capture=best.capmodel,	survival=paste(best.weather.1,best.ac.3)
164	capture=best.capmodel,	survival=paste(best.weather.1,best.ac.4)
165	capture=best.capmodel,	survival=paste(best.weather.1,best.ac.5)
166	capture=best.capmodel,	survival=paste(best.weather.1,"+nta.hsi.centered")
167	capture=best.capmodel,	survival=paste(best.weather.1,"+Nest_HSI")
168	capture=best.capmodel,	survival=paste(best.weather.1,"+ln.nta.hsi")
169	capture=best.capmodel,	survival=paste(best.weather.1,"ln_nest_HSI")
170	capture=best.capmodel,	survival=paste(best.weather.1,"+opn.ed")
171	capture=best.capmodel,	survival=paste(best.weather.1,"+ln.opn.ed")
172	capture=best.capmodel,	survival=mod1

173	capture=best.capmodel,	survival=mod2
174	capture=best.capmodel,	survival=mod3
175	capture=best.capmodel,	survival=mod4
176	capture=best.capmodel,	survival=mod5
177	capture=best.capmodel,	survival=mod11
178	capture=best.capmodel,	survival=mod12
179	capture=best.capmodel,	survival=mod13
180	capture=best.capmodel,	survival=mod14
181	capture=best.capmodel,	survival=mod15
182	capture=best.capmodel,	survival=mod16
183	capture=best.capmodel,	survival=paste(best.weather.2,best.ac.1)
184	capture=best.capmodel,	survival=paste(best.weather.2,best.ac.2)
185	capture=best.capmodel,	survival=paste(best.weather.2,best.ac.3)
186	capture=best.capmodel,	survival=paste(best.weather.2,best.ac.4)
187	capture=best.capmodel,	survival=paste(best.weather.2,best.ac.5)
188	capture=best.capmodel,	survival=paste(best.weather.2,"+nta.hsi.centered")
189	capture=best.capmodel,	survival=paste(best.weather.2,"+Nest_HSI")
190	capture=best.capmodel,	survival=paste(best.weather.2,"+ln.nta.hsi")
191	capture=best.capmodel,	survival=paste(best.weather.2,"ln_nest_HSI")
192	capture=best.capmodel,	survival=paste(best.weather.2,"+opn.ed")
193	capture=best.capmodel,	survival=paste(best.weather.2,"+ln.opn.ed")
194	capture=best.capmodel,	survival=mod6
195	capture=best.capmodel,	survival=mod7
196	capture=best.capmodel,	survival=mod8
197	capture=best.capmodel,	survival=mod9
198	capture=best.capmodel,	survival=mod10
199	capture=best.capmodel,	survival=mod17
200	capture=best.capmodel,	survival=mod18
201	capture=best.capmodel,	survival=mod19
202	capture=best.capmodel,	survival=mod20
203	capture=best.capmodel,	survival=mod21
204	capture=best.capmodel,	survival=mod22
205	capture=best.capmodel,	survival=~ln.T
206	capture=best.capmodel,	survival=~sex
207	capture=best.capmodel,	survival=~age.s1+age.s2
208	capture=best.capmodel,	survival=~age.s1
209	capture=best.capmodel,	survival=~set_aside_out +set_aside_near
210	capture=best.capmodel,	survival=~take
211	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+lin.T
212	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+ln.T
213	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+sex
214	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+age.s1+age.s2
215	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+age.s1
216	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+set aside out
217	capture=best.capmodel,	survival=~t1+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+take
218	capture=best.capmodel,	survival=~lin.T+sex
219	capture=best.capmodel,	survival=~lin.T+age.s1+age.s2
220	capture=best.capmodel,	survival=~lin.T+age.s1
221	capture=best.capmodel,	survival=~lin.T+set_aside_out +set_aside_near
222	capture=best.capmodel,	survival=~lin.T+take
223	capture=best.capmodel,	survival=~ln.T+sex
224	capture=best.capmodel,	survival=~ln.T+age.s1+age.s2
225	capture=best.capmodel,	survival=~ln.T+age.s1
226	capture=best.capmodel,	survival=~ln.T+set_aside_out +set_aside_near
227	capture=best.capmodel,	survival=~ln.T+take
228	capture=best.capmodel,	survival=~sex+age.s1+age.s2
229	capture=best.capmodel,	survival=~sex+age.s1
230	capture=best.capmodel,	survival=~sex+set_aside_out +set_aside_near
231	capture=best.capmodel,	survival=~sex+take

232	capture=best.capmodel,	survival=~age.s1+age.s2+set_aside_out +set_aside_near
233	capture=best.capmodel,	survival=~age.s1+age.s2+take
234	capture=best.capmodel,	survival=~age.s1+set_aside_out +set_aside_near
235	capture=best.capmodel,	survival=~age.s1+take
236	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2
237	capture=best.capmodel,	survival=~lin.T+sex+age.s1
238	capture=best.capmodel,	survival=~lin.T+sex+set_aside_out +set_aside_near
239	capture=best.capmodel,	survival=~lin.T+sex+take
240	capture=best.capmodel,	survival=~lin.T+age.s1+age.s2+set_aside_out +set_aside_near
241	capture=best.capmodel,	survival=~lin.T+age.s1+age.s2+take
242	capture=best.capmodel,	survival=~lin.T+age.s1+set_aside_out +set_aside_near
243	capture=best.capmodel,	survival=~lin.T+age.s1+age.s2+take
244	capture=best.capmodel,	survival=~lin.T+set_aside_out +set_aside_near +take
245	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2
246	capture=best.capmodel,	survival=~ln.T+sex+age.s1
247	capture=best.capmodel,	survival=~ln.T+sex+set_aside_out +set_aside_near
248	capture=best.capmodel,	survival=~ln.T+sex+take
249	capture=best.capmodel,	survival=~ln.T+age.s1+age.s2+set_aside_out +set_aside_near
250	capture=best.capmodel,	survival=~ln.T+age.s1+age.s2+take
251	capture=best.capmodel,	survival=~ln.T+age.s1+set_aside_out +set_aside_near
252	capture=best.capmodel,	survival=~ln.T+age.s1+age.s2+take
253	capture=best.capmodel,	survival=~ln.T+set_aside_out +set_aside_near +take
254	capture=best.capmodel,	survival=~sex+age.s1+age.s2+set_aside_out +set_aside_near
255	capture=best.capmodel,	survival=~sex+age.s1+age.s2+take
256	capture=best.capmodel,	survival=~sex+age.s1+set_aside_out +set_aside_near
257	capture=best.capmodel,	survival=~sex+age.s1+take
258	capture=best.capmodel,	survival=~sex+set_aside_out +set_aside_near +take
259	capture=best.capmodel,	survival=~age.s1+age.s2+set_aside_out +set_aside_near +take
260	capture=best.capmodel,	survival=~age.s1+set_aside_out +set_aside_near +take
261	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2+set_aside_out +set_aside_near
262	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2+take
263	capture=best.capmodel,	survival=~lin.T+sex+age.s1+set_aside_out +set_aside_near
264	capture=best.capmodel,	survival=~lin.T+sex+age.s1+take
265	capture=best.capmodel,	survival=~lin.T+age.s1+age.s2+set_aside_out +set_aside_near +take
266	capture=best.capmodel,	survival=~lin.T+age.s1+set_aside_out +set_aside_near +take
267	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2+set_aside_out +set_aside_near
268	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2+take
269	capture=best.capmodel,	survival=~ln.T+sex+age.s1+set_aside_out +set_aside_near
270	capture=best.capmodel,	survival=~ln.T+sex+age.s1+take
271	capture=best.capmodel,	survival=~ln.T+age.s1+age.s2+set_aside_out +set_aside_near +take
272	capture=best.capmodel,	survival=~ln.T+age.s1+set_aside_out +set_aside_near +take
273	capture=best.capmodel,	survival=~sex+age.s1+age.s2+set_aside_out +set_aside_near +take
274	capture=best.capmodel,	survival=~sex+age.s1+set_aside_out +set_aside_near +take
275	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2+set_aside_out +set_aside_near +take
276	capture=best.capmodel,	survival=~lin.T+sex+age.s1+set_aside_out +set_aside_near +take
277	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2+set_aside_out +set_aside_near +take
278	capture=best.capmodel,	survival=~ln.T+sex+age.s1+set_aside_out +set_aside_near +take
279	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2+sex.by.linT
280	capture=best.capmodel,	survival=~lin.T+sex+age.s1+age.s2+ages1.by.linT+ages2.by.linT
281	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2+sex.by.lnT
282	capture=best.capmodel,	survival=~ln.T+sex+age.s1+age.s2+ages1.by.lnT+ages2.by.lnT
283	capture=best.capmodel,	survival=~set_aside_out +set_aside_near
284	capture=best.capmodel,	survival=~lin.T+set_aside_out +set_aside_near
285	capture=best.capmodel,	survival=~ln.T+set_aside_out +set_aside_near
286	capture=best.capmodel,	survival=paste(best.weatherhab.1,best.nbrainer.1)
287	capture=best.capmodel,	survival=paste(best.weatherhab.1,best.nbrainer.2)
288	capture=best.capmodel,	survival=paste(best.weatherhab.1,best.nbrainer.3)
289	capture=best.capmodel,	survival=paste(best.weatherhab.1,best.nbrainer.4)
290	capture=best.capmodel,	survival=paste(best.weatherhab.1,best.nbrainer.5)

291	capture=best.capmodel,	survival=paste(best.weatherhab.2,best.nbrainer.1)
292	capture=best.capmodel,	survival=paste(best.weatherhab.2,best.nbrainer.2)
293	capture=best.capmodel,	survival=paste(best.weatherhab.2,best.nbrainer.3)
294	capture=best.capmodel,	survival=paste(best.weatherhab.2,best.nbrainer.4)
295	capture=best.capmodel,	survival=paste(best.weatherhab.2,best.nbrainer.5)
296	capture=best.capmodel,	survival=paste(best.weatherhab.3,best.nbrainer.1)
297	capture=best.capmodel,	survival=paste(best.weatherhab.3,best.nbrainer.2)
298	capture=best.capmodel,	survival=paste(best.weatherhab.3,best.nbrainer.3)
299	capture=best.capmodel,	survival=paste(best.weatherhab.3,best.nbrainer.4)
300	capture=best.capmodel,	survival=paste(best.weatherhab.3,best.nbrainer.5)
301	capture=best.capmodel,	survival=paste(best.weatherhab.4,best.nbrainer.1)
302	capture=best.capmodel,	survival=paste(best.weatherhab.4,best.nbrainer.2)
303	capture=best.capmodel,	survival=paste(best.weatherhab.4,best.nbrainer.3)
304	capture=best.capmodel,	survival=paste(best.weatherhab.4,best.nbrainer.4)
305	capture=best.capmodel,	survival=paste(best.weatherhab.4,best.nbrainer.5)
306	capture=best.capmodel,	survival=paste(best.weatherhab.5,best.nbrainer.1)
307	capture=best.capmodel,	survival=paste(best.weatherhab.5,best.nbrainer.2)
308	capture=best.capmodel,	survival=paste(best.weatherhab.5,best.nbrainer.3)
309	capture=best.capmodel,	survival=paste(best.weatherhab.5,best.nbrainer.4)
310	capture=best.capmodel,	survival=paste(best.weatherhab.5,best.nbrainer.5)
311	capture=~1,	survival=best.survmod.1
312	capture=~t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.1
313	capture=~lin.T,	survival=best.survmod.1
314	capture=~ln.T,	survival=best.survmod.1
315	capture=~sex,	survival=best.survmod.1
316	capture=~precip_nesting,	survival=best.survmod.1
317	capture=~fl.per.pair,	survival=best.survmod.1
318	capture=~eo,	survival=best.survmod.1
319	capture=~precip_nesting+eo,	survival=best.survmod.1
320	capture=~sex+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.1
321	capture=~sex+lin.T,	survival=best.survmod.1
322	capture=~sex+lin.T+sex.by.linT,	survival=best.survmod.1
323	capture=~sex+lin.T+lin.TT+sex.by.linT+sex.by.linTT,	survival=best.survmod.1
324	capture=~sex+ln.T,	survival=best.survmod.1
325	capture=~sex+ln.T+sex.by.lnT,	survival=best.survmod.1
326	capture=~sex+precip_nesting,	survival=best.survmod.1
327	capture=~sex+fl.per.pair,	survival=best.survmod.1
328	capture=~sex+eo,	survival=best.survmod.1
329	capture=~sex+precip_nesting+eo,	survival=best.survmod.1
330	capture=~sex+fl.per.pair+sex.by.fl.per.pair,	survival=best.survmod.1
331	capture=~age.s2,	survival=best.survmod.1
332	capture=~age.s2+sex,	survival=best.survmod.1
333	capture=~age.s2+lin.T,	survival=best.survmod.1
334	capture=~age.s2+lin.T+ages2.by.linT,	survival=best.survmod.1
335	capture=~age.s2+ln.T,	survival=best.survmod.1
336	capture=~age.s2+ln.T+ages2.by.lnT,	survival=best.survmod.1
337	capture=~age.s2+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.1
338	capture=~age.s2+precip_nesting,	survival=best.survmod.1
339	capture=~age.s2+fl.per.pair,	survival=best.survmod.1
340	capture=~age.s2+eo,	survival=best.survmod.1
341	capture=~age.s2+precip_nesting+eo,	survival=best.survmod.1
342	capture=~age.s2+sex+fl.per.pair+sex.by.fl.per.pair,	survival=best.survmod.1
343	capture=~1,	survival=best.survmod.2
344	capture=~t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.2
345	capture=~lin.T,	survival=best.survmod.2
346	capture=~ln.T,	survival=best.survmod.2
347	capture=~sex,	survival=best.survmod.2

348	capture=~precip_nesting,	survival=best.survmod.2
349	capture=~fl.per.pair,	survival=best.survmod.2
350	capture=~eo,	survival=best.survmod.2
351	capture=~precip_nesting+eo,	survival=best.survmod.2
352	capture=~sex+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.2
353	capture=~sex+lin.T,	survival=best.survmod.2
354	capture=~sex+lin.T+sex.by.linT,	survival=best.survmod.2
355	capture=~sex+lin.T+lin.TT+sex.by.linT+sex.by.linTT,	survival=best.survmod.2
356	capture=~sex+ln.T,	survival=best.survmod.2
357	capture=~sex+ln.T+sex.by.lnT,	survival=best.survmod.2
358	capture=~sex+precip_nesting,	survival=best.survmod.2
359	capture=~sex+fl.per.pair,	survival=best.survmod.2
360	capture=~sex+eo,	survival=best.survmod.2
361	capture=~sex+precip_nesting+eo,	survival=best.survmod.2
362	capture=~sex+fl.per.pair+sex.by.fl.per.pair,	survival=best.survmod.2
363	capture=~age.s2,	survival=best.survmod.2
364	capture=~age.s2+sex,	survival=best.survmod.2
365	capture=~age.s2+lin.T,	survival=best.survmod.2
366	capture=~age.s2+lin.T+ages2.by.linT,	survival=best.survmod.2
367	capture=~age.s2+ln.T,	survival=best.survmod.2
368	capture=~age.s2+ln.T+ages2.by.lnT,	survival=best.survmod.2
369	capture=~age.s2+t2+t3+t4+t5+t6+t7+t8+t9+t10+t11+t12+t13,	survival=best.survmod.2
370	capture=~age.s2+precip_nesting,	survival=best.survmod.2
371	capture=~age.s2+fl.per.pair,	survival=best.survmod.2
372	capture=~age.s2+eo,	survival=best.survmod.2
373	capture=~age.s2+precip_nesting+eo,	survival=best.survmod.2
374	capture=~age.s2+sex+fl.per.pair+sex.by.fl.per.pair,	survival=best.survmod.2

Table 4.6. Top 20 capture-resight models fit to Green Diamond Resource Company Northern Spotted Owl data for estimating survival. See Table 4.4 for definitions of variables. Models numbers are from Table 4.5 and are ordered by QAICc.

Model No.	Capture Model	Survival Model	QAICc	df	ΔQAIC
291	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1584.194	7	0.000
286	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1584.229	7	0.034
292	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ age_S1+ set_aside_out + set_aside_near	1584.586	8	0.292
287	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ age_S1+ set_aside_out + set_aside_near	1584.619	8	0.325
169	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI	1584.587	5	0.554
316	(Intercept)+precip_nesting	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1584.911	8	0.617
348	(Intercept)+precip_nesting	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1584.980	8	0.685
331	(Intercept)+age.s2	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1585.048	8	0.753
363	(Intercept)+age.s2	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1585.070	8	0.776
167	ones	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI	1584.883	5	0.850
313	(Intercept)+lin.T	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1585.267	8	0.972
345	(Intercept)+lin.T	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1585.299	8	1.004
338	(Intercept)+age.s2+precip_nesting	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1585.765	9	1.357
370	(Intercept)+age.s2+precip_nesting	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1585.822	9	1.414
366	(Intercept)+age.s2+lin.T+ages2.by.linT	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1586.083	10	1.549
315	(Intercept)+sex	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1585.849	8	1.555
334	(Intercept)+age.s2+lin.T+ages2.by.linT	(Intercept) + ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1586.103	10	1.570
347	(Intercept)+sex	(Intercept) + ln_precip_nesting+ temp_nesting+ ln_nest_HSI+ set_aside_out + set_aside_near	1585.890	8	1.596
303	ones	(Intercept) + precip.a + temp.a + precip_nesting + temp_nesting+ nest_HSI+ ln.T + set_aside_out + set_aside_near	1586.147	10	1.613
314	(Intercept)+ln.T	(Intercept)+ln_precip_nesting+ temp_nesting+ nest_HSI+ set_aside_out + set_aside_near	1585.917	8	1.623

Table 4.7. Parameter estimates from the top capture-resight model fit to Green Diamond Resource Company Northern Spotted Owl data for estimating survival. See Table 4.4 for definitions of variables.

Model	Effect	Estimate	SE	95% Confidence Interval
Capture	(Intercept)	1.52929	0.09917	(1.335,1.724)
Survival	(Intercept)	1.54916	1.50402	(-1.399,4.497)
	Log_precip_nesting	-0.4305	0.4475	(-1.308,0.447)
	Temp_nesting	0.00685	0.00292	(0.001,0.013)
	Nest_HSI	0.21848	0.11648	(-0.01,0.447)
	Set_aside_out	-0.2072	0.20482	(-0.609,0.194)
	Set_aside_near	0.30734	0.28722	(-0.256,0.87)

Table 4.8. Variables considered in mixed linear model analysis of fecundity for Northern Spotted Owls on Green Diamond Resource Company land.

Variable	Description	Ln Value[1]
Fecundity	Response variable = number of female young fledged	N
Year	Year observed.	N
Yr	Year – 1989. Used in coding covariance structure.	N
T	Linear time, parameterized as -6, -5, …, 5, 6, 7	N
TT	Quadratic time, parameterized as 36, 25, …, 25, 36, 49	N
EO	Indicator for even numbered years. Odd years were the reference level.	N
Age	Age class of female. S1 = 1 year old (reference level), S2 = 2 years old, Adult ≥3 years old.	N
NTA_HSI	Average nighttime activity Habitat Suitability Index within 600 m radius buffer using 400 m grid of locations.	Y
Nest_HSI	Average nesting Habitat Suitability Index within 600 m radius buffer using 400 m grid of locations.	Y
Open_edge_density	Average open edge density within 600 m radius buffer using 400 m grid of locations. Open defined as non-forest or forest < 6 years old.	Y
Take	Categorical variable (0,1). No take (0) was reference level.	N
%_0-5yrs_600m	% age class 0-5 years old in a 600 m buffer	Y
%_6-20yrs_600m	% age class 6-20 years old in a 600 m buffer	Y
%_21-40yrs_600m	% age class 21-40 years old in a 600 m buffer	Y
%_41-60yrs_600m	% age class 41-60 years old in a 600 m buffer	Y
%_61-80yrs_600m	% age class 61-80 years old in a 600 m buffer	Y
%_80+yrs_600m	% age class 80+ years old in a 600 m buffer	Y
%_NF_600m	% non-forest in a 600 m buffer	Y
%_0-5yrs_921m	% age class 0-5 years old in a 921 m buffer	Y
%_6-20yrs_921m	% age class 6-20 years old in a 921 m buffer	Y
%_21-40yrs_921m	% age class 21-40 years old in a 921 m buffer	Y
%_41-60yrs_921m	% age class 41-60 years old in a 921 m buffer	Y
%_61-80yrs_921m	% age class 61-80 years old in a 921 m buffer	Y
%_80+yrs_921m	% age class 80+ years old in a 921 m buffer	Y
%_NF_921m	% non-forest in a 921 m buffer	Y
%_6-20yrs_ann	% age class 6-20 years old in a 600-921m annulus	Y
%_21-40yrs_ann	% age class 21-40 years old in a 600-921m annulus	Y
Set_aside	Categorical variable: *set_aside_out* (not near set-aside; reference level); *set_aside_in* (within set-aside); *set_aside_near* (within 0.8 km buffer of set-aside).	N
Temp_winter	Heating degree days during winter: Integral under daily temperature graph, measured at associated weather station during winter season (Nov-Feb)	N
Temp_nesting_early	Heating degree days during early nesting: Integral under daily temperature graph, measured at associated weather station during early nesting season (Mar – Apr)	N
Temp_nesting_late	Heating degree days during early nesting: Integral under daily temperature graph, measured at associated weather station during late nesting period (May)	N
Precip_winter	Number of days with measurable precipitation (>0.03 cm) during winter stress period (Nov – Feb)	Y
Precip_nesting_early	Number of days with measurable precipitation (>0.03 cm) during early nesting period (Mar – Apr)	Y
Precip_nesting_late	Number of days with measurable precipitation (>0.03 cm) during late nesting period (May)	Y

[1] Natural lnarithm transformation calculated as *ln* [value + 0.01]

Table 4.9. Variables, model rank based on AICc, and AICc weights for 5 of 26 models containing 90% AICc weight among all fitted models of fecundity of Northern Spotted Owls. Values in the table were estimated coefficients.

	Model 1	Model 2	Model 3	Model 4	Model 5
	AICc wt =	AICc wt =	AICc wt =	AICc wt =	AICc wt =
Variable	0.0968	0.0966	0.0786	0.0723)	0.0457
Intercept (set_aside_out)	0.3422	-0.0664	0.04413	0.6014	-0.045
Set_aside_in	-0.0194	-0.0201	-0.0216	-0.0206	-0.0154
Set_aside_near	0.1193	0.1184	0.1174	0.1185	0.1185
EO (even/odd year)	0.0748	0.07319	-	-	0.07432
S2_female	0.1715	0.1728	0.1729	0.1713	0.1631
Adult_female	0.3184	0.3197	0.32	0.3184	0.3048
Take	-0.087	-0.0869	-0.0876	-0.088	-
Ln of %_41-60yrs_600m	0.00742	0.00743	0.0072	0.00718	0.00814
Ln of. %_21-40yrs_ann	0.01967	0.01984	0.0203	0.02007	0.02026
NTA_HSI	3.10E-05	3.10E-05	2.90E-05	2.90E-05	3.10E-05
Open_edge_density	0.00274	0.00276	0.00271	0.00269	0.00229
Precip_nesting_early	-	-0.0064	-0.0087	-	-0.0069
Ln of precip_nesting_early	-0.1777	-	-	-0.242	-

[1]AICc weights constructed using only the models reported in this table (thus, sum of weights = 1)

Table 4.10. Measured and latent variables used in the sensitivity analysis. Notes column contains information on what was considered the typical value or typical location during the sensitivity analysis, and whether typical values for additional variables were also changed when estimating the sensitivity of λ.

Variable Type	Variable	Model	Notes
Categorical	age class of nearest stand	NTA RSF	Typical location had nearest stand = age class 1
	EO (even-odd yr effect)	Fecundity	Average of Even-Odd year effect was typical value
	take	Fecundity	No take was typical value
	age of female	Fecundity	Sensitivity not computed for age of female; Adult was typical value
	2nd Growth	Nest RSF	Medians of all variables in the Nest RSF changed; Inside 2nd Growth was considered typical location.
	Set Aside	Fecundity, Survival	Medians of all variables in Fecundity and Survival models changed; Typical location was > 1/2 mile from SA.
Continuous	% age class 41+ yrs	NTA RSF	Median and SD from NTA RSF input
	% hardwood	NTA RSF, Nest RSF	Median and SD from NTA RSF input
	slope position	NTA RSF	Median and SD from NTA RSF input
	age of stand	Nest RSF	Median and SD from Nest RSF input where 2nd Growth = 1
	open edge density	Nest RSF, Fecundity	Median and SD from Nest RSF input where 2nd Growth = 1
	% residual	Nest RSF	Median and SD from Nest RSF input where 2nd Growth = 1
	% age class 41 to 60 yrs	Fecundity	Median and SD from Fecundity input where SA = 0 (in matrix)
	% age class 21 to 40 yrs in annulus	Fecundity	Median and SD from Fecundity input where SA = 0 (in matrix)
	precipitation during early nesting	Fecundity, Survival	Median and SD measured from 3 weather stations 1990-2003
	temperature during early nesting		Median and SD measured from 3 weather stations 1990-2003
Latent	NTA_HSI	Nest RSF, Fecundity	Median and SD measured on common areas in OMUs in 1992
	nest_HSI	Survival	Median and SD measured on common areas in OMUs in 1992
	fecundity	Site Fitness	Median and SD measured on common areas in OMUs in 1992
	survival	Site Fitness	Median and SD measured on common areas in OMUs in 1992

Table 4.11. Sensitivity values of λ_H computed for measured categorical variables. "Sensitivity" was change in λ associated with changing a class of the categorical variable. For sensitivity of λ_H to 2nd Growth and Set-aside, typical values of the other variables were set to their respective medians in the area in order to better represent realistic changes in habitat.

Change in Habitat Type	Sensitivity of lambda x 10,000
Set-aside: Outside 1/2-mile buffer to within 1/2-mile buffer	450.69
2nd Growth to "other"	306.40
Age class of nearest stand from 0-5 to 6-20 yrs	193.36
Age class of nearest stand from 6-20 to 21-40 yrs	9.62
Age class of nearest stand from 21-40 to 41+ yrs	-223.17
Even to Odd yr	-471.25
No-Take to Take	-565.88
Set-aside: Within 1/2-mile buffer to inside Set-aside	-1193.68

Table 4.12. Sensitivity values of λ_H computed for measured continuous variables. Sensitivity was change in λ_H associated with changing from median value to median + ½ Standard Deviation (change in typical value). Sensitivity is an estimate of the derivative (gradient) of the λ_H surface at median values.

Variable	Median	Change in Typical Value	Sensitivity of lambda x 10,000
Open edge density	10.00	11.41	16.94
% Age class 41 to 60 yrs	0.87	15.12	8.82
Temperature during early nesting	227.55	18.29	6.82
% Age class 41+ yrs	39.98	16.76	5.46
% Age class 21 to 40 yrs in annulus	23.03	14.95	4.00
% Hardwood	18.00	9.29	3.28
% Residual	0.00	6.33	1.04
Age of stand	28.00	9.95	0.47
Slope position	36.00	14.74	-5.70
Precipitation during early nesting	28.00	3.80	-52.68

Table 4.13. Sensitivity values of λ_H computed for latent variables. Sensitivity was change in λ associated with changing from median value to median + ½ x Standard Deviation (change in typical value). Sensitivity is an estimate of the derivative (gradient) of the λ_H surface at median values. Medians and standard deviations were calculated from all common areas of interest in 1992.

Variable	Median	Change in Typical Value	Sensitivity of lambda x 10,000
Survival	0.79	0.02	8167.61
Fecundity	0.25	0.05	6624.69
Nest_HSI	-0.77	0.32	67.14
NTA RSF	2015.63	603.83	0.20

Table 4.14. Area in ha of Green Diamond Resource Company land in each of five categories of habitat survival potential, 1992, 2002, 2012, and 2002. Classification break points (column 2) were defined to guarantee 20% ownership in each class during 1992. The same break points where applied to predicted values for subsequent years.

Survival		Total Area							
		1992		2002		2012		2022	
	Category	%	ha	%	ha	%	ha	%	ha
0.82 to 1.00	5 High	20	17100	25	21042	32	27337	37	32067
0.81 to 0.82	4	20	17100	19	15916	16	13350	11	9843
0.77 to 0.81	3 Med.	20	17100	17	14770	18	15566	27	23553
0.74 to 0.77	2	20	17097	20	17057	26	22370	22	18814
0.00 to 0.74	1 Low	20	17103	20	16949	8	7110	2	1456
	Total	100	85501	100	85733	100	85733	100	85733

Table 4.15. Area in ha of Green Diamond Resource Company land in each of five categories of fecundity potential, 1992, 2002, 2012, and 2002. Classification break points (column 2) were defined to guarantee 20% ownership in each class during 1992. The same break points where applied to predicted values for subsequent years.

Fecundity			Total Area							
			1992		2002		2012		2022	
	Category		%	ha	%	ha	%	ha	%	ha
0.33 to 0.71	5	High	20	17101	29	25054	41	34950	57	48583
0.27 to 0.33	4		20	17101	25	21135	34	29007	23	19815
0.23 to 0.27	3	Med.	20	17101	18	15218	14	11641	11	9119
0.19 to 0.23	2		20	17101	18	15509	8	7086	5	4538
0.00 to 0.19	1	Low	20	17100	10	8845	4	3077	4	3706
	Total		100	85504	100	85760	100	85760	100	85760

Table 4.16. Area in ha of Green Diamond Resource Company land in each of five categories of habitat fitness potential, 1992, 2002, 2012, and 2002. Classification break points (column 2) were defined to guarantee 20% ownership in each class during 1992. The same break points where applied to predicted values for subsequent years.

Lambda	Category		Total Area 1992 %	1992 ha	2002 %	2002 ha	2012 %	2012 ha	2022 %	2022 ha
1.06 to 1.62	5	High	20	17097	26	22281	35	29704	45	38824
0.98 to 1.06	4		20	17097	25	21484	30	25641	31	26379
0.94 to 0.98	3	Med.	20	17097	16	14089	17	14867	14	12112
0.88 to 0.94	2		20	17097	19	16010	14	11905	8	6691
0.70 to 0.88	1	Low	20	17096	14	11856	4	3603	2	1713
	Total		100	85484	100	85719	100	85719	100	85733

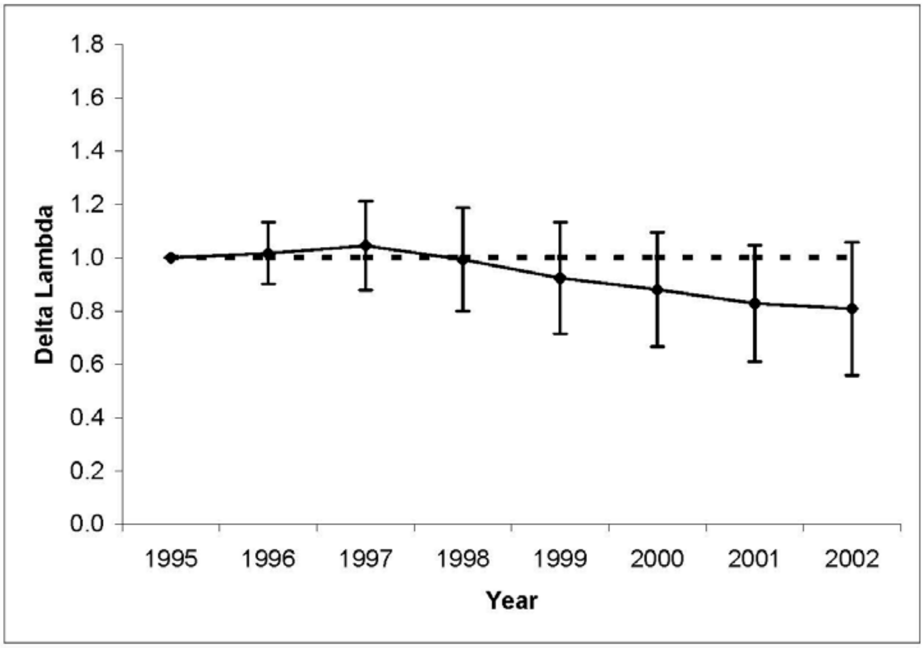


Figure 4.1. Estimated population change (with 95% confidence intervals) for Northern Spotted Owls on Green Diamond Resource Company land, 1995-2002.

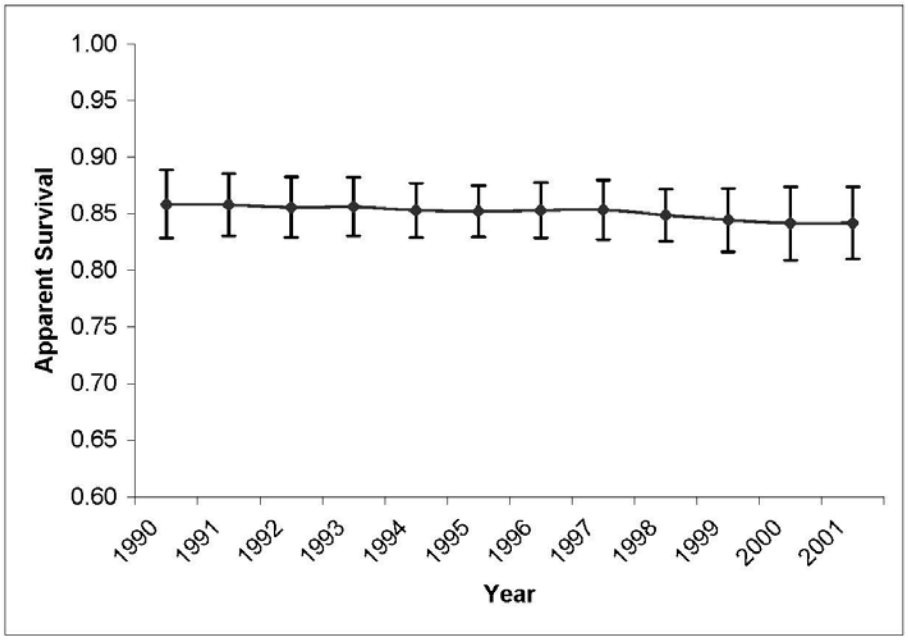


Figure 4.2. Estimated apparent survival probability for Northern Spotted Owls on Green Diamond Resource Company land, 1990-2002.

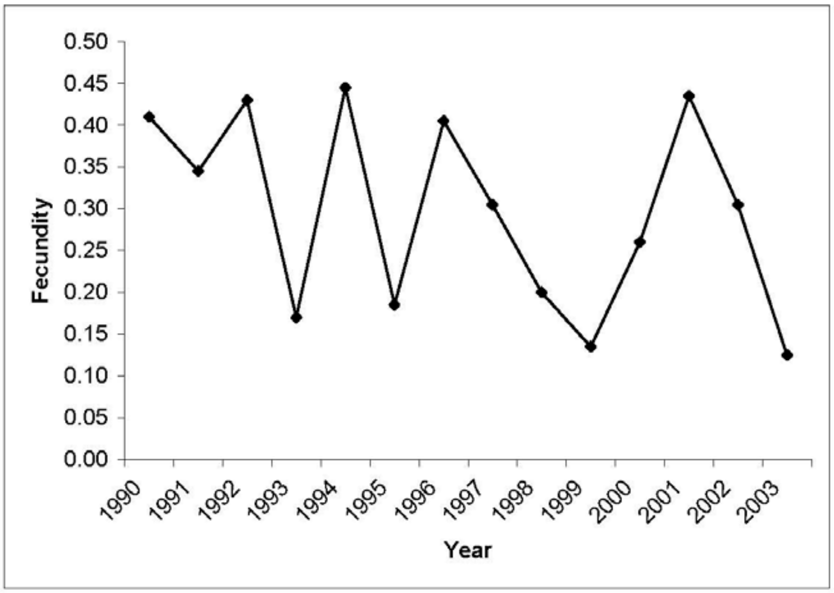


Figure 4.3. Estimated fecundity (with 95% confidence intervals) of Northern Spotted Owls on Green Diamond Resource Company land, 1990-2003.

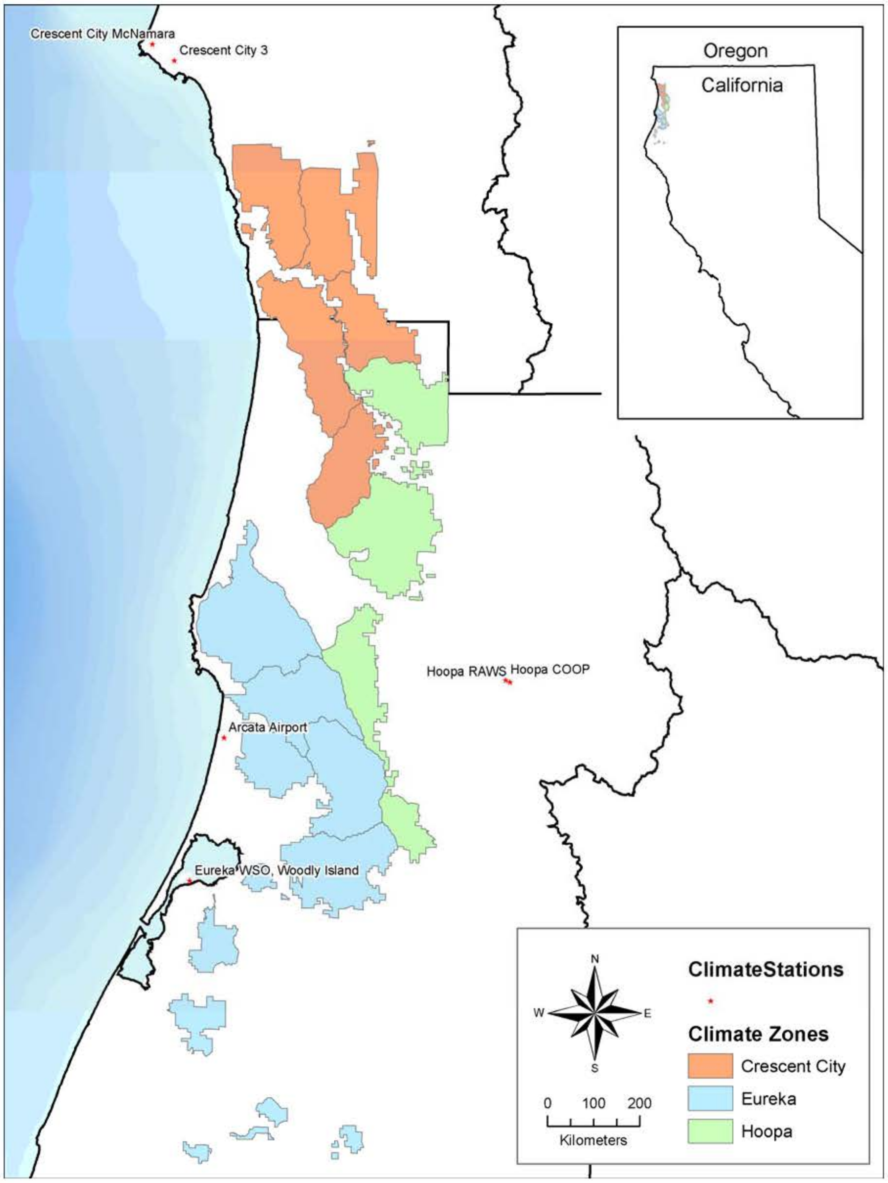


Figure 4.4. Climate stations from which temperature and precipitation variables were collected for incorporation into models of Northern Spotted Owls survival and fecundity on Green Diamond Resource Company land.

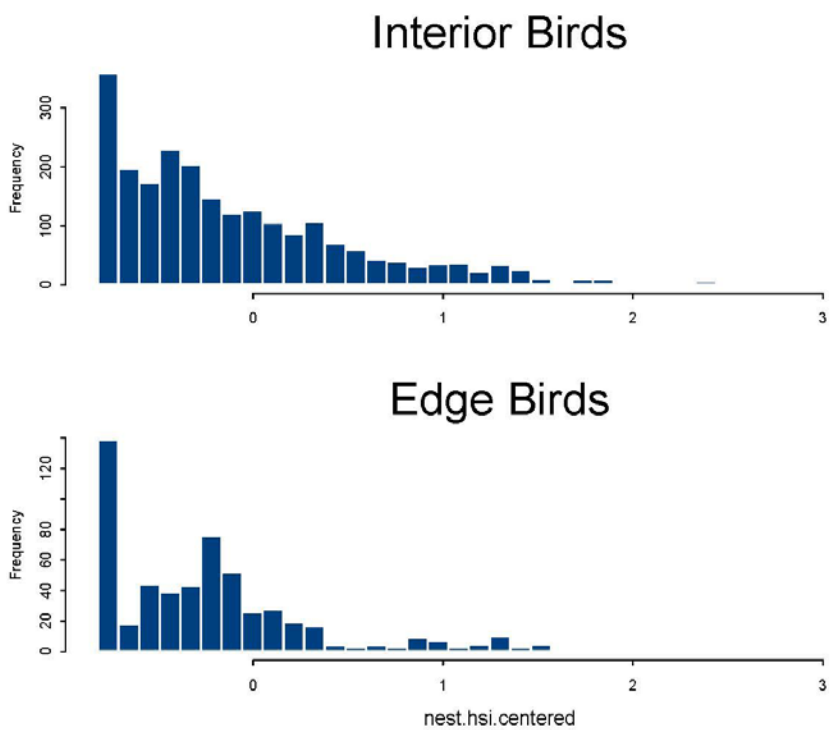


Figure 4.5. Nest habitat suitability index centered values for Northern Spotted Owls in the interior of the Green Diamond Resource Company study area (top) and near the edge of the study area (bottom).

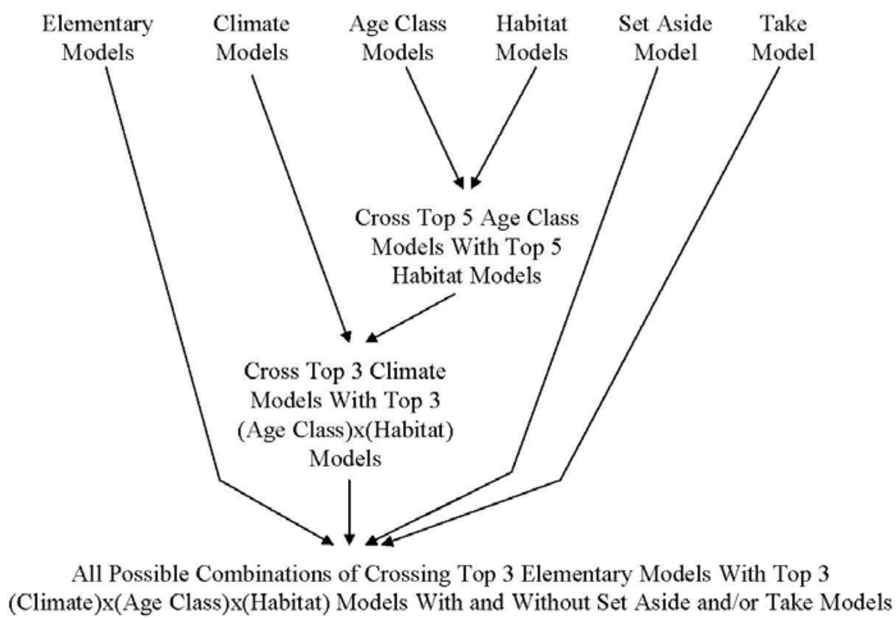


Figure 4.6. Flow-chart illustrating combinations of models were fit to estimate fecundity of Northern Spotted Owls on Green Diamond Resource Company land. See Table 4.9 for specific models in each group.

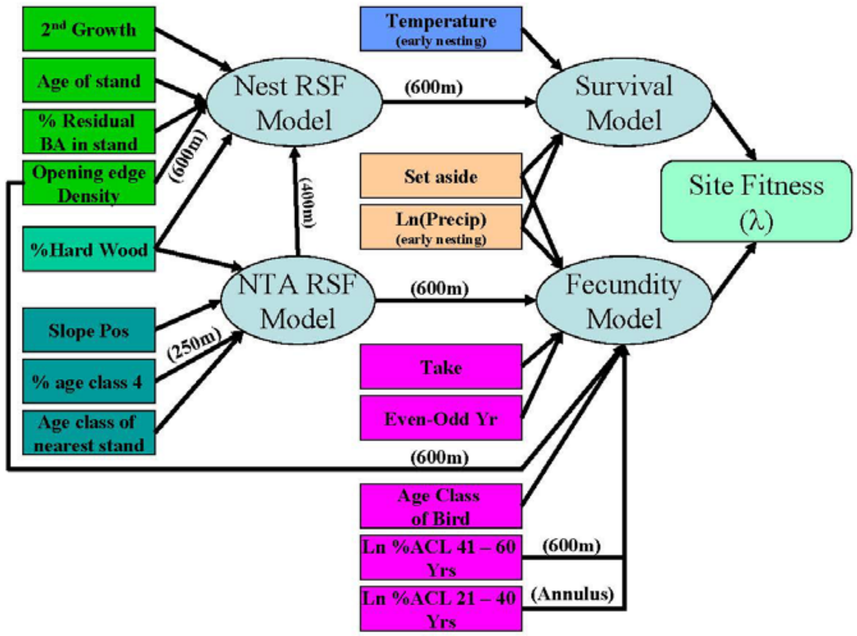


Figure 4.7. Schematic diagram of the site fitness model showing measured variables (rectangles) and latent variables (ovals). Size of the circular buffer upon which habitat variables were measured is shown along the arrow. Arrows without buffer sizes are for variables that were either measured at the point (e. g, slope position, set aside), measured in the stand containing the point (e.g., % hard wood, % residual BA), or are not habitat variables (e.g., temperature, even-odd year). The link function for the NTA RSF and Nest RSF models was exponential (i.e., rsf=exp(x′**β**)). Link function for survival was logistic (i.e., ϕ= exp(x′**β**) / (1+exp(x′**β**))). Link function for fecundity was the identity (i.e., b = x′**β**). The form of the equation for λ is given in the text.

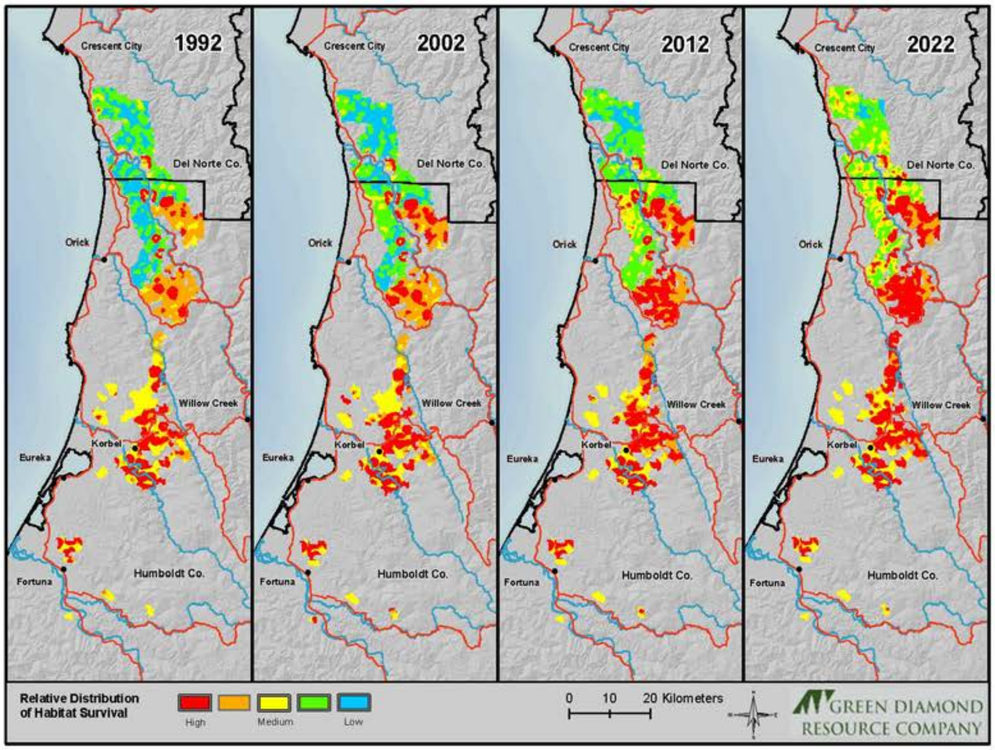


Figure 4.8. Relative distribution of Northern Spotted Owl habitat with respect to survival potential on Green Diamond Resource Company land in 1992, 2002, 2012, and 2022. Mapped area is limited to regions considered in analyses.

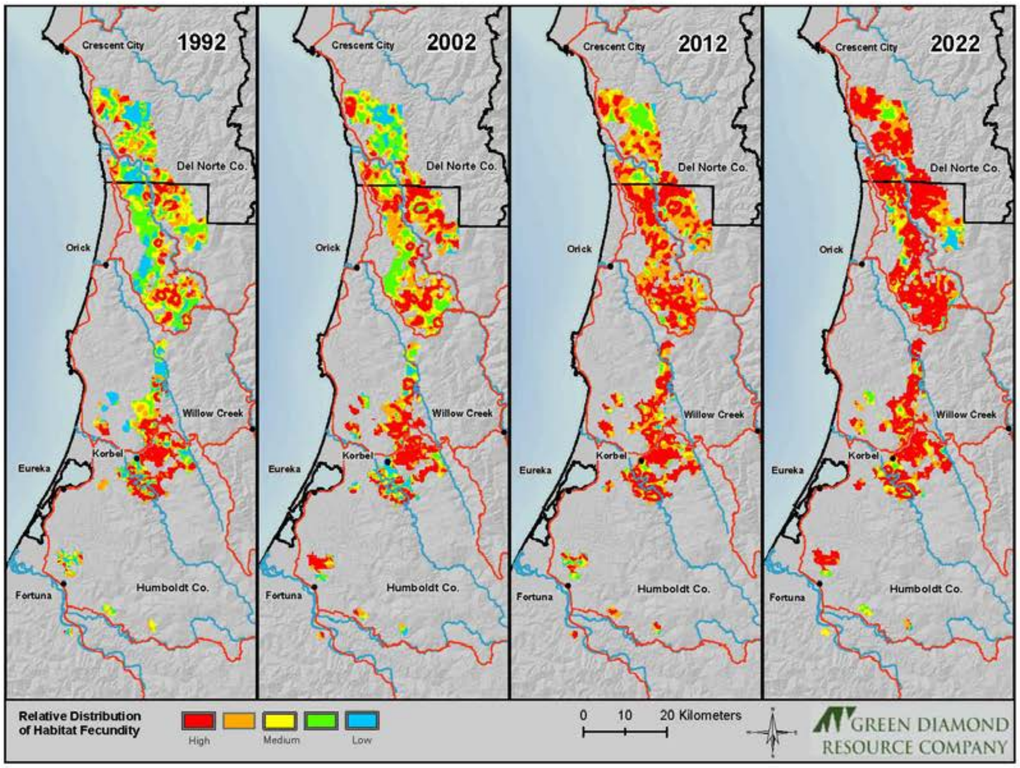


Figure 4.9. Relative distribution of Northern Spotted Owl habitat with respect to fecundity potential on Green Diamond Resource Company land in 1992, 2002, 2012, and 2022. Mapped area is limited to regions considered in analyses.

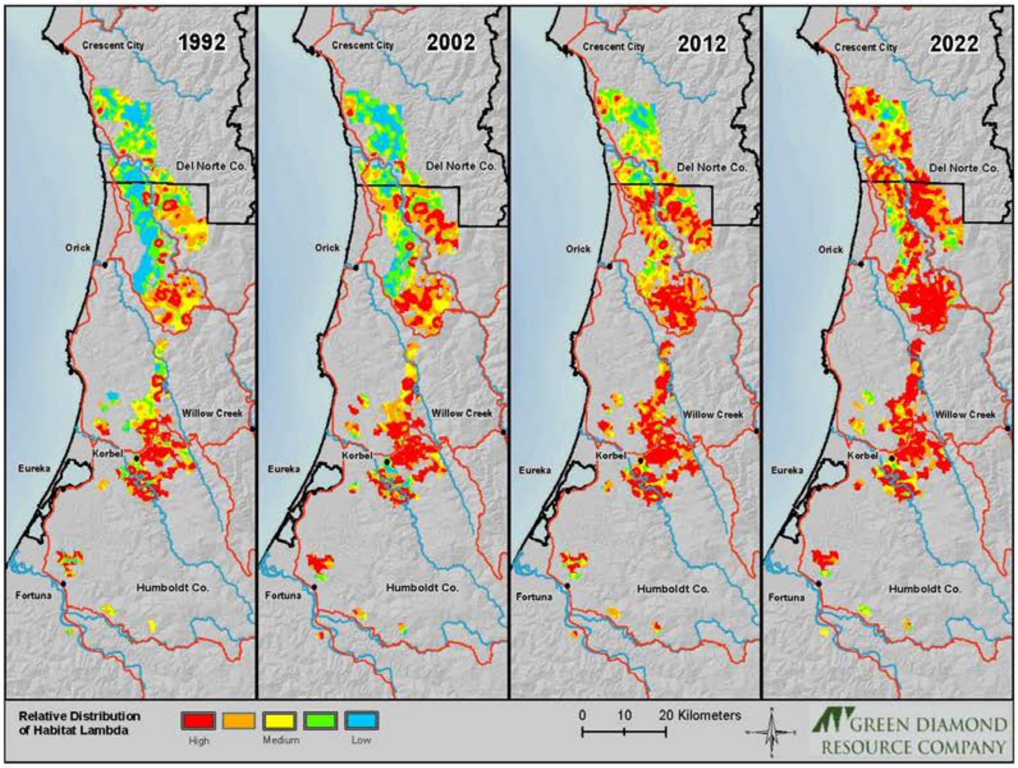


Figure 4.10. Relative distribution of Northern Spotted Owl habitat fitness potential on Green Diamond Resource Company land in 1992, 2002, 2012, and 2022. Mapped area is limited to regions considered in analyses.

Chapter 5 – Estimates of Annual Owl Displacement

This chapter is based on the requirement for "an estimate of annual owl displacement for the remainder of the permit period."

During preparation of the 10-year review in 2002, the FWS and GD agreed that additional data collection would enhance the scientific quality of the comprehensive review. In addition, the permitted level of take (50 pairs) was less than anticipated for the first ten years of plan implementation. The FWS extended the time for the comprehensive review and the time frame for the original 50 permitted takes. In 2006, GD submitted phase one of the comprehensive review, and as a result of that analysis and review, GD proposed amendments to the HCP and ITP. In 2007, the FWS approved the first amendment to the HCP permitting take of up to 58 pairs of owls until 2012 when the updated Comprehensive Review would occur. The additional takes through 2012 would allow the company to continue its sustained yield harvest activities, implement initial research on northern spotted owl and barred owl interactions and report the results to the FWS as part of the Comprehensive Review update in plan year twenty.

ADDENDUM A

Long-Term Projections of Habitat for Northern Spotted Owls and Fishers

During the time that the numerous different analyses were being done for the 10-Year Review, Green Diamond (GD) projected spatially realistic landscapes through the year 2022, because it coincided with the term of the HCP. This addendum uses several model outputs from the 10-Year Review and an independent fisher occupancy analysis to make habitat projections 50 years into the future. These projections coincide with the projected term of the "Forest HCP" and utilize new forest growth and harvesting schedules developed by GD during 2008 and 2009. Consequently, these spatially realistic projections begin in 2010 using probable timber harvest and re-growth of forest stands to predict the proportion of GD's future ownership that will fall within various habitat categories for 50 years into the future

Methods

Using anticipated harvest plans in the near term (next 10 years) and projected harvests derived through a harvest schedule model, we compared habitat on GD's study area at 10 year intervals from 2010 to 2060. We predicted these parameters for every location on the landscape from which the respective owl and fisher models were developed for 2010, 2020, 2030, 2040, 2050 and 2060. Using these model outputs, we created maps and tabulated the percent of GD's ownership that fell within different categories of habitat quality.

Results

Trends in Northern Spotted Owl habitat fitness (λ_H)

Along with other objectives, Chapter 4 assessed the long-term viability of the Northern Spotted Owl population on Green Diamond's (GD) property. One part of that was to develop models that predicted the influence of habitat on spotted owl survival, fecundity and to integrate those two parameters into a single measure of owl fitness based on habitat quality called "habitat fitness" (λ_H) (see Section 4.B). Assuming important non-habitat variables (e.g., weather and barred owls) remain at some mean value, spatially explicit estimates of λ_H were calculated for three decades: 1992 (baseline when the original spotted owl HCP was signed), 2002, 2012 and 2022 (year the permit was scheduled to expire) (see Section 4.C). Here we use the same λ_H model developed in Section 4.B and use it to project future landscapes from 2010-2060.

The changes in λ_H across GD's ownership can be seen by decade in Figure A.1. The figure indicates the dynamic nature of λ_H across the ownership, where specific areas wax and wane in their relative habitat value for owls. However, Figure A.2 shows that overall the proportion of the ownership in the highest categories of λ_H increase through time. The proportion of GD's ownership in the highest category of λ_H (λ_H >1.05 which indicates habitat capable to support an increasing population of spotted owls) increased from 95,899 acres (35% of ownership) in 2010 to 179,959 acres (64% of ownership) in 2060. In 2060, a total of 87% of GD's ownership is projected to be in the two highest categories of λ_H, which would support stable or increasing populations of spotted owls if other non-habitat variables (e.g., weather and barred owls) remain within acceptable limits.

Trends in Northern Spotted Owl site abandonment

In addition to λ_H, spotted owl sites were also analyzed to determine what habitat covariates were associated with site abandonment (see Section 1.B). The probability that spotted owls will continue to occupy a site equals 1 - site abandonment so the desired future condition is to have large well distributed areas with a low probability of abandonment. The results of the top model from this abandonment analysis indicated that abandonment was lowest (i.e., continued occupancy highest) when a 1000 acre buffer around spotted owl sites was composed of small patches (mean patch size < 20 acres) and approximately 40-65% of the stands were in the 41-60 year old age class (see Section 1.B). Using the same future projected landscape as described above, we also calculated the probability of site abandonment on GD landscapes for 50 years into the future.

The changes in site abandonment across GD's ownership can be seen by decade in Figure A.3. In a manner similar to λ_H, the probability of site abandonment was somewhat dynamic across the ownership. In addition, the lowest probability of site abandonment ($p < 0.20$ or occupancy > 0.80) increased over time (Figure A.4). The proportion of GD's ownership in the lowest category of abandonment increased from 168,105 acres (58% of ownership) in 2010 to 271,151 acres (93% of ownership) in 2060.

Trends in probability of fisher occupancy

There are no data available to estimate λ_H for fishers as was done for spotted owls, but we used repeated track plate surveys to estimate the probability of fisher occupancy associated with various habitat and physiographic variables (Hamm et al. *In prep.*). Given that track plate detections are the result of a fisher responding positively to bait; habitat associated with fisher occupancy can be best described as foraging habitat. The probability of fisher occupancy increased with increasing elevation across the ownership, but the final model for fisher occupancy also contained the habitat covariates for percent whitewood (positive association) and the amount of 6 to 20 year old forest within an 800m buffer around the track plate station (negative association). Using the same future landscape as described above, we also projected the probability of fisher occupancy on GD landscapes 50 years into the future.

The changes in probability of fisher occupancy across GD's ownership can be seen by decade in Figure A.5. The figure indicates that projections of fisher occupancy are dynamic across the ownership, but there is also a tendency for the lower elevation more coastal regions tend to have lower estimates of occupancy. The overall trend indicates that the habitat associated with the highest projected occupancy (> 0.80) declines from 135,592 acres (47% of ownership) in 2010 to 103,826 acres (36% of ownership) in 2040 and then stabilizes for the next 20 years (Figure A.6). However, if the two highest categories of projected occupancy are combined, the proportion of

GD's ownership in these two categories only declines a modest amount from 206,292 acres (71% of ownership) in 2010 to 180,248 acres (62% of ownership) in 2060. It should also be noted that the fisher occupancy model is best characterized as predicting the probability that habitat will be used as foraging by fisher and it does not include a more comprehensive assessment of habitat in a manner similar to the spotted owl λ_H. Although we had no way to quantify future potential fisher denning and rest site habitat, implementation of GD's aquatic HCP will result in an overall increase in the amount of older stands that will develop as part of riparian and geologic reserve areas (Green Diamond Aquatic HCP 2007). Presumably, this will result in an overall increase in potential denning and resting habitat for fishers, but it is an untested hypothesis that age alone is sufficient to create this type of habitat for fishers.

The analyses above indicated that GD's future landscape should provide good habitat for both spotted owls and fishers. However, we also did a temporal and spatial comparison of habitat for spotted owls and fishers to determine the extent to which habitat quality for the two species matched at any given place and time on GD's ownership. Specifically, we did a spatially explicit comparison of spotted owl λ_H and fisher probability of occupancy by decade from 2010 to 2060. Figure A7 indicates that the percentage of the ownership that simultaneously will be in the highest owl-highest fisher habitat by decade will be 17.4, 22.1, 18.8, 14.1, 16.2 and 22.7, respectively. While this is not a large proportion of the ownership, it was the single largest category each decade except for 2040. If the two highest categories of habitat for each species are combined, then these 4 of the total 25 categories will represent 48.8, 54.0, 57.4, 53.9, 51.6 and 52.8% of the ownership, respectively.

Discussion

In Section 4.C, it was shown that the highest category of λ_H for spotted owls increased from 1992 (signing of GD's HCP) to 2022 (termination of the HCP). When future landscapes were projected 50 years to 2060, this increasing trend in the highest quality of λ_H was projected to continue to increase. Based on the sensitivity analysis of λ_H (Section 4.B.3), the habitat variable that most likely contributed to the trend was open edge density. The proportion of older stands (41-60 yrs) adjacent to younger stands (6-20 and 21-40 yrs) also contributed to the trend. Both of these variables are related to creating more habitat heterogeneity that is projected to increase mostly due to implementation of GD's aquatic HCP and the California Forest Practice Rules (see Discussion Section 4.C). Although different and far fewer habitat covariates were involved (small mean patch size and intermediate amounts of older stands), the decrease in probability of abandonment (increase in occupancy) was also a function of increasing habitat heterogeneity through time. Combined with λ_H, these projections of site abandonment provided a very positive assessment of future habitat for spotted owls. Compared to habitat in the past, the modeled habitat on GD's ownership is predicted to be able to support a stable or increasing population of spotted owls assuming that other non-habitat variables (e.g., weather and barred owls) remain within acceptable limits.

The fisher occupancy model included two static covariates that were completely independent (elevation) or only slightly influenced (percent whitewood) by forest management. Only one remaining variable (amount of 6 to 20 year old forest within an 800m buffer around the track plate station) was readily influenced by management. Six to 20 year old stands only occur on

GD's ownership in areas with active timber harvest, which suggests that fishers are less likely to be foraging in areas with high levels of recent timber harvest. The decline in habitat with the highest probability of occupancy from 2010 to 2040 is possibly a result of increased timber harvest due to a greater amount of area in the harvestable (~50 years) age class. By 2040, the amount of older forest has stabilized through implementation of the current Forest Practice Rules. If we could predict beyond 2060, we expect that the amount of habitat in the highest occupancy category would be relatively stable through time. These predictions are testable hypotheses in that continued monitoring for occupancy by fisher will allow us to further refine the models that best predict areas that fisher will occupy in the future.

The comparison of spotted owl λ_H and fisher probability of occupancy indicated that the two species are fairly compatible at the moderately high levels of habitat quality, but there is some spatial and temporal separation at the highest levels of habitat quality. The best fisher habitat will be in areas with little recent timber harvest at higher elevation where whitewoods are more prevalent. In contrast, spotted owls are not predicted to be strongly influenced by elevation or predominant conifer species and recent timber harvest will tend to improve habitat by increasing habitat heterogeneity.

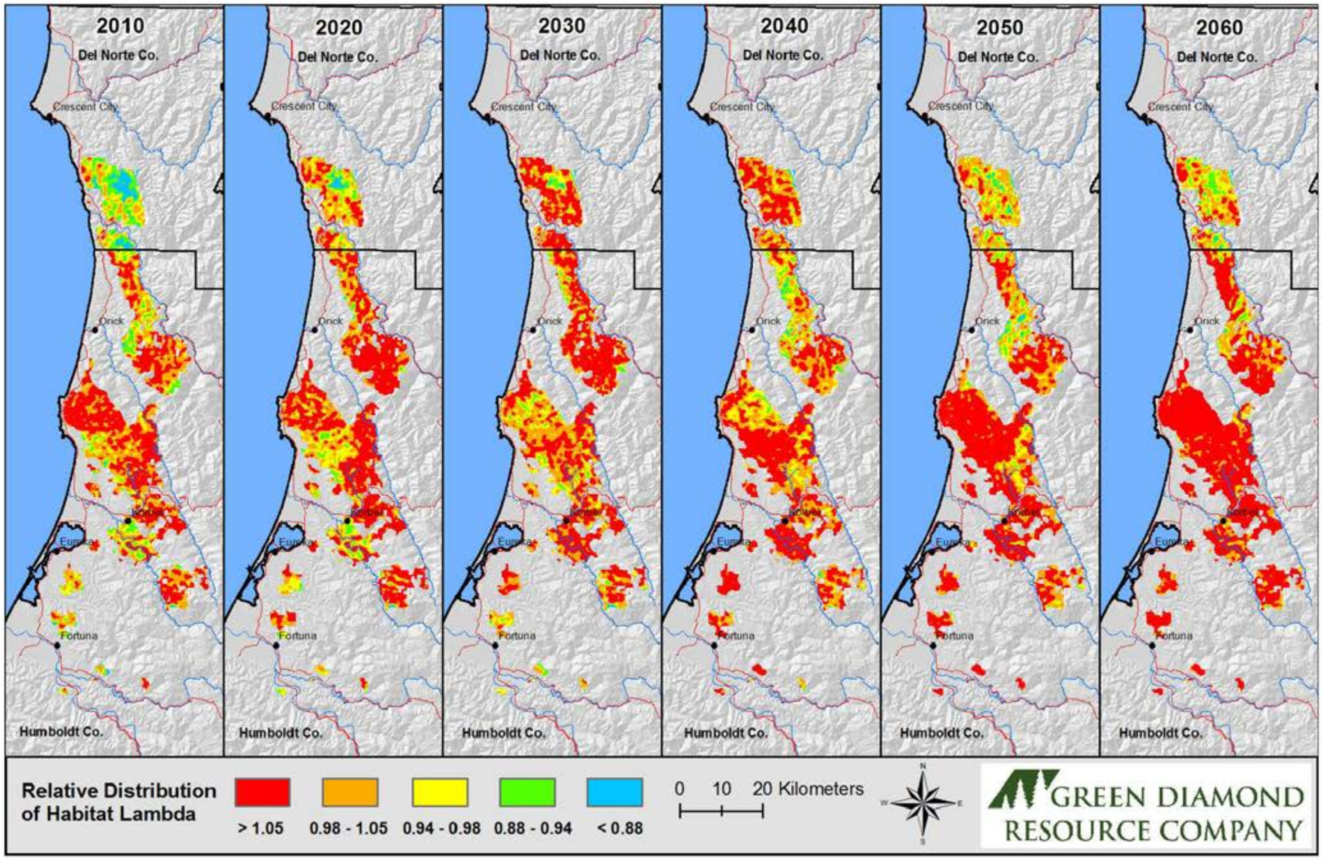


Figure A.1. Relative distribution of Northern Spotted Owl habitat fitness potential on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in habitat fitness analysis.

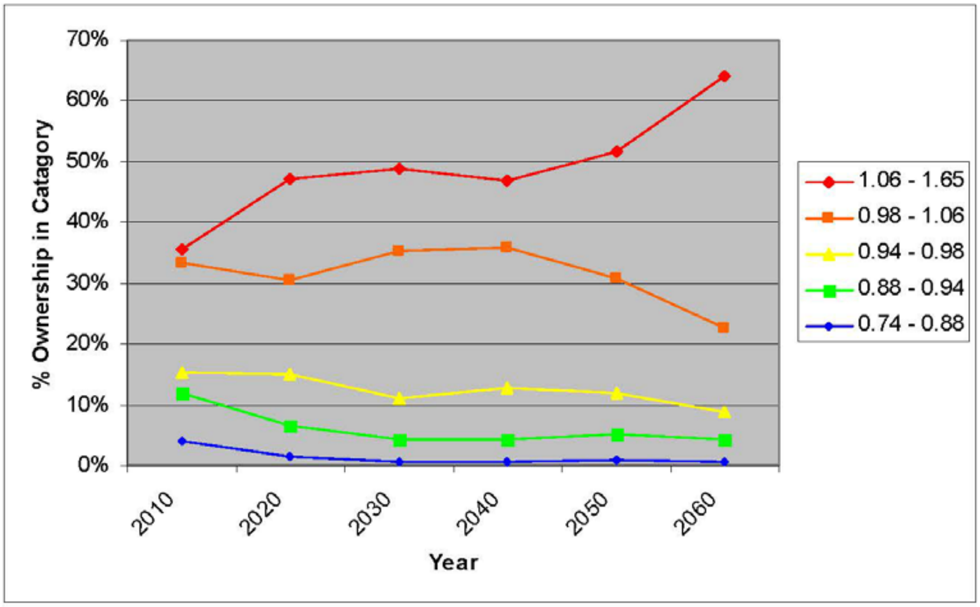


Figure A.2. Percentage of Green Diamond Resource Company land in different projected Northern Spotted Owl habitat fitness values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in habitat fitness analysis.

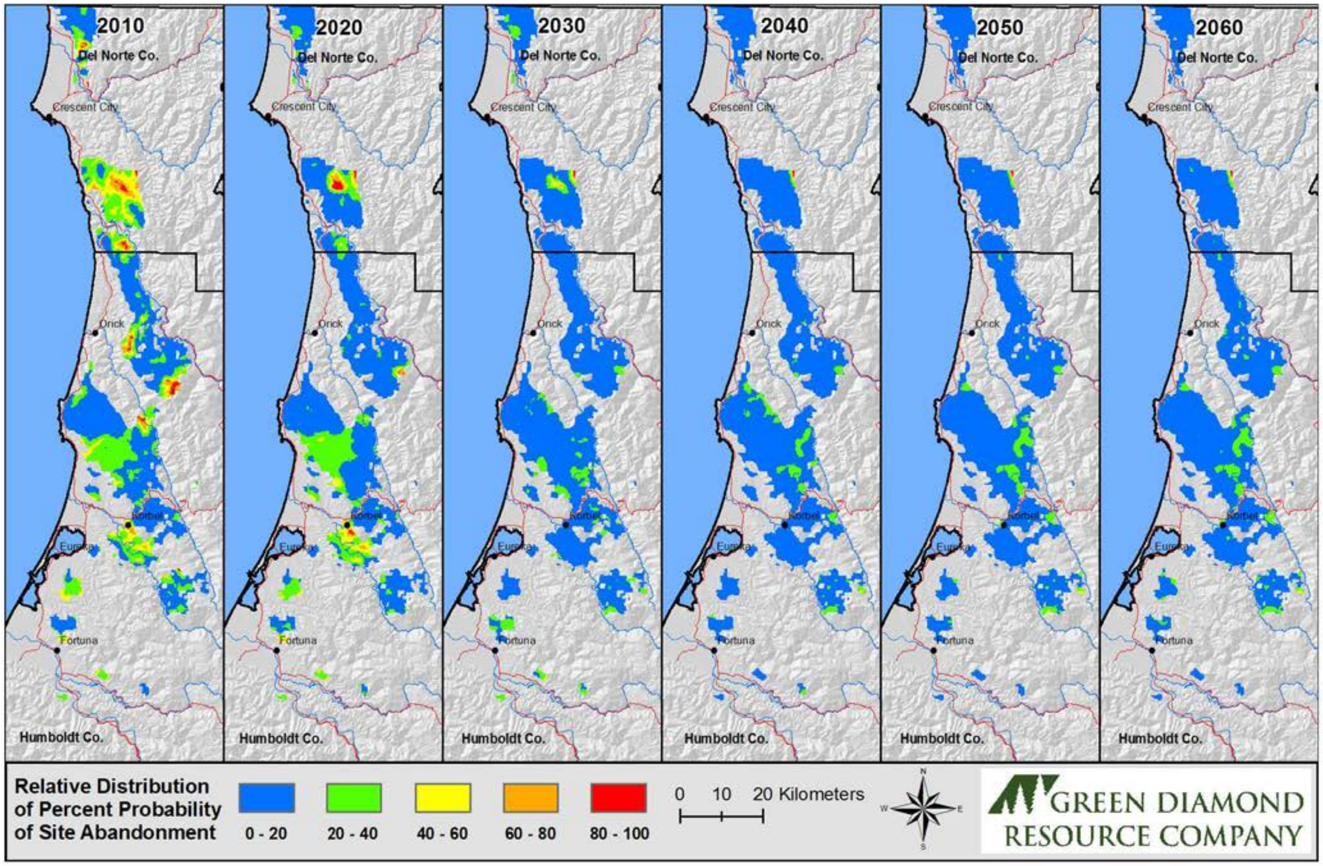


Figure A.3. Relative distribution of Northern Spotted Owl probability of site abandonment on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in analyses.

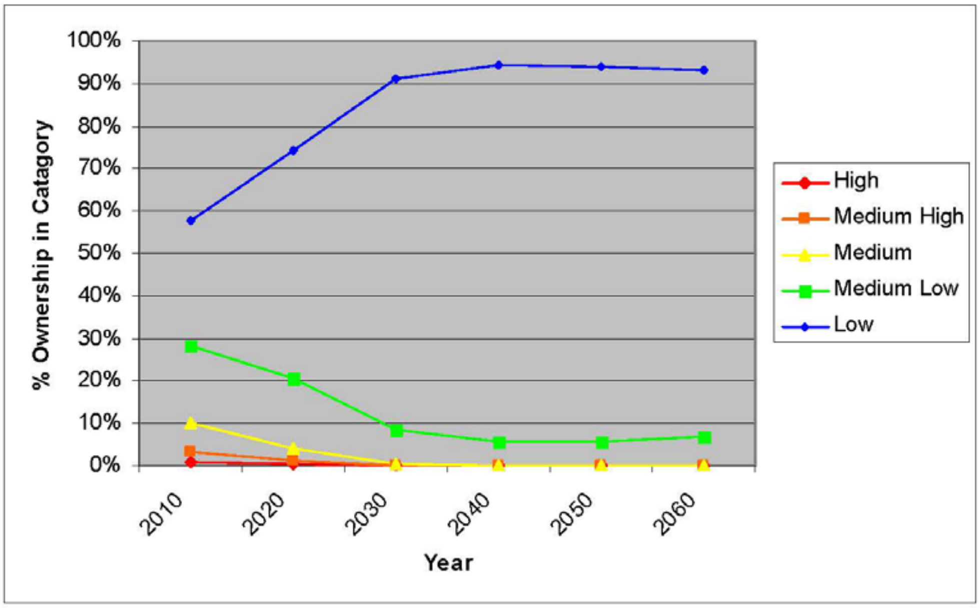


Figure A.4. Percentage of Green Diamond Resource Company land in different projected Northern Spotted Owl probability of abandonment values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in abandonment analysis.

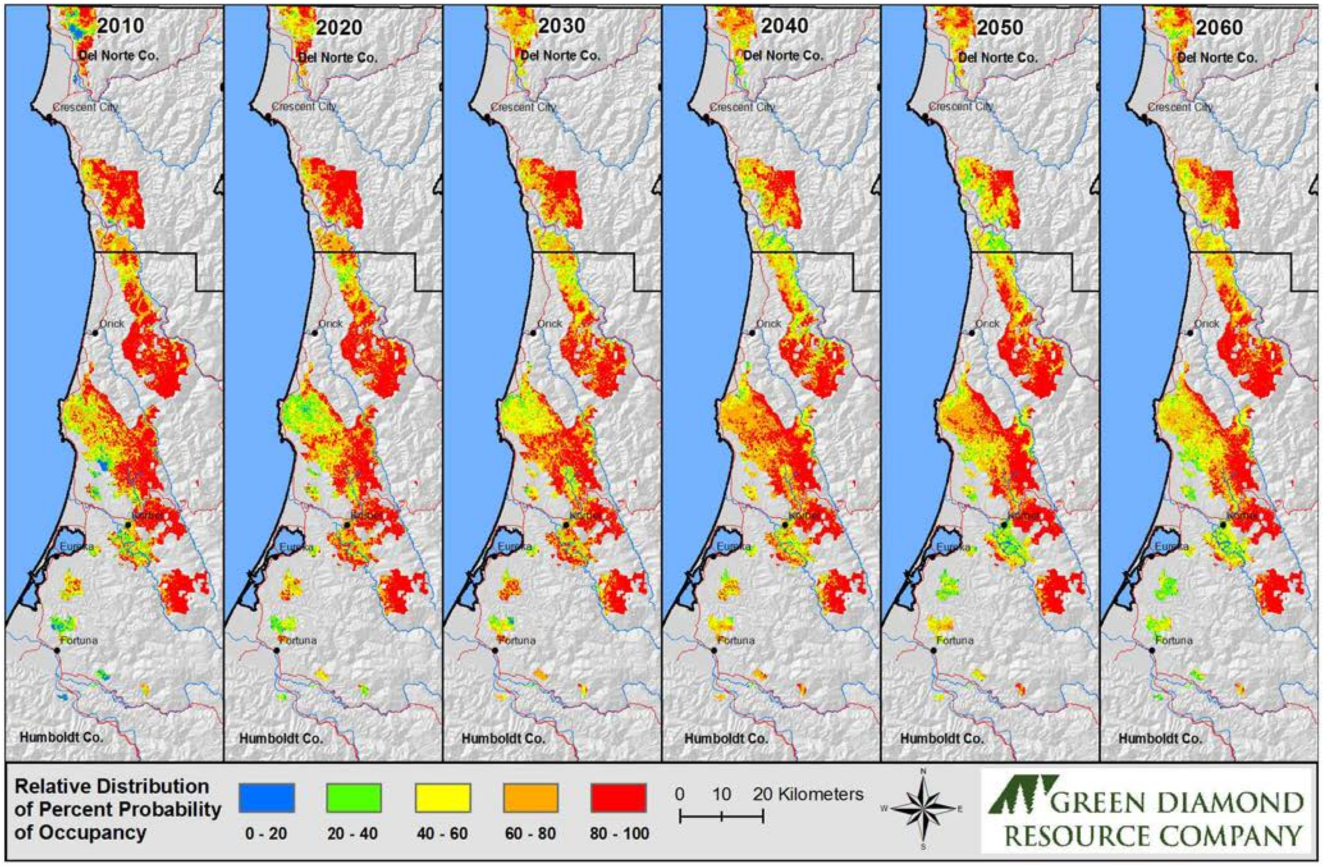


Figure A.5. Relative distribution of fisher probability of occupancy on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in fisher occupancy analysis.

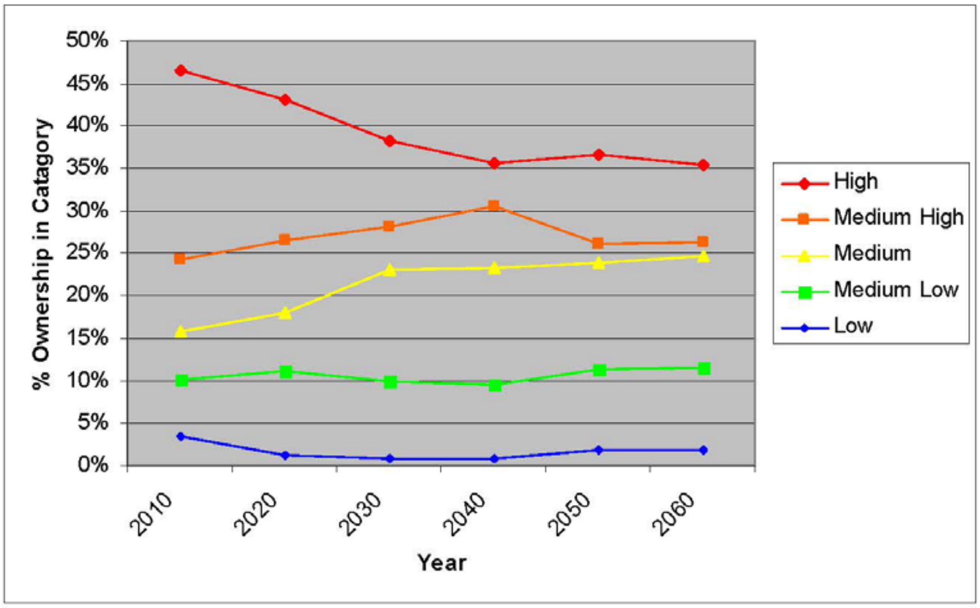


Figure A.6. Percentage of Green Diamond Resource Company land in different projected fisher probability of occupancy values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in occupancy analysis.

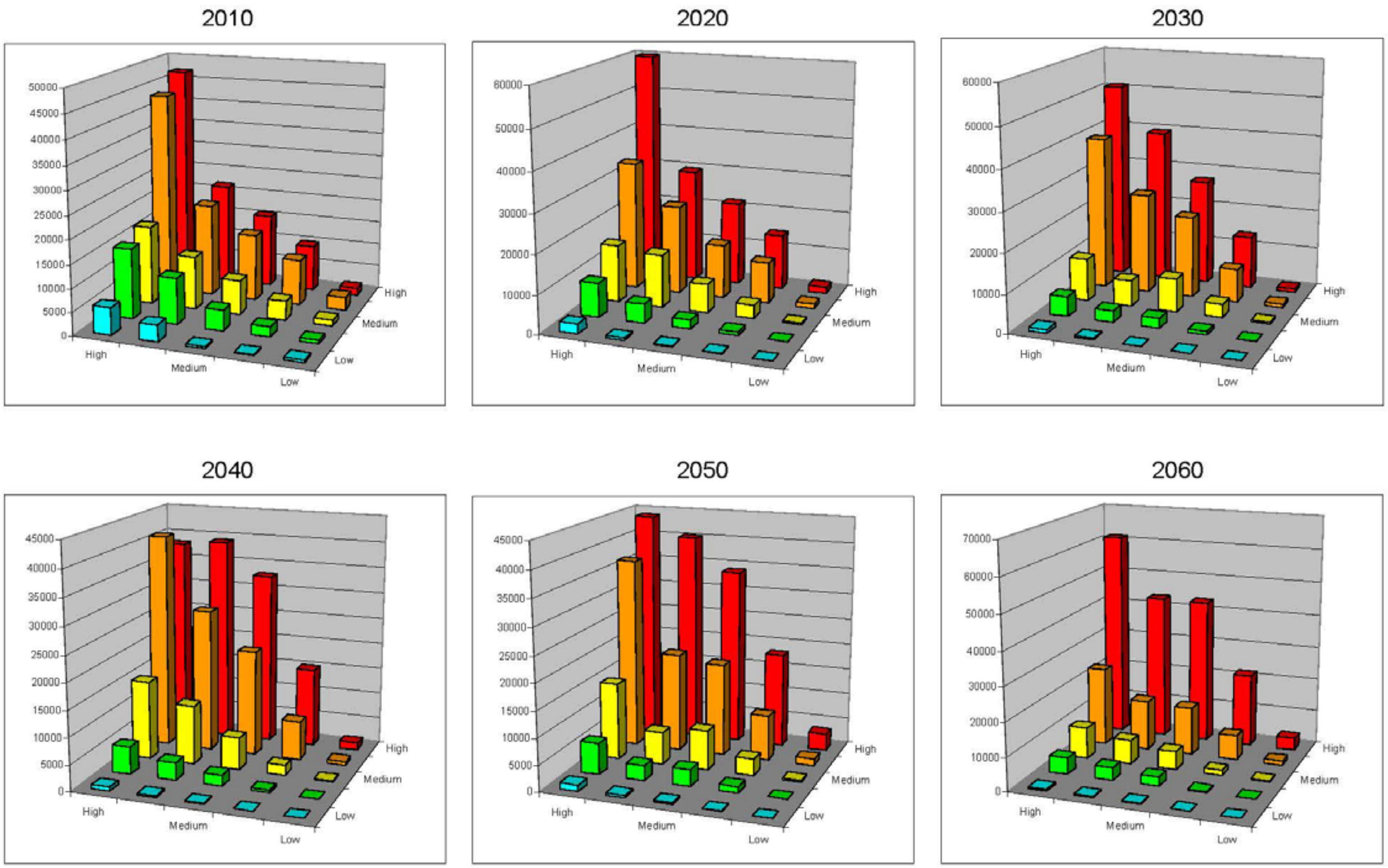


Figure A.7. Comparison of projected fisher probability of occupancy versus Northern Spotted Owl habitat fitness values on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Vertical (x) axis is acres of ownership, y-axis is fisher occupancy class (high on the right – low on the left) and z-axis is spotted owl habitat fitness class (high in the back – low in the front).

ADDENDUM B:

GREEN DIAMOND RESOURCE COMPANY RESPONSE TO COMMENTS

Below in italics are comments received from the U.S. Fish and Wildlife Service (FWS) on the draft 10-Year Review Report that was submitted by Green Diamond (GD) to the FWS. Below each of the FWS comments is an explanation of how GD responded to the comment

U.S. FISH AND WILDLIFE SERVICE COMMENTS ON GREEN DIAMOND COMPREHENSIVE [10-YEAR] REPORT (VERSION RECEIVED IN JULY-SEPTEMBER, 2008).
March, 2009

The following incorporates comments from U.S. Fish and Wildlife Service (FWS) reviews, as well as issues raised in a review conducted by Dr. Alan Franklin, at the request of the FWS. The General Comments section focuses on general, substantive issues. Additional feedback are provided in the Data Requests and Specific Comments sections below, as well as in the attachments, which include written comments from Alan Franklin, dated 9 January, 2009, on Chapter 4 (appended to this document), and additional comments via 'track changes' versions of Chapters 2 and 4 (sent as separate files).

GENERAL COMMENTS

1. *Model evaluation and validation:*

- *In addition to AIC values, please provide data on overall performance of the models, specifically, an estimate of the percent of total variation explained by the top models (this was discussed at earlier meetings).*

A statistic analogous to R^2 for these models does not exist. Instead, we conducted more sophisticated validation tests. The validation tests done for the night time activity model are described on page 2-8, with results of that exercise on page 2-9. Validation tests for the Nesting model are described on page 2-17, with results on page 2-19. There is no accepted validation method for the remaining models beyond collecting additional data and refitting.

- *As discussed in chapter 4 (pg 4-21), and in Alan Franklin comments #2 and #3 (9 January 2009 memo), the models developed in chapters 1, 2 and 4 should be treated as testable hypotheses for how owls interact with habitat characteristics on the Green Diamond ownership. The appropriate testing of the hypotheses would be against independent data. In addition to testing the models in the future (see Alan Franklin comment #3, 9 January 2009 memo), can the models be tested currently (e.g., the post-hoc models referred to in Franklin comment #3, 9 Jan 2009 memo)? For some models, such as for nocturnal habitat selection, the report includes validation results, but other models did not report validation results.*

Green Diamond's intent is to continue data collection and to validate models using new data. However, as part of the original analysis, k-fold cross validation, a published and accepted technique, has been performed for night-time activity RSF models and is a good approximation to validation on independent data. Model validation for the nesting model was performed by comparing RSF predictions for successful and unsuccessful nests. This method provides support that the model can distinguish between "good" nesting sites and "bad" nesting sites. There is no accepted validation technique for capture-recapture models (i.e., the survival model). There is no accepted validation method for the fecundity model beyond inspection of residuals; however, inspection of residuals in this case was pointless given the extreme discreteness (0, 1 or 2 fledglings) in the fecundity data analyzed.

Even though we did the validation and believe these models are accurate, whether or not the night-time activity and nesting models are validated by current or subsequent data is somewhat irrelevant. We only developed the night-time activity and nesting models to provide good habitat predictors for the survival and fecundity models. As for validating the final habitat fitness model, there is no accepted validation method that uses concurrent data. Evidence for this comes from the fact that Franklin et al. (2000) developed the method and did not perform validation using concurrent data. In addition, we have confidence in our habitat fitness model because it primarily agrees with the results obtained on a nearby study area (Franklin et al. 2000) (i.e., habitat heterogeneity is important to provide the best overall habitat quality). Finally, the new habitat conservation plan being developed based on the results of the 10-Year Review Report will stipulate that additional data will be collected to validate the habitat fitness model.

2. Chapter 1
    - *The term "owl site" as used in the report was confusing. In section 1.B, sites were referred to alternately as "owl sites" and "owl nest sites". The former refers to an area while the latter refers to a tree. In terms of occupied versus unoccupied, it was unclear whether results and discussion referred to nest trees or actual areas used by owls. This needs to be clarified using consistent terminology.*

This was completed as requested.

- *Section 1B: The follow-up data in Table 1.2 suggest that cumulative impacts of harvesting a large area within a territory (indirect take) may have greater impact than harvest of a smaller area within or near the nest (direct take). Does GD have any thoughts on this? Also, in addition to the modeling provided on factors affecting nest site abandonment, please include basic statistics on fate of displaced owls: survivorship and reproduction, in a form that is comparable with same data for non-displaced owls. Some of this can be addressed by our Data Request #1 below, but in addition, it would be helpful, for evaluating the HCP, to have simple descriptive data. Also, in Table 1-2, it would help to include statistics (mean, SE) for number of acres* *harvested within the take assessment circles for displaced owls within each category.*

The cumulative impacts of timber harvesting on spotted owl occupancy and nesting was addressed in Section 1.A. The request to provide simple descriptive statistics on the fate of displaced (take birds) and non-displaced owls were summarized in the table below. The most appropriate methodology to assess the impact of take (displacement) on survival was to use capture-recapture data as was done in Chapter 4 (Sections 4.A and 4.B), but to satisfy the information request, we needed some simple statistic that would provide an index of survivorship. The index that we used was the number of years that an owl was known to live divided by the total number of years since its first capture expressed as "percent of years lived." This was calculated from the time the bird was first captured and also from "post displacement." Although this index was clearly biased since there was no accounting for detection probabilities, we made the assumption that detection probabilities were the same for displaced and non-displaced owls. If this assumption relative to detection probabilities was correct (or not substantially violated) then the index of survival should be similar for both groups. Providing an index of fecundity was more direct and potentially less biased relative to a statistically rigorous estimate of fecundity. We simply calculated a mean annual number of fledglings for displaced and non-displaced owls. Similar to detection probabilities relative to survival discussed above, we also made the assumption that the probability of detecting fledglings was equal for displaced and non-displaced owls.

	Survival			**Reproduction**	
	N	% Yrs lived		N	Fledged/yr
Non-displaced	1317	49.8		1271	0.64
Displaced (lifetime)	130	60.6		120	0.50
Displaced (post period)	130	51.6		120	0.38

This simplistic analysis suggested that survival of spotted owls was not negatively influenced by displacement, but reproduction appeared to be lower for owls that were displaced. While we have little confidence in these comparisons, it is interesting to note that the results are consistent with the analyses in Chapter 4.

- *AF: in terms of sites, the issue of abandonment would be better addressed using current theory on occupancy modeling, rather than just logistic regression (see MacKenzie et al. 2003. Ecology 84:220-2207 and MacKenzie 2005. Australian & New Zealand Journal of Statistics 47:65-74; PDF copies available from FWS). This type of analysis can also be performed using covariates in, for example, program MARK, which would remove subjectivity in defining sites as unoccupied versus occupied and would allow for the estimation of difference in detectability. The current logistic regression analysis assumes equal detectability across sites and time. This doesn't* *necessarily need to be done for this report but FWS would like to see used in tracking sites in the future and looking at the relationships, e.g. of colonization and extinction rates in relationship to harvested versus unharvested sites.*

Initially, we attempted to apply an occupancy-type analysis as suggested. However, after inspection of the data, we concluded that such an analysis on past data was not possible. The basic problem was that past electronic datasets only included the summary conclusion for an owl site (i.e., occupied, not occupied or unknown), but the results of individual surveys at an owl site were not available in this format. Without this information, it was not feasible to construct the sequence of visits at a particular owl site in a particular year in order to estimate probability of detection. Thus, we opted for the "pre-MacKenzie" approach. That said, information on individual surveys at each owl site is now being systematically input and this type of analysis will be possible in the future.

- *AF: The logistic regression analysis used primarily data dredging to achieve the model from which they made inferences. Although the model made sense to a point, see comments above regarding the need for model validation using independent data. In future tracking of sites, would it be possible to make predictions about the probability that a harvested site will remain occupied based on the model, and then compare predictions with the actual outcome? Over several years, enough sites will be harvested that the model proposed could be evaluated and then revised accordingly. This might also incorporate a more formal adaptive management approach (Nichols and Williams 2006. TREE 221:668-673; available from FWS)*

Future projections of occupancy have been made (see Addendum A) and a fundamental premise of the proposed new HCP will to gather data to validate these model predictions. Adaptive management measures will also be tied to the results of this model validation.

3. <u>Chapter 2</u>
    - *By dropping age of stand, and replacing that with age classes, are we losing important data? "41+ years" is the oldest age class, why wasn't this subdivided into more classes (41-60, 61-80, ≥81, as was done in some other chapters, as this broad class includes fairly uniform young growth as well as mature and old-growth forest? The 41+ was a class in the initial analyses. Later we went to more older classes. How many stands >41?*

Stand age was initially included in the analysis, but it was dropped from further analyses due to colinearity with another variable (i.e., tree height). Since tree height is a better indicator of stand conditions than age, we chose to drop age. The age classes that were created for this night time activity analysis were based on hypothesized prey base associations. Studies done on GD's ownership have shown that stands 41+ have almost no woodrats (see Chapter 3), although these older stands could provide habitat for tree voles, flying squirrels and other small mammals. Given that there were no prey base related reasons to further sub-divide the 41+ age class, we allowed tree height to be the variable that would account for potential selection of older age classes.

- *Discuss the tests GD performed to assess bias of using only points within 250m of roads, to provide support for this restriction. We believe this assessment was presented in a meeting; the results should be included in the report.*

As reported in Chapter 2 (Section 2B.1), we found that radio-signal strength declined appreciably >250 m from roads, which compromised our ability to obtain fixes at more distant points from the roads. However, we did not believe that this would introduce any bias in our analysis, because roads were ubiquitous in our study area and <5% of the study area was >250m from a road.

4. Factors Influencing Survival (Chapter 4, pages 4-9 - 4-11)
   - *Per comment #4 in Franklin's 9 January 2009 memo, it would be useful to include the actual results of the survival modeling (Chapter 4, pp 4-9 and 4-10) without edge/boundary-crossing birds, along with a discussion of why this analysis was done both ways, and the ecological implications of the results.*

The actual results were included in the text as requested and the paragraph in question was rewritten to make clear our motivation and conclusions from the temporary emigration sensitivity analysis.

- *On page 4-10, the discussion of "edge" birds in context of survivorship appears to address 2 or more different situations: 1) birds with activity centers located near the edge of the GD ownership, and/or 2) birds whose activity centers crossed the interior-edge boundary of the ownership between years, and 3) birds near the edge of set-asides. Please clarify when the discussion refers to situation 1 versus 2.*

This was clarified as requested.

- *Edge birds and the survival model: Clarify how the addition of the "edge bird" covariate helps distinguish from the 2 hypotheses (bottom of pg 4-10: "The observed increase….") regarding why eliminating edge birds from the analysis increased apparent survival. Please include a table with the top model results with edge birds eliminated. See also comments 3 and 4 in Alan Franklin's January 9, 2009 memo (appended below).*

We included the *edge bird* covariate to determine if the difference in survival between interior and edge birds was most likely due to a real difference in survival or just a difference in temporary emigration between interior and edge birds. This was clarified in the discussion.

- *Also, how many of the 55 edge birds eliminated from analysis were birds associated with set-asides (were set-asides being affecting by their proximity to property edge?). One way to provide this last information would be in the map of NSO sites on the ownership that was discussed at our March 5, 2009 meeting—sites associated with those edge birds could be distinguished from other sites on that map (assuming that most of the 55 birds were associated with map-able 'sites').*

Our assessment identified 29 of 55 (53%) edge birds as being associated with a set-aside at some point during their capture histories. It was also evident (see linked map below) that many of these 29 individual birds did not spend their entire life within or adjacent to a set-aside but frequently moved from or to an interior site. Once we determined that derivation of vegetation based habitat covariates along the boundary of the property was invalid, it also became impossible to compare the effects of removing these 29 individual birds from the data set. The unique attribute of edge versus interior birds was that relatively minor movements of an edge bird could result in it moving outside our study area and making it unavailable for "recapture."

The following link provides the map of NSO sites associated with set-asides that was requested: Edge_Bird_Map.pdf

- *Page 4-10: It reads as if the evaluation of models with and without edge birds was conducted on the second-ranked models. Why not do this analysis on the first-ranked survival model instead?*

The second-ranked survival model was used for this analysis, because during both runs (with and without edge birds) it had identical covariates in the models and nearly identical estimated coefficients. This simplified interpretation of the changes that occurred in the coefficient with and without the *edge* covariate. In addition, the intercept in the second-ranked model fit to interior birds was larger, implying higher average survival of interior birds (i.e., adding a covariate for "edge birds" would be more likely to improve the model fit for survival in the second-ranked model if "edge birds" were statistically different relative to interior birds).

5. *Factors Influencing Fecundity (Chapter 4, section 4.B.2, pg 4-12):*
    - *Please clarify how fecundity was calculated. Were pairs that did not nest included in the fecundity analyses and calculations?*

The original language in this section was inaccurate and implied we used a different method to calculate fecundity relative to the method used in all the NSO meta-analyses. This was corrected so that it was clear that we calculated fecundity consistent with the accepted methodology.

- *If pairs that did not nest were excluded, discuss and evaluate potential bias and effects on the model outcomes and conclusions regarding habitat quality* *and fitness. Fecundity definitions and analyses, including the fitness analysis of this chapter, typically have included non-nesting adult birds.*

Females that did not nest were not excluded – this misinterpretation was corrected as described above.

- *Also, how many (if any) of the 92 nests analyzed were classified as edge sites, and how might edge versus interior have affected fecundity/reproduction as reported?*

None of the 92 nests were categorized as edge sites, because we did not believe this phenomenon applied to fecundity. We hypothesized that the edge phenomenon would increase the probability of temporary emigration, which has the potential to influence estimates of survival. However, fecundity was only calculated for females that were known to occupy an owl site, so that a female that temporarily emigrated would not be included in the fecundity estimate.

6. *Factors Influencing Habitat Fitness, and Future Viability (Chapter 4, pp 4-17 – 4-24)*
   - *Pg 4-19, approximation of 'take' variable: This is a difficult variable to visualize. Diagrams illustrating the spatial calculation method might help, along with more explanation. For example, clarify what is meant by "20% of the common analysis area between our four years", and the rationale for using 20% and ½ mile as buffers around clearcut units for this analysis. How sensitive is the model output to the 20% and ½-mile values used?*

This was a complicated analysis that was undertaken to apply an average *take* covariate to future projections. We have revised the description in hopes that it will be less confusing. The rationale for applying take to 20% of the landscape was based on the fact that this provided a liberal estimation of the percentage of future owls that will be subjected to take based on 17% of owls having been subjected to take in the past. The ½ mile buffer around clearcuts was applied, because the original HCP assessed timber harvest in a ½ mile radius around owl sites to determine if a potential displacement (take) had occurred. Whether or not our approach accurately estimated future take, this covariate was applied as a constant throughout all future habitat projections and our primary objective in this analysis was estimating the trend in habitat.

- *Methods, pg 4-22: The approach used subdivides the GD ownership into 5 fitness potential categories based on 1992 conditions. This classified the top 20% of the 1992 ownership as "best" quality. While this approach works for providing a relative measure of the change in ownership conditions over time -- which is useful, it does not address absolute habitat quality.*

This is correct, but we contend that there is no such thing as "absolute habitat quality", since at any given point in time, factors such as weather, interaction with other species (e.g., barred owls) and natural cycles in prey base densities all interact to create dynamic habitat conditions. The goal of this analysis was to look at trends in habitat quality with the best habitat being defined as the habitat that supported a high and stable population of spotted owls before barred owls and other potential factors resulted in the recent spotted owl decline.

- *Hypothetically, if habitat conditions in 1992 were poor across the ownership, the top 20% would be categorized as good ("high" or "best" category), even while poor, in absolute terms. As noted in Franklin's comment #8 (9 Jan 2009 memo), for survival, fecundity and habitat fitness potentials, the "high" categories encompass a wide range of fitness potential values, compared to the ranges represented in categories 1-4. For example, category 4 for habitat survival (Table 4.14) spans a range of only 0.80-0.81, compared to 0.82-1.0 for category 5. We recommend working together to find alternative categorical approaches that better reflect absolute quality or fitness potential on the landscape.*

Hypothetically, habitat could have been poor across the ownership in 1992, but in fact the ownership supported the highest reported density of spotted owls any where in the Northwest (Diller and Thome 1999) and the owl population was stable or increasing throughout the 1990's (see Fig 10 in Forsman et al. *In review*). The factors contributing to the large and stable population could have included favorable weather conditions and the absence of any competitors, but it seems reasonable to assume that habitat was also good.

The different categories of habitat fitness were created to initially divide the ownership up into 5 categories with equal area. This was done so that future projections of habitat could be quantified in terms of changes in the amount of the ownership in these 5 categories. The fact that the range in fitness values was variable among categories was a function of the initial habitat across the ownership. The narrow range in habitat fitness values for some categories simply indicated that there was much more of this quality of habitat available on the ownership.

- *Future projections of habitat: Merits more discussion at the top of page 4-23 to reconcile the projections of increasing habitat fitness from 1992-2012, with the meta-analysis results (and your own), which indicate a declining trend in fecundity that is likely responsible for the declining population trend (in terms of active sites) on the GD ownership. Why do results of habitat fitness modeling not match the observed population trend? This might be a place to discuss potential impacts of barred owls.*

The reasons why the owl population trend does not match the habitat trend is not definitively known. However, as noted in Chapter 4 (Section 4A), the only hypothesis for the decline in the spotted owl population on GD's ownership with any analytical support is the increase in barred owls.

7. <u>Methods</u>
    - *Please include more information on methods, such as GIS analytic methods.*

This is a very broad request and we are not sure what specific methods needed additional elaboration. Presumably, this request is related to the GIS analyses associated with Fragstats, which are quite complex. We did not attempt to include those methods in this report, because it would literally require many pages to explain how the Fragstat variables were calculated. Instead, we provided the link to the Fragstat website where the interested reader could learn more about this methodology.

Data Requests

1. *Please include results from the January 2009 NSO "meta-analysis" for lambda, survival and fecundity for the GD demographic study area, comparing 1) within-set-asides to outside-set-asides, and 2) take vs non-take owls. (This was discussed and requested at our xx meeting).*

This analysis was completed as requested and the results are in Chapter 4, Section 4.A.

2. *Please provide data on the status, numbers and productivity of owl sites by year, based on land status (set-asides, SMA, remaining GD Ownership). Table 1 below, which we provided to GD at our December 2008 meeting, illustrates the information being requested. These descriptive statistics will assist the FWS in evaluating NSO status on the GD ownership, in addition to the models and other information in the Comprehensive Report.*

The table is provided below as requested. However, although the same data were provided as requested in the sample table, it was necessary to invert the axes of the table to get all the information in a single table.

Table 1: Data request from FWS-- example of format for NSO Statistics from Green Diamond ownership in CA

	SetAsides					SMAs					Remaining Ownership					
Year	# of Pairs	# successful nests	Total young	# of Singles	Status unknown	# of Pairs	# successful nests	Total young	# of Singles	Status unknown	# of Pairs	# successful nests	Total young	# of Singles	Status unknown	Acres Basis
1992																
1993																
...																
...																
...																
2008																

Table 1. Annual number of spotted owl sites (pairs, singles and unknown status) and number of young fledged from successful nests at those sites within three land categories under the HCP. The Set Aside acreage includes a 0.5 mile buffer around the Set Aside, which accounted for owl sites potentially using the area.

		Year																	
		1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	$\bar{x}$
Set Asides	**Pairs**	57	49	55	50	56	50	51	47	49	44	43	44	33	33	28	29	26	43.8
	Singles	3	2	1	4	1	1	2	5	2	2	3	1	3	1	1	5	3	2.4
	Unk	1	7	4	6	3	6	1	3	3	4	7	5	10	3	13	8	5	5.2
	Nests	26	9	29	19	27	16	11	5	21	22	15	8	16	11	7	2	13	15.1
	Young	44	12	42	26	45	28	15	6	30	38	26	14	28	17	8	2	24	23.8
	Acres	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	71990	
SMA*	**Pairs**	7	5	6	5	4	5	5	6	5	6	5	6	3	2	1	3	2	4.5
	Singles	0	1	0	1	0	0	1	0	0	0	0	1	0	1	0	0	1	0.4
	Unk	1	1	3	1	0	0	0	0	1	2	2	0	3	0	1	0	0	0.9
	Nests	1	0	5	0	3	1	0	3	0	2	1	0	0	2	1	0	0	1.1
	Young	1	0	9	0	4	1	0	5	0	4	1	0	0	3	2	0	0	1.8
	Acres	35237	35237	35237	35237	35237	35237	35237	35237	35237	35237	35237	35237	35237	35237	18762	18762	18762	
Remaining Ownership*	**Pairs**	75	77	77	63	59	58	62	66	62	68	63	57	63	56	48	41	39	60.8
	Singles	4	1	2	2	2	0	8	3	2	3	1	3	4	0	6	1	1	2.5
	Unk	9	19	13	11	7	15	3	9	9	5	13	11	6	8	12	8	6	9.6
	Nests	32	9	34	10	26	14	13	7	14	28	20	6	25	12	4	4	9	15.7
	Young	52	15	53	15	39	22	19	10	24	48	28	8	42	19	6	7	13	24.7
	Acres	231893	231893	231893	231893	231893	231893	231893	297547	297547	297547	297547	297547	297547	297547	286715	286715	286715	

*Special Management Area

Specific Comments

1. *Table 1-2: define "incomplete assessment" and provide breakdown by category (direct, indirect) for those 23 displacements.*

This was completed as requested.

2. *Pg 1-11 (Chapter 1 Results): what do the 109 "unknown" sites represent?*

Unknown sites represented owl site were the occupancy status not determined either because the field survey results were ambiguous or there were too few surveys conducted to meet the occupancy protocol.

3. *For the multi-species terrestrial HCP, it would be helpful to update tables to include data on owls since 2005-06 (e.g., Tables 1-1 and 1-2).*

This was completed as requested.

4. *Chapter 2, model validation, pg 2-9: what was model's predictive ability in the South region, or for North and South combined if sample sizes were too small to evaluate for South alone?*

This was provided in the Results of Chapter 2, Section 2.A.1.

5. *Figure 2-10: The legend states that figure represents "Relative probability.. of selection", while the text within lower left corner of the figure refers to "Change in relative probability of selection…". Please clarify which is represented by this figure. If it refers to a change in probability over some period, clarify interpretation of the different scenarios in the figure.*

An error was made and the wrong graph was included in Figure 2.10. This has been corrected

6. *Chapter 3, page 3-6 (Conclusions): Clarify what is meant by the statement "Managing forest seral stages to promote an abundance of woodrats is likely to have the greatest positive influence on spotted owl populations in our area". "Greatest" compared to what?*

This has been clarified in Chapter 3 that the positive influence is relative to any other forest management activities?

7. *Chapter 3, page 3-24 (section 3.C.2): some words are missing in the sentence starting "In 2001-2002, Jones (2005)….".*

There was a word missing in the sentence ("studied"), which was corrected.

8. *Chapter 3, page 3-37 (Barred Owls): Typo in sentence: "In no cases were female spotted owls paired with male barred ~~spotted~~ owls (Kelly and Forsman 2004).*

This was corrected as suggested.

9. *Chapter 3, Table 3.6: Codes for 2 secondary covariates appear to be switched: GCLWD and OSHWBA. Also, definition of GCSD should likely be "…<30cm across" rather than ">30cm across"*

This was corrected as suggested.

Attachment 1:
Text of January 9, 2009 Memo from Dr. Alan Franklin

***Date**: 9 January 2009*

***Subject**: Review of Chapter 4 of GDRC 10-year Report*

***To**: Gary Falxa, U.S. Fish and Wildlife Service*

***From:** Alan Franklin*

I reviewed the draft Chapter 4 (Spotted Owl Viability and Set-Asides) of the 10-year Report for Green Diamond Resource Company. I made my comments in two places. First, I included some comments in the attached draft file using Track Changes in Word. Second, I included more lengthy comments below, which I cross-referenced with comments in the draft file. My more lengthy comments are as follows:

1. *You need to be careful with these comparisons because the WC area has been conducted for a longer time period than GDRC or Hoopa. Part of the trends in WC are due to earlier years; the best time-trend model from the meta-analysis was a quadratic, suggesting that survival declined and then tapered off in the later years (see figure 4c in Anthony et al 2004).*

This was clarified in the text that the comment was based on the summary conclusions from Anthony et al. (2006).

2. *In the Model Development section, there should be a more explicit statement that the approach here did depart from Anthony et al (2004) in that the approach used here involved more data dredging whereas Anthony et al. (2004) used more of an a priori hypothesis approach. In addition, were the top models from Franklin et al., Olsen et al., and Dugger et al. included in the model set? This would seem reasonable to do for comparative purposes.*

The language in this section was modified to better describe the model development process that we used. In addition, we believe there is no single model selection technique that is valid or even appropriate in all situations. There are many valid ways to construct a statistical model, each with their strengths and weaknesses. The model building approach we used was indeed more exploratory and comprehensive than that used by Anthony et al. (2006) and others, but we believe it was disparaging and inappropriate to characterize it as "data dredging." Our approach was required in order to completely extract the predictive power of our comprehensive set of covariates. Many previous studies (e.g., Franklin et al. 2000, Olsen et al. 2004, and Dugger et al. 2005) had a more limited and restricted sets of covariates available to them, because they lacked the extensive forest stand-level data commonly maintained by a commercial timber land manager such as Green Diamond. Thus, we believe our approach was valid for the extensive dataset that was at our disposal.

3. *I was confused by the statement that stated that there was little difference in QAIC among all the 374 models. Table 4.6 provided the top 20 models but all these models were very similar in that they had the same effects but just slight structural differences (e.g., log transforms). How did these compare to a means model or models different in terms of their effects? In addition, most of the effects in the top model had large SE and would not be different than zero. Could some post-hoc modeling be done with just the effects that had smaller SE in this model (i.e., Temp_nesting and Nest_HSI) with some interactions and nonlinear structure? Or was this already included in the initial model set? Because a data dredging approach was already used that some post-hoc modeling would not make much difference in terms of inference.*

Despite the fact that our model building approach was more exploratory and comprehensive than others (see above), we continue to object to it being characterized as "data dredging." We established a comprehensive model fitting procedure before we knew the results and to go beyond what was planned would be inappropriate. We believe our approach was objective and repeatable and to add post-hoc model building, as suggested, would introduce too much subjectivity into the analysis.

4. *It would be useful to provide the results for this [survival] modeling effort without the edge birds. Was this the analysis chosen for inference? I could not gauge whether the analysis without birds was substantially better without being able to review the results, especially the parameter estimates and their standard errors. I would make some initial decisions about which of these analyses was most appropriate and go from there.*

The series of paragraphs in question have been rewritten to rectify the confusing language. In summary, the model chosen to make our primary inferences was the original, and was based on all birds (edge and non-edge). This exercise was to convince ourselves and the reader that birds near the edge that most likely have higher probability of temporary emigration than others do not drastically effect the results of the primary survival model.

5. *There was a lot of information in the Discussion that could not be adequately evaluated because this information was not reported in the Results.*

The missing information (e.g., coefficients and confidence intervals for the model that includes edge birds) was added to the Results Table 4.7.

6. *Does this mean that pairs that did not nest (i.e., with fecundity = 0) were not included? This should be explicitly stated because the results will not be comparable to other studies where non-nesting birds were included. Also, this is not really fecundity because that term is generally used to refer to reproductive*

output of individuals or pairs, regardless of whether they nested or not. By conditioning on nesting, the response variable is something different than fecundity.

The original language in this section was inaccurate and implied we used a different method to calculate fecundity relative to the method used in all the NSO meta-analyses. This was corrected so that it was clear that we calculated fecundity consistent with the accepted methodology.

7. *In both the survival and fecundity modeling, there was no estimate of how much variation the top models explained. This would be useful to gauge how well the top model explained the survival and fecundity data, respectively.*

We assume this comment suggests that an R^2-type statistic would be useful, and does not refer to delta AIC values. Assuming this is correct, we are not aware of an accepted measure of overall percent variation explained for the type of capture-recapture used to estimate survival. We reported goodness of fit for the top survival models. In the draft of Chapter 4, this comment referenced the Results section on page 4-15 that contained information on the fecundity model. We, in fact, included an R^2-type statistic based on PRESS values in the second paragraph of this section. A regular R^2 statistic was not computed for the fecundity model because the model has a random component. Based on the PRESS statistic, total amount of variation in fecundity data explained by the model was approximately 10%.

8. *It took me awhile to figure out how the categories were delineated; it would help if this section could be made clearer. I wondered if this categorization could be misleading in terms in that the High category is also the broadest category for all three parameters. In some cases, the categorization did not seem to make much sense (e.g., Category 4 in Table 4.14 which only spans 0.81-0.82 whereas category 5 spans 0.82-1.00). Also, was the actual landscape present in 2002 used or were the predicted values based on harvest plans?*

The different categories of habitat fitness were created using the actual 1992 landscape to initially divide the ownership up into 5 categories with equal area. This was done so that future projections of habitat could be quantified in terms of changes in the amount of the ownership in these 5 categories. The fact that the range in fitness values was variable among categories was a function of the initial habitat across the ownership. The narrow range in habitat fitness values for some categories simply indicated that there was much more of this quality of habitat available on the ownership.

9. *I wonder how much of this was driven by the different way that fecundity was estimated. While edge may be important, I think it probably needs to be tempered with sufficient forest habitat. I still have concerns with how fecundity was estimated using only nesting birds (i.e., fecundity was conditional on nesting). In our study area, only about 1/3 of the birds nest in any given year and these zero's would be eliminated from the fecundity estimates here. Habitat*

Unfortunately, this misunderstanding was created by our error in describing the methodology for estimating fecundity. As noted above, this was corrected so that it was clear that we calculated fecundity consistent with the accepted methodology.

Attachment 2:
Comments (in-text, in "Track Changes") on Chapters 2 and 4

These comments were mostly very specific and were addressed by making minor edits as indicated. The broader comments were cross-referenced to the "General Comments" and were addressed above.

LITERATURE CITED

Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gerhardt, S. A. Gremel, R. J. Gutiérrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L. L. Irwin, P. J. Loschl, J. A. Reid, and S. G. Sovern. 2006. Status and trends in demography of northern spotted owls, 1985-2003. Wildlife Monographs 163:1-48.

Arthur, S. M., B. F. J. Manly, L. L. McDonald, and G. W. Garner. 1996. Assessing habitat selection when availability changes. Ecology 77:215–227.

Atsatt, P. R., and T. Ingram. 1983. Adaptation to oak and other fibrous, phenolic-rich foliage by a small mammal, *Neotoma fuscipes*. Oecologia 60:135-142.

Bellinger, M. R., S. M. Haig, E. D. Forsman, and T. D. Mullins. 2005. Taxonomic relationships among *Phenacomys* voles as inferred by cytochrome *b*. Journal of Mammalogy 86:201-210.

Benson, S. B., and A. E. Borell. 1931. Notes on the life history of the red tree mouse, Phenacomys longicaudus. Journal of Mammalogy 12:226-233.

Blakesley, J. A., A. B. Franklin, and R. J. Gutiérrez. 1990. Sexual dimorphism in northern spotted owls from northwestern California. Journal of Field Ornithology 61:320-327.

Blakesley, J. A., A. B. Franklin, and R. J. Gutiérrez. 1992. Spotted owl roost and nest site selection in northwestern California. Journal of Wildlife Management 56:388-392.

Bollen, K. A. 1989. Structural Equations with Latent Variables.: John Wiley, New York.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modeling 157:281-300.

Buchanan, J. B., L. L. Irwin, and E. L. McCutchen. 1993. Characteristics of spotted owl nest trees in the Wenatchee National Forest. Journal of Raptor Research 27:1-7.

Buchanan, J. B., L. L. Irwin, and E. L. McCutchen. 1995. Within stand nest site selection by spotted owls in the eastern Washington Cascades. Journal of Wildlife Management 59:301-310.

Bull, E. L., M. G. Henjum, and R. S. Rohweder. 1989. Diet and optimal foraging of great gray owls. Journal of Wildlife Management 53(1):47-50.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York.

Cameron, A. C., and P. K. Trivedi. 1998. Regression analysis of count data. Cambridge University Press, Cambridge, UK.

Carey, A. B.1991. The biology of arboreal rodents in Douglas fir forests. Pages 6-8 *in*: Huff, H. M., R. S. Holthausen, and K. B. Aubry, technical coordinators. Biology and management of old-growth forests. USDA Forest Service General Technical Report PNW-GTR-276.

Carey, A. B. 2003. Biocomplexity and restoration of biodiversity in temperate coniferous forest: Inducing heterogeneity with variable-density thinning. Forestry 76(2):127-136.

Carey, A. B., B. L. Biswell, and J. W. Witt. 1991. Methods for measuring populations of arboreal rodents. USDA Forest Service General Technical Report PNW-GTR-273. 18p.

Carey, A. B., S. P. Horton, and B. L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs 62:223-250.

Carey, A. B., J. A. Reid, and S. P. Horton. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. Journal of Wildlife Management 54:11-17.

Carey, A. B., and K. C. Peeler. 1995. Spotted owls: resource and space use in mosaic landscapes. Journal of Raptor Research 29:223-239.

Caswell, H. 1989. Matrix population models. Sinauer Associates, Sunderland, Massachusetts, USA.

Chow, N. 2001. Distribution and habitat associations of northern spotted owls in Marin County, California. M.S. thesis, Humboldt State University, Arcata, CA.

Cook, C. W., and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society for range management, Denver, Colorado, USA.

Cooper, A. B., and J. J. Millspaugh. 1999. The application of discrete choice models to wildlife resource selection studies. Ecology 80:566-575.

Courtney, S. P., J. A. Blakesley, R. E. Bigley, M. L. Cody, J. P. Dumbacher, R. C. Fleisher, A. B. Franklin, J. F. Franklin, R. J. Gutiérrez, J. M. Marzluff, L. Sztukowski. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Cranford, J. A. 1977. Home range and habitat utilization by *Neotoma fuscipes* as determined by radiotelemetry. Journal of Mammalogy. 58:165-172.

Cutler, T. L., and D. W. Hays. 1991. Food habits of northern spotted owls in high elevation forests of Pelican Butte, southwestern Oregon. Northwestern Naturalist 72:66-69.

Diller, L. V., and D. M. Thome. 1999. Population density of northern spotted owls in managed young-growth forests in coastal northern California. Journal of Raptor Research 33:275-286.

Dugger, K. M., F. Wagner, R. G. Anthony, and G. S. Olson. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor 107:863-878.

Evens, J., and R. LeValley. 1982. The spring migration, middle Pacific Coast Region. American Birds 36:889–892.

Fehring, K.E., D.B. Adams, and D. Hatch. 2003. Northern Spotted Owls in Marin County California: 2002 Annual Report. Prepared by: Katherine E. Fehring, Point Reyes Bird Observatory, Stinson Beach, CA.

Fielding, A. L., and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38-49.

Fitts, K. M., and P. T. Northen. 1992. Small mammal populations in clearcut areas of the Jackson Demonstration State Forest, Mendocino County, California. A technical report for the California Department of Fish and Game. 59 p.

Folliard, L. B. 1993. Nest-site characteristics of northern spotted owls in managed forests of northwest California. M.S. thesis, University of Idaho, Moscow. 106p.

Folliard, L. B., K. P. Reese, and L. V. Diller. 2000. Landscape characteristics of northern spotted owl nest sites in managed forests of northwestern California. Journal of Raptor Research 34:75-84.

Forsman, E. D., R. G. Anthony, E. C. Meslow, and C. J. Zabel. 2004a. Diets and foraging behavior of northern spotted owls in Oregon. Journal of Raptor Research 38:214-230.

Forsman, E. D., R. G. Anthony, and C. J. Zabel. 2004b. Distribution and abundance of red tree voles in Oregon based on occurrence in pellets of northern spotted owls. Northwest Science 78:294-302.

Forsman, E. D., R G Anthony, K. M. Dugger, E. M. Glenn, A. B. Franklin, G. C. White, C. J. Schwarz, K. P. Burnham, D. R. Anderson, J. D. Nichols, J. E. Hines, J. B. Lint, R. J. Davis, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, S. A. Gremel, D. R. Herter, J. M. Higley, R. B. Horn, J. A. Reid, J. Rockweit, J. Schaberel, T. J. Snetsinger and S. G. Sovern. 2010. Demographic trends of northern spotted owls: a meta-analysis, 1985-2008. In Review, Studies in Avian Biology.

Forsman, E. D., S. DeStefano, M. G. Raphael, and R. J. Gutiérrez, editors. 1996. Demography of the northern spotted owl. Studies in Avian Biology No. 17.

Forsman, E. D., E. C. Meslow, and H. M. Wright. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monograph 87:1-64.

Forsman, E. D., I. A. Otto, S. G. Sovern, M. Taylor, D. W. Hays, H. Allen, S. L. Roberts, and D. E. Seaman. 2001. Spatial and temporal variation in diets of spotted owls in Washington. Journal of Raptor Research 35:141-150.

Franklin, A. B., D. R. Anderson, R. J. Gutierrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern Spotted Owl populations in northwestern California. Ecological Monographs 70:539-590.

Franklin, A. B., K. P. Burnham, G. C. White, R. J. Anthony, E. D. Forsman, C. Schwarz, J. D. Nichols, and J. Hines. 1999. Range-wide status and trends in northern spotted owl populations. Unpublished Report. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

Franklin, A. B., R. J. Gutierrez, J. D. Nichols, M. E. Seamans, G. C. White, G. S. Zimmerman, J. E. Hines, T. E. Munton, W. S. LaHaye, J. A. Blakesley, G. N. Steger, B. R. Noon, D. W. H Shaw, J. J Keane, T. L. McDonald, and S. Britting. 2004. Population dynamics of the California Spotted Owl (*Strix Occidentalis occidentalis*): A meta-analysis. Ornithological Monographs 54.

Franklin, J. F., T. A. Spies, R. Van Pelt, A. B. Carey, D. A. Thornburgh, D. Rae Berg, D. B. Lindenmayer, M. E. Harmon, W. S. Keeton, D. C. Shaw, K. Bible and J. Chen. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications using Douglas-fir forest as an example. Forest Ecology and Management. 155:399-423.

Furnival, G. M., and R. W. Wilson. 1974. Regression by leaps and bounds. Technometrics 16:499-511.

Gutiérrez, R. J., A. B. Franklin, and W. S. LaHaye. 1995. Spotted owl (Strix occidentalis). *In* The birds of North America, No. 179, A. Poole and F. Gill, eds.

Haig, S. M., T. D. Mullins, E. D. Forsman, P. W. Trail, and L. Wennerberg. 2004. Genetic identification of spotted owls, barred owls, and their hybrids: Legal implications of hybrid identity. Conservation Biology 18:1347-1357.

Hall, E. F. 1981. The mammals of North America, 2nd edition. John Wiley and Sons, New York, USA. 1181 p.

Hamer, T. E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. M.S. thesis, Western Washington University, Bellingham, WA.

Hamer, T. E., D. L. Hays, C. M. Senger, and E. D. Forsman. 2001. Diets of northern barred owls and northern spotted owls in an area of sympatry. Journal of Raptor Research 35:221-227.

Hamm, K. A. 1995. Abundance of dusky-footed woodrats in managed forests of north coastal California. M.S. Thesis, Humboldt State University, Arcata, CA. 46 p.

Hamm, K.A., J.L. Thompson, L.V. Diller, T.M. McDonald and D.W. Lamphear. *In prep.* Occupancy of Managed Forests by Fisher in Northwestern California. Will be submitted to: Journal of Wildlife Management.

Herter, D. R. and L. L. Hicks. 2000. Barred owl and spotted owl populations and habitat in the central Cascade Range of Washington. Journal of Raptor Research 34:279-286.

Hooven, E. F. 1959. Dusky-footed wood rat in youn Douglas-fir. Oregon Forest Research Center, Corvallis, Oregon. Research Note 41, 23 p.

Horton, J. S., and J. T. Wright. 1944. The wood rat as an ecological factor in southern California watersheds. Ecology 25:341-351.

Hosmer, D. W. and S. Lemeshow. 2000. *Applied Logistic Regression, 2nd edition.* New York: John Wiley and Sons.

Howlin, S., W. P. Erickson, and R. M. Nielson. In Press. Validation techniques for assessing predictive ability of resource selection functions. Proceedings of the First International Conference on Resource Selection by Animals.

Hughes, K. D. 2005. Habitat associations of dusky-footed woodrats in managed Douglas-fir / hardwood forests or northern California. M.S. Thesis, Humboldt State University, Arcata, CA. 40 p.

Hunter, J. E., R. J. Gutiérrez, and A. B. Franklin. 1995. Habitat configuration around spotted owl sites in northwestern California. Condor 97:684-693.

Irwin, L. I., L. A. Clark, D. C. Rock and S. L. Rock. 2007. Modeling foraging habitat of California spotted owls. Journal of Wildlife Management 71(4):1183-1191.

James, F. C., and H. H. Shugart, Jr. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727-736.

Johnson, M. L., and S. B. George. 1991. Species limits within the Arborimus longicaudus species complex (Mammalia: Rodentia) with a description of a new species from California. Contributions in Science 429:1-16.

Jones, J. 2004. Habitat associations and ecology of the Sonoma tree vole (*Arborimus pomo*) in Northwestern California. Presentation at American Society of Mammologists, June 2004, Arcata, CA.

Jones, M. T., G. J. Niemi, J. M. Hanowski, and R. R. Regal. 2002. Poisson regression: a better approach to modeling abundance data? Pages 411-418 *in* J. M. Scott, P. J. Heglund, M. L. Morrison, J. B. Haufler, M. G. Raphael, W. A. Wall, and F. B. Samson, editors. Predicting species occurrences: issues of accuracy and scale. Island Press, Washington D.C., USA.

Kelly, E. G., and E. D. Forsman. 2004. Recent records of hybridization between barred owls and northern spotted owls. Auk 121:806-810.

Kelly, E. G., E. D. Forsman, and R. G. Anthony. 2003. Are barred owls displacing spotted owls? Condor 105:45-53.

Kuhfeld, W. F. 2000 Multinomial logit, discrete choice modeling: An introduction to designing choice experiments, and collecting, processing, and analyzing choice data with the SAS System. SAS Technical Report TS-621. SAS Institute, Cary, NC.

Lehmkuhl, J. F., and M. G. Raphael. 1993. Habitat pattern around northern spotted owl locations on the Olympic Peninsula, Washington. Journal of Wildlife Management 57:302-315.

Linsdale, J. M., and L. P. Tevis. 1951. The dusky-footed woodrat: a record of observations made on the hastings Natural History Reservation. University of California Press, Davis, California, USA.

Littell, R. C., G. A Miliken, W. W. Stroup, and R. D. Wolfinger (1996), *SAS System for Mixed Models,* SAS Institute Inc., Cary, NC, USA.

M'Closkey, R. T. 1976. Community structure in sympatric rodents. Ecology 57:728-739.

Manly, B. F. J. 1997. Randomization: Bootstrap and Monte Carlo methods in biology. Second edition. Chapman and Hall, London.

Manly, B. F. J., L. L. McDonald, and D. L. Thomas. 1993. Resource selection by animals: Statistical design and analysis for field studies. Chapman and Hall, London.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA Forest Service General Technical Report PNW-GTR-133. 496p.

MathSoft Inc. 1999. S-Plus 2000 guide to statistics, Volume 1. MathSoft Inc., Seattle, WA.

McCracken, M. L., B. F. J. Manly, and M. Vander Heyden. 1998. The use of discrete-choice models for evaluating resource selection. Journal of Agricultural, Biological, and Environmental Statistics 3:268–279.

McDonald, T. L., S. C. Amstrup, E. V. Regehr, and B. F. J. Manly. 2005. Examples. Chapter 9 in Handbook of Capture-Recapture Analysis. Amstrup, S. C., T. L. McDonald, and B. F. J. Manly eds. Princeton NJ: Princeton University Press.

McDonald, T. L., and L. L. McDonald. 2002. A New Ecological Risk Assessment Procedure Using Resource Selection Models and Geographic Information Systems. Wildlife Society Bulletin. 30:1015-1021.

McDonald, T. L., and G. C. White. 2010. A Comparison of Regression Models for Small Counts. Journal of Wildlife Management 74:514–521.

McGraw, J. B., and H. Caswell. 1996. Estimation of individual fitness from life-history data. American Naturalist 147:47-64.

McKelvey, K. S., and D. E. Pearson. 2001. Population estimation with sparse data: the role of estimators versus indices revisited. Canadian Journal of Zoology 79:1754-1765.

Meyer, J.S., L.L. Irwin, and M.S. Boyce. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. Wildlife Monographs No. 139.

Meiselman, N., and A. T. Doyle. 1996. Habitat and microhabitat use by the red tree vole (Phenacomys longicaudus). American Midland Naturalist 135:33-42.

Murray, K. F., and A. M. Barnes. 1969. Distribution and habitat of the woodrat, *Neotoma fuscipes*, in northeastern California. Journal of Mammalogy 50:43-48.

Murray, M. A. 1995. Biochemical systematics of the genus *Arborimus*. M. S. Thesis, Humboldt State University, Arcata, CA. 46p.

Neter, J., W. Wasserman, and M. H. Kutner. 1985. Applied linear statistical models: Regression, analysis of variance, and experimental designs. Second edition. Richard D. Irwin, Inc., Homewood, IL.

Nichols, J. D. 2005. Modern open-population capture-recapture models. Chapter 5 in Handbook of Capture-Recapture Analysis. Amstrup, S. C., T. L. McDonald, and B. F. J. Manly eds. Princeton NJ: Princeton University Press.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin 5:113-117.

Olson, G. S., E. M. Glenn, R. G. Anthony, E. D. Forsman, J. A. Reid, P. J. Loschl, and W. J. Ripple. 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039-1053.

Olson, G. S., R. G. Anthony, E. D. Forsman, S. H. Ackers, P. J. Loschl, J. A. Reid, K. M. Dugger, E. M. Glenn, and W. J. Ripple. 2005. Modeling of site occupancy dynamics for northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918-932.

Pearson, R. R., and K. B. Livezey. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265-275.

Pious, M. 1994. Nesting and roosting habitat of spotted owls in managed Redwood/Douglas-fir forests, California. Louisiana-Pacific Corporation, Forestry Department, Calpella, CA.

Pugh, S. R., S. Johnson and R. H. Tamarin. 2003. Voles: *Microtus* species. Pages 349-370 *in* Feldhamer, G. A., B. C. Thompson and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. 2nd edition. The John Hopkins University Press, Baltimore, MD.

Raphael, M. G. 1987. Wildlife-tan oak associations in Douglas-fir forests of northwestern California. Pages 183-189 *in* T. R. Plumb and N. H. Pillsbury, technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources, 1986. USDA Forest Service General Technical Report PSW-100.

Raphael, M. G. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in douglas-fir forests of northwestern California. Pages 23-31 *in* Szaro, R. C., K. E. Severson, and D. R. Patton (technical coordinators). Management of Amphibians, reptiles, and small mammals in North America: July 19-21, 1998, Flagstaff, Arizona. USDA Forest Service General Technical Report RM-166.

Ripple, W. J., D. H. Johnson, K. T. Hershey, and E. C. Meslow. 1991. Old-growth and mature forests near spotted owl nests in western Oregon. Journal of Wildlife Management 55:316-318.

Ripple, W. J., P. D. Lattin, K. T. Hershey, F. F. Wagner, and E. C. Meslow. 1997. Landscape composition and pattern around northern spotted owl nest sites in southwest Oregon. Journal of Wildlife Management 61:151-158.

Rogers, T. H. 1966. The fall migration. Northern Rocky Mountain-intermountain region. Audubon Field Notes 20:74.

Rosenberg, D. K., K. A. Swindle, and R. G. Anthony. 2003. Influence of prey abundance on northern spotted owl reproductive success in western Oregon. Canadian Journal of Zoology 18:1715-1725.

Sakai, H. F. and B. R. Noon. 1993. Dusky-footed woodrat abundance in different-aged forests in northwestern California. Journal of Wildlife Management 57(2):373-382.

Sakai, H. F. and B. R. Noon. 1997. Between-habitat movement of dusky-footed woodrats and vulnerability to predation. Journal of Wildlife Management 61:343-350.

SAS Institute, Inc. 2000. SAS/STAT Users Guide. SAS Institute, Cary NC.

Schmidt, K. 2005. Northern spotted owl monitoring and inventory, Redwood National and State Parks, 2004 Annual Report. Unpublished. 20 p.

Schwarz, G. 1978. Estimating the dimension of a model. Annals of Statistics 6:461-464.

Solis, D. M., Jr., and R. J. Gutiérrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92:739-748.

Sovern, S. G., E. D. Forsman, B. L. Biswell, D. N. Rolph, and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200-202.

Swingle, J. K., and E. D. Forsman. 2004. Daily and seasonal activity patterns and movements of red tree voles in western Oregon. Presentation at American Society of Mammalogists, June 2004 Arcata, CA.

Tanner, R.G. 1999. Habitat use by northern spotted owls in coastal redwood forests of northwestern California. M.S. thesis, Humboldt State University, Arcata, CA.

Taylor, A. L., Jr., and E. D. Forsman. 1976. Recent range extensions of the barred owl in western North America, including the first records for Oregon. Condor 78:560-561.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. A report by the Interagency Scientific Committee to address the conservation of the northern spotted owl. USDA, Forest Service, and U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Portland, OR.

Thome, D. M. 1997. The influence of habitat on northern spotted owl reproductive success in northern California. M. S. Thesis, Humboldt State University, Arcata, CA. 43p.

Thome, D. M., C. J. Zabel, and L. V. Diller. 1999. Forest stand characteristics and reproduction of northern spotted owls in managed north-coastal California forests. Journal of Wildlife Management 63:44-59.

Thome, D. M., C. J. Zabel, and L. V. Diller. 2000. Spotted owl turnover and reproduction in managed forests of north-coastal California. Journal of Field Ornithology 71:140-146.

Thompson, J. L., and L. V. Diller. 2002. Relative abundance, nest site characteristics, and nest dynamics of Sonoma tree voles on managed timberlands in coastal northwest California. Northwest Naturalist 83:91-100.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl; standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. USDA Forest Service, Portland, Oregon, and USDI Bureau of Land Management, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1990. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl. Federal Register 55:26114–26194.

USFWS (U.S. Fish and Wildlife Service). 2008. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. xii + 142 pp.

Verbeke, G. and G. Molenberghs (2000), *Linear Mixed Models for Longitudinal Data*, Springer, New York, NY, USA.

Vestal, E. H. 1938. Biotic relations of the wood rat (*Neotoma fuscips*) in the Berkeley Hills. Journal of Mammalogy 19:1-36.

Vreeland, J. K., and W. D. Teitje. 1999. Counts of woodrat houses to index relative population abundance. Wildlife Society Bulletin 27:337-343.

Wand, M. P., and M. C. Jones. 1995. Kernel smoothing. Chapman and Hall, London.

Ward, J. P., Jr., R. J. Gutiérrez, and B. R. Noon. 1998. Habitat selection by northern spotted owls: The consequences of prey selection and distribution. Condor 100:79-92.

Whitaker, D. A. 2003. Relation of thin and release timber management practices to abundance of woodrats, chipmunks, mice and ticks within the Hoopa Valley Indian Reservation. M.S. Thesis, Humboldt State University, Arcata, California, USA.

Young, J. S., and R. L. Hutto . 2002. Use of regional-scale exploratory studies to determine bird-habitat relationships. Pages 107-109 *in* J. M. Scott, P. J. Heglund, M. L. Morrison, J. B. Haufler, M. G. Raphael, W. A. Wall, and F. B. Samson, editors. Predicting species occurrences: issues of accuracy and scale. Island Press, Washington D.C., USA.

Zabel, C. J., K. McKelvey, and J. P. Ward, Jr. 1995. Influence of primary prey on home range size and habitat use patterns of spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433-439.

Zar, J. H. 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, N.J., USA.

ADDENDUM A

Long-Term Projections of Habitat for Northern Spotted Owls and Fishers

During the time that the numerous different analyses were being done for the 10-Year Review, Green Diamond (GD) projected spatially realistic landscapes through the year 2022, because it coincided with the term of the HCP. This addendum uses several model outputs from the 10-Year Review and an independent fisher occupancy analysis to make habitat projections 50 years into the future. These projections coincide with the projected term of the "Forest HCP" and utilize new forest growth and harvesting schedules developed by GD during 2008 and 2009. Consequently, these spatially realistic projections begin in 2010 using probable timber harvest and re-growth of forest stands to predict the proportion of GD's future ownership that will fall within various habitat categories for 50 years into the future

Methods

Using anticipated harvest plans in the near term (next 10 years) and projected harvests derived through a harvest schedule model, we compared habitat on GD's study area at 10 year intervals from 2010 to 2060. We predicted these parameters for every location on the landscape from which the respective owl and fisher models were developed for 2010, 2020, 2030, 2040, 2050 and 2060. Using these model outputs, we created maps and tabulated the percent of GD's ownership that fell within different categories of habitat quality.

Results

Trends in Northern Spotted Owl habitat fitness (λ_H)

Along with other objectives, Chapter 4 assessed the long-term viability of the Northern Spotted Owl population on Green Diamond's (GD) property. One part of that was to develop models that predicted the influence of habitat on spotted owl survival, fecundity and to integrate those two parameters into a single measure of owl fitness based on habitat quality called "habitat fitness" (λ_H) (see Section 4.B). Assuming important non-habitat variables (e.g., weather and barred owls) remain at some mean value, spatially explicit estimates of λ_H were calculated for three decades: 1992 (baseline when the original spotted owl HCP was signed), 2002, 2012 and 2022 (year the permit was scheduled to expire) (see Section 4.C). Here we use the same λ_H model developed in Section 4.B and use it to project future landscapes from 2010-2060.

The changes in λ_H across GD's ownership can be seen by decade in Figure A.1. The figure indicates the dynamic nature of λ_H across the ownership, where specific areas wax and wane in their relative habitat value for owls. However, Figure A.2 shows that overall the proportion of the ownership in the highest categories of λ_H increase through time. The proportion of GD's ownership in the highest category of λ_H (λ_H >1.05 which indicates habitat capable to support an increasing population of spotted owls) increased from 95,899 acres (35% of ownership) in 2010 to 179,959 acres (64% of ownership) in 2060. In 2060, a total of 87% of GD's ownership is projected to be in the two highest categories of λ_H, which would support stable or increasing populations of spotted owls if other non-habitat variables (e.g., weather and barred owls) remain within acceptable limits.

Trends in Northern Spotted Owl site abandonment

In addition to λ_H, spotted owl sites were also analyzed to determine what habitat covariates were associated with site abandonment (see Section 1.B). The probability that spotted owls will continue to occupy a site equals 1 - site abandonment so the desired future condition is to have large well distributed areas with a low probability of abandonment. The results of the top model from this abandonment analysis indicated that abandonment was lowest (i.e., continued occupancy highest) when a 1000 acre buffer around spotted owl sites was composed of small patches (mean patch size < 20 acres) and approximately 40-65% of the stands were in the 41-60 year old age class (see Section 1.B). Using the same future projected landscape as described above, we also calculated the probability of site abandonment on GD landscapes for 50 years into the future.

The changes in site abandonment across GD's ownership can be seen by decade in Figure A.3. In a manner similar to λ_H, the probability of site abandonment was somewhat dynamic across the ownership. In addition, the lowest probability of site abandonment ($p < 0.20$ or occupancy $>$ 0.80) increased over time (Figure A.4). The proportion of GD's ownership in the lowest category of abandonment increased from 168,105 acres (58% of ownership) in 2010 to 271,151 acres (93% of ownership) in 2060.

Trends in probability of fisher occupancy

There are no data available to estimate λ_H for fishers as was done for spotted owls, but we used repeated track plate surveys to estimate the probability of fisher occupancy associated with various habitat and physiographic variables (Hamm et al. *In prep.*). Given that track plate detections are the result of a fisher responding positively to bait; habitat associated with fisher occupancy can be best described as foraging habitat. The probability of fisher occupancy increased with increasing elevation across the ownership, but the final model for fisher occupancy also contained the habitat covariates for percent whitewood (positive association) and the amount of 6 to 20 year old forest within an 800m buffer around the track plate station (negative association). Using the same future landscape as described above, we also projected the probability of fisher occupancy on GD landscapes 50 years into the future.

The changes in probability of fisher occupancy across GD's ownership can be seen by decade in Figure A.5. The figure indicates that projections of fisher occupancy are dynamic across the ownership, but there is also a tendency for the lower elevation more coastal regions tend to have lower estimates of occupancy. The overall trend indicates that the habitat associated with the highest projected occupancy (> 0.80) declines from 135,592 acres (47% of ownership) in 2010 to 103,826 acres (36% of ownership) in 2040 and then stabilizes for the next 20 years (Figure A.6). However, if the two highest categories of projected occupancy are combined, the proportion of

GD's ownership in these two categories only declines a modest amount from 206,292 acres (71% of ownership) in 2010 to 180,248 acres (62% of ownership) in 2060. It should also be noted that the fisher occupancy model is best characterized as predicting the probability that habitat will be used as foraging by fisher and it does not include a more comprehensive assessment of habitat in a manner similar to the spotted owl λ_H. Although we had no way to quantify future potential fisher denning and rest site habitat, implementation of GD's aquatic HCP will result in an overall increase in the amount of older stands that will develop as part of riparian and geologic reserve areas (Green Diamond Aquatic HCP 2007). Presumably, this will result in an overall increase in potential denning and resting habitat for fishers, but it is an untested hypothesis that age alone is sufficient to create this type of habitat for fishers.

The analyses above indicated that GD's future landscape should provide good habitat for both spotted owls and fishers. However, we also did a temporal and spatial comparison of habitat for spotted owls and fishers to determine the extent to which habitat quality for the two species matched at any given place and time on GD's ownership. Specifically, we did a spatially explicit comparison of spotted owl λ_H and fisher probability of occupancy by decade from 2010 to 2060. Figure A7 indicates that the percentage of the ownership that simultaneously will be in the highest owl-highest fisher habitat by decade will be 17.4, 22.1, 18.8, 14.1, 16.2 and 22.7, respectively. While this is not a large proportion of the ownership, it was the single largest category each decade except for 2040. If the two highest categories of habitat for each species are combined, then these 4 of the total 25 categories will represent 48.8, 54.0, 57.4, 53.9, 51.6 and 52.8% of the ownership, respectively.

Discussion

In Section 4.C, it was shown that the highest category of λ_H for spotted owls increased from 1992 (signing of GD's HCP) to 2022 (termination of the HCP). When future landscapes were projected 50 years to 2060, this increasing trend in the highest quality of λ_H was projected to continue to increase. Based on the sensitivity analysis of λ_H (Section 4.B.3), the habitat variable that most likely contributed to the trend was open edge density. The proportion of older stands (41-60 yrs) adjacent to younger stands (6-20 and 21-40 yrs) also contributed to the trend. Both of these variables are related to creating more habitat heterogeneity that is projected to increase mostly due to implementation of GD's aquatic HCP and the California Forest Practice Rules (see Discussion Section 4.C). Although different and far fewer habitat covariates were involved (small mean patch size and intermediate amounts of older stands), the decrease in probability of abandonment (increase in occupancy) was also a function of increasing habitat heterogeneity through time. Combined with λ_H, these projections of site abandonment provided a very positive assessment of future habitat for spotted owls. Compared to habitat in the past, the modeled habitat on GD's ownership is predicted to be able to support a stable or increasing population of spotted owls assuming that other non-habitat variables (e.g., weather and barred owls) remain within acceptable limits.

The fisher occupancy model included two static covariates that were completely independent (elevation) or only slightly influenced (percent whitewood) by forest management. Only one remaining variable (amount of 6 to 20 year old forest within an 800m buffer around the track plate station) was readily influenced by management. Six to 20 year old stands only occur on

GD's ownership in areas with active timber harvest, which suggests that fishers are less likely to be foraging in areas with high levels of recent timber harvest. The decline in habitat with the highest probability of occupancy from 2010 to 2040 is possibly a result of increased timber harvest due to a greater amount of area in the harvestable (~50 years) age class. By 2040, the amount of older forest has stabilized through implementation of the current Forest Practice Rules. If we could predict beyond 2060, we expect that the amount of habitat in the highest occupancy category would be relatively stable through time. These predictions are testable hypotheses in that continued monitoring for occupancy by fisher will allow us to further refine the models that best predict areas that fisher will occupy in the future.

The comparison of spotted owl λ_H and fisher probability of occupancy indicated that the two species are fairly compatible at the moderately high levels of habitat quality, but there is some spatial and temporal separation at the highest levels of habitat quality. The best fisher habitat will be in areas with little recent timber harvest at higher elevation where whitewoods are more prevalent. In contrast, spotted owls are not predicted to be strongly influenced by elevation or predominant conifer species and recent timber harvest will tend to improve habitat by increasing habitat heterogeneity.

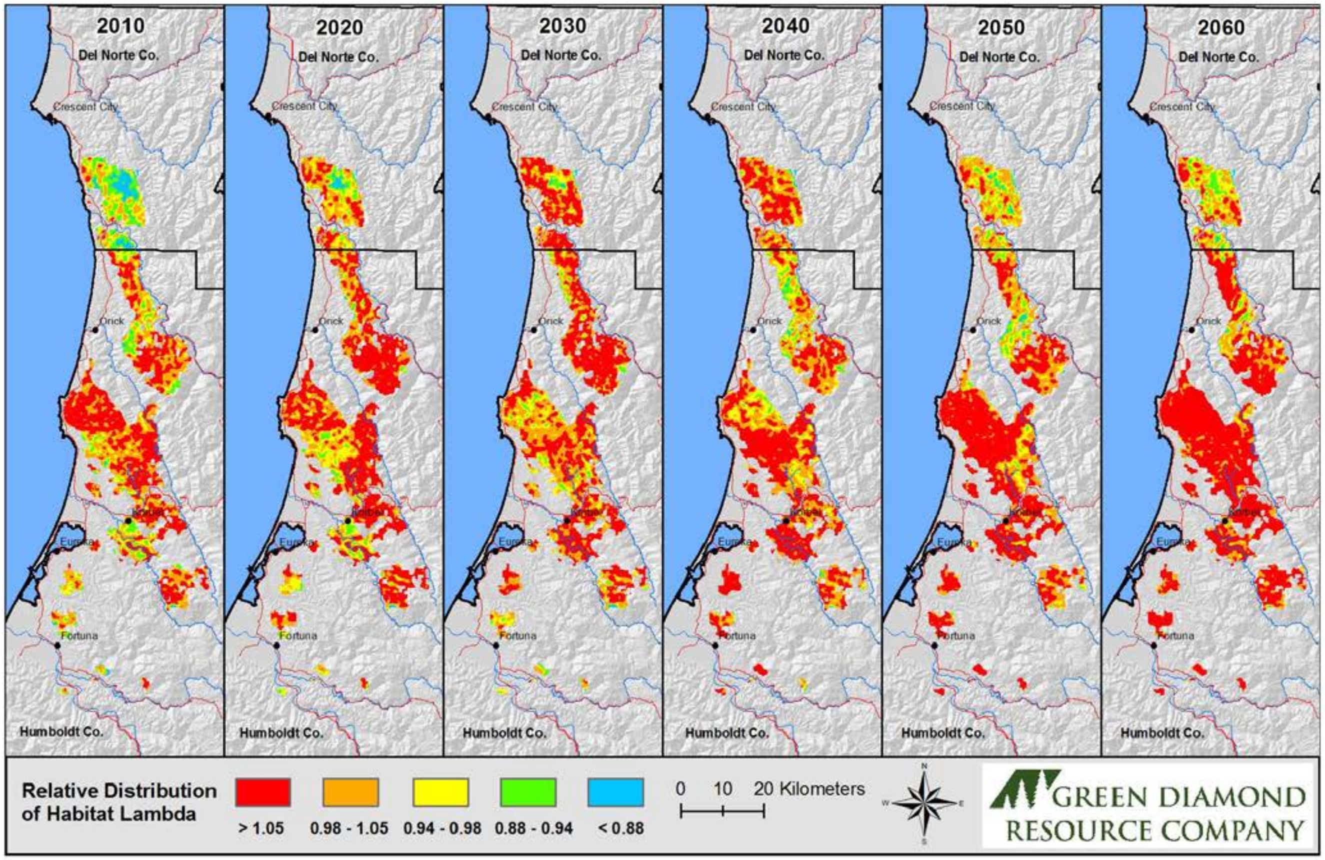


Figure A.1. Relative distribution of Northern Spotted Owl habitat fitness potential on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in habitat fitness analysis.

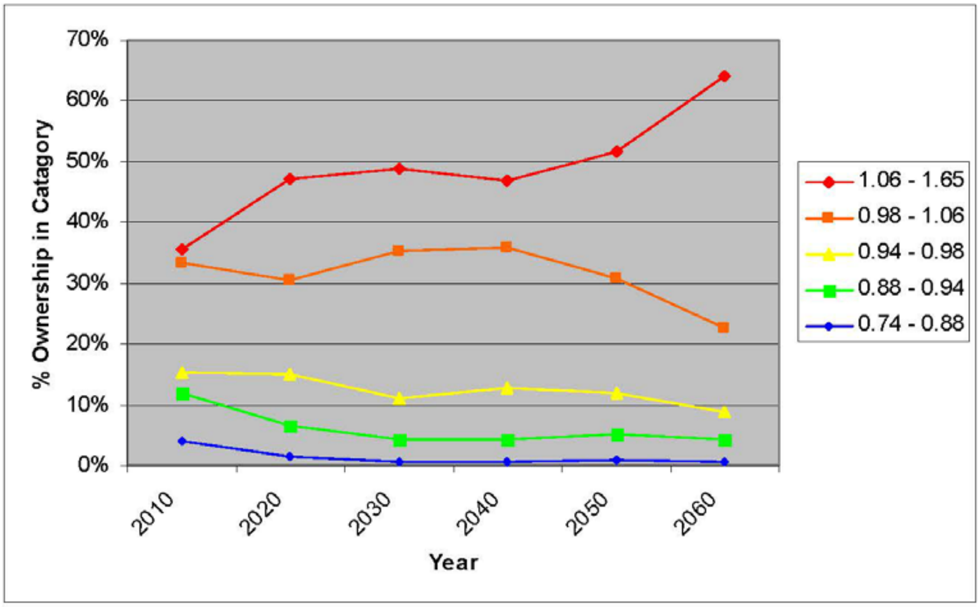


Figure A.2. Percentage of Green Diamond Resource Company land in different projected Northern Spotted Owl habitat fitness values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in habitat fitness analysis.

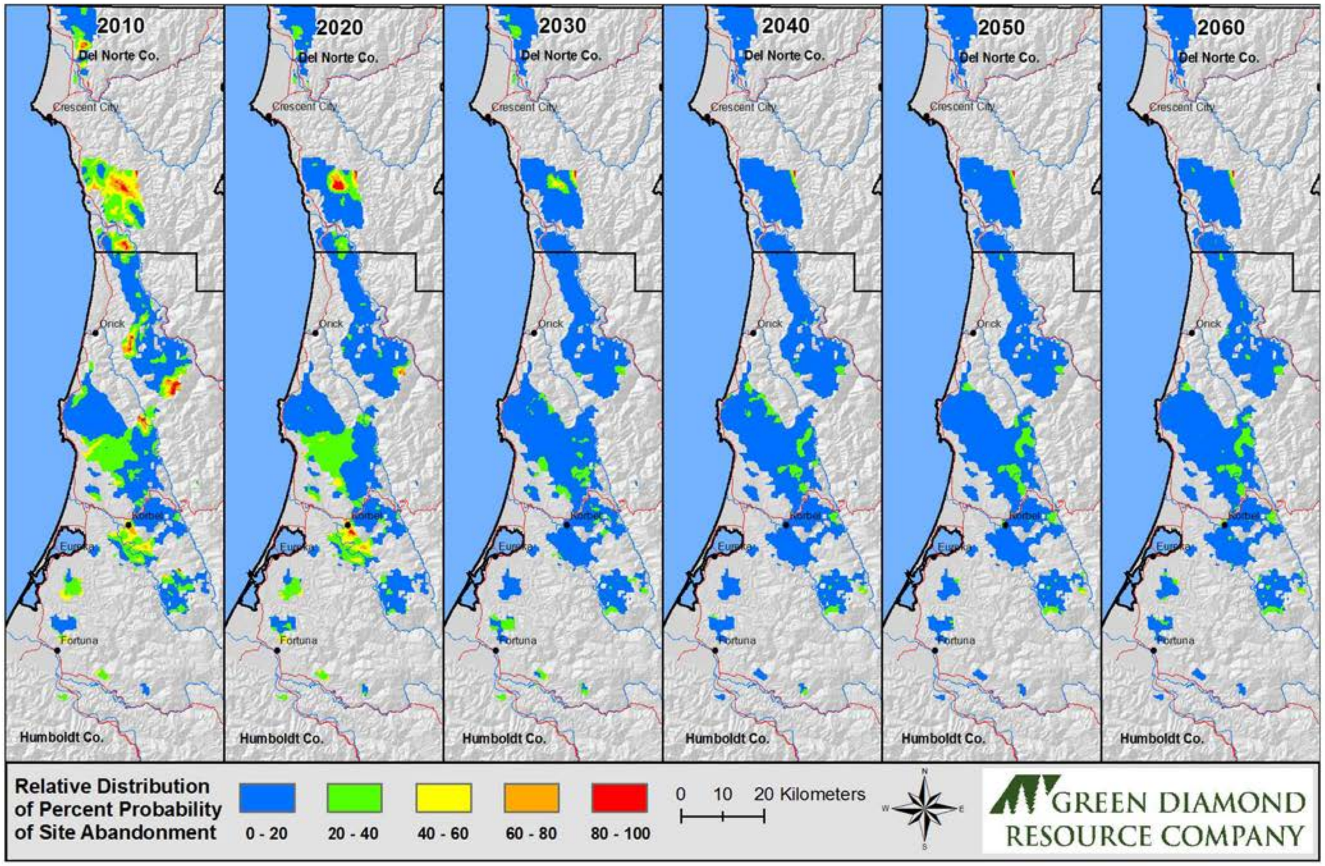


Figure A.3. Relative distribution of Northern Spotted Owl probability of site abandonment on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in analyses.

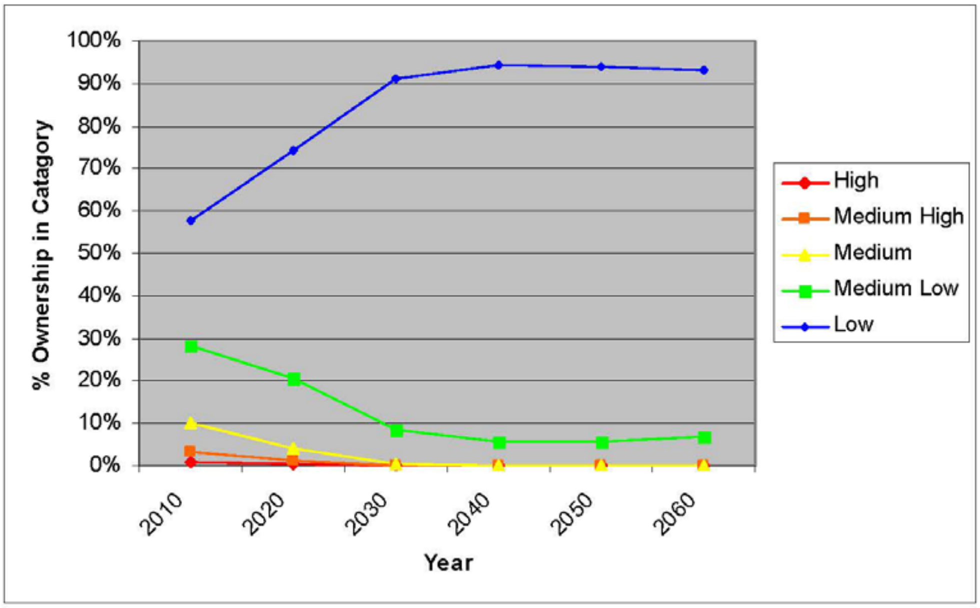


Figure A.4. Percentage of Green Diamond Resource Company land in different projected Northern Spotted Owl probability of abandonment values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in abandonment analysis.

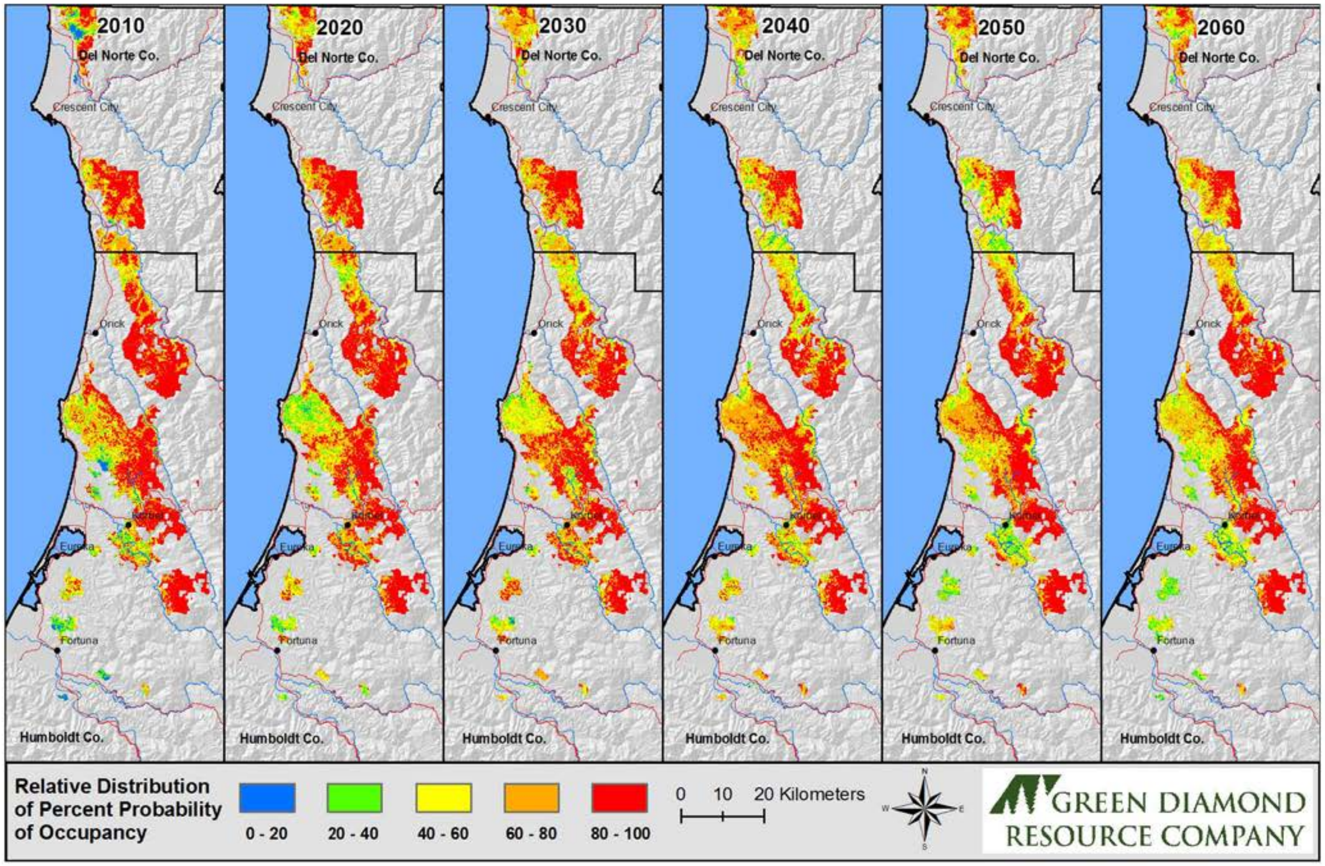


Figure A.5. Relative distribution of fisher probability of occupancy on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in fisher occupancy analysis.

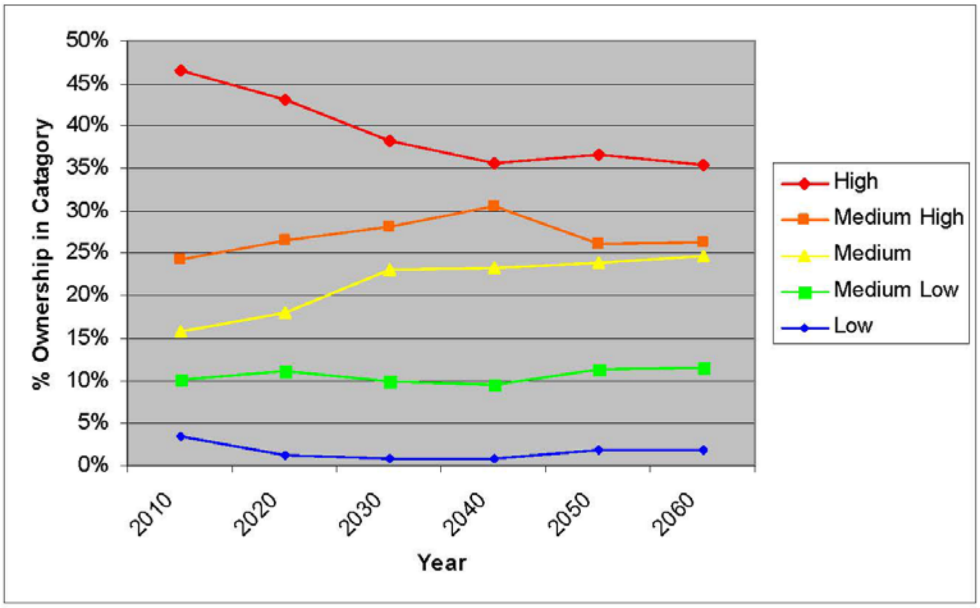


Figure A.6. Percentage of Green Diamond Resource Company land in different projected fisher probability of occupancy values in 2010, 2020, 2030, 2040, 2050 and 2060. Percentages limited to regions considered in occupancy analysis.

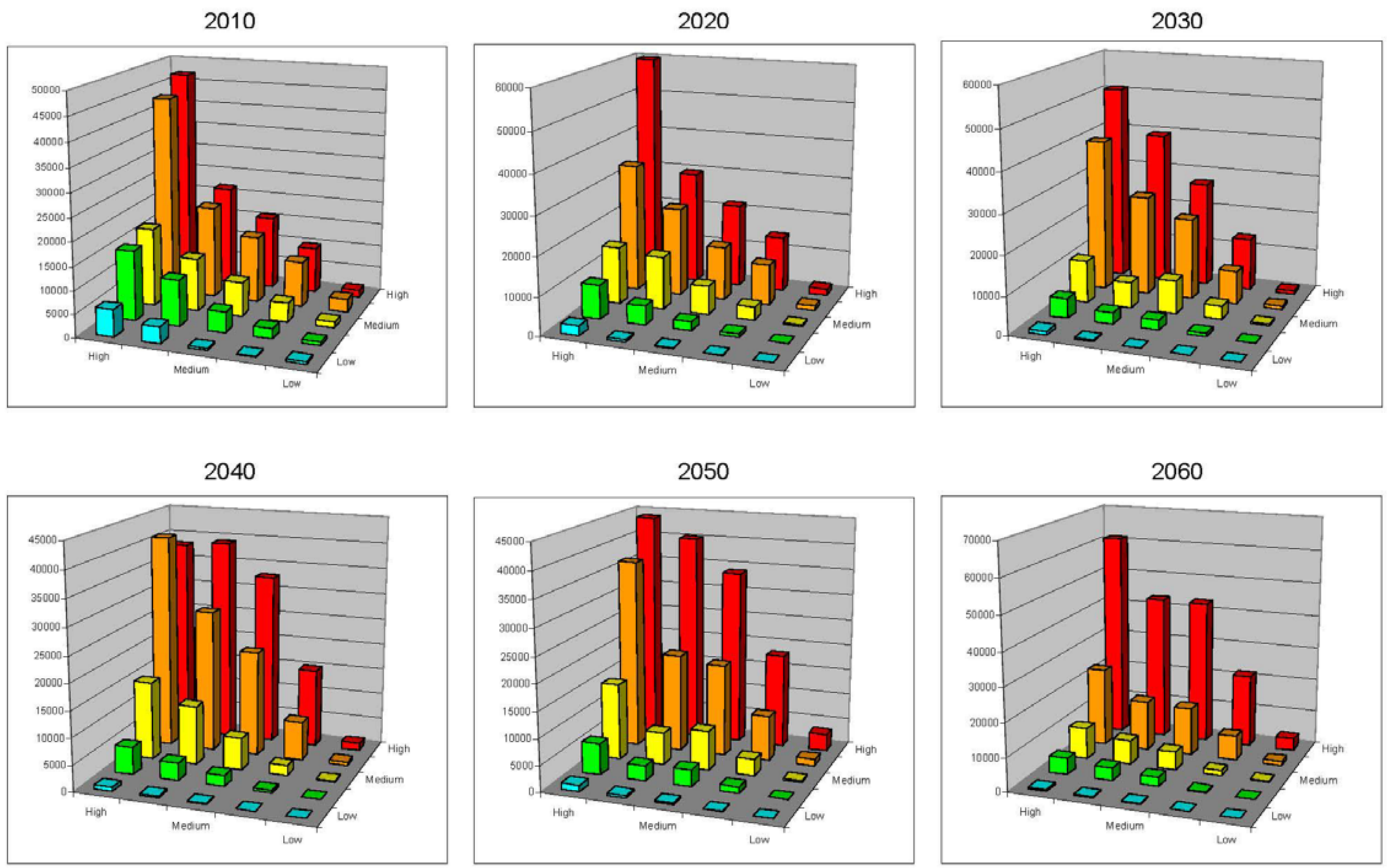


Figure A.7. Comparison of projected fisher probability of occupancy versus Northern Spotted Owl habitat fitness values on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Vertical (x) axis is acres of ownership, y-axis is fisher occupancy class (high on the right – low on the left) and z-axis is spotted owl habitat fitness class (high in the back – low in the front).

C.3 FISHER STUDIES AND MONITORING

Section C.3 is a review of all fisher work that was conducted on Green Diamond's (and formerly Simpson's) ownership. A review of all the studies conducted from 1994-2006 was completed in 2009 and submitted to the California Department of Fish and Game. The submittal was in response to a request from the Department for all fisher information that could be used for a fisher status review within the state.

SUMMARY OF FISHER (*MARTES PENNANTI*) STUDIES ON GREEN DIAMOND RESOURCE COMPANY TIMBERLANDS, NORTH COASTAL CALIFORNIA

August 13, 2009

Compiled by: Lowell Diller, Keith Hamm and David Lamphear, Green Diamond Resource Company, Korbel, CA; and Joel Thompson, Western EcoSystems Technology, Inc. Cheyenne, WY

DISTRIBUTION AND HABITAT ASSOCIATIONS (MS graduate study)

1994 and 1995: Richard Klug, Department of Wildlife, Humboldt State University, major advisor, Dr. Rick Golightly, – "*Occurrence of Pacific fisher (Martes pennanti pacifica) in the redwood zone of northern California and the habitat attributes associated with their detections.*" (Full details can be found in masters thesis, Klug 1997.)

The study employed sooted track plates to assess the distribution, relative abundance and habitat associations of the species on Simpson Timber Company's ownership (now Green Diamond Resource Company). The methodology employed a baited station to attract the target species to a sooted plate whereby a permanent foot imprint was captured on contact paper. The specific objectives were to use sooted track plates to: 1) determine the distribution of fishers across the ownership, 2) assess differences in fisher occurrence among three major vegetation types (redwood, *Sequoia sempervirens*, Douglas-fir, *Pseudotsuga menziesii*, and mixed redwood-Douglas-fir) and 3) to identify habitat attributes associated with stands where fishers were and were not detected.

We established 40 survey segments throughout the ownership with each segment consisting of six sooted track plates (stations) at 1-km intervals. We sampled 238 stations distributed among the 40 survey segments (2 segments contained only 5 stations). Two complete surveys were conducted: once each from 15 January to 16 June 1994 and again in 1995. (Five stations sampled in 1994 were not sampled in 1995, because the habitat at the sampling station had been disturbed.)

A total of 99 and 139 fisher detections were obtained in 1994 and 1995 respectively. At least one fisher detection occurred at 71 different stations during the 1994 and 1995 surveys. Fishers were detected on 26 of the 40 (65%) survey segments during both surveys combined (Figure 1). Fishers were the third most frequently detected mammalian species with only gray fox and spotted skunks detected in higher numbers (Figure 2). Other species detected were black bear, raccoon, opossum, ringtail, unknown weasel species, bobcat and striped skunk. The distributional pattern of detections across the study area indicated that almost all survey segments in the more interior Douglas-fir and mixed redwood-Douglas-fir had detections, while there were few detections in the more coastal redwood areas and southern regions near Humboldt Bay and the Eel River drainage. There were also few detections in the northern region near the Oregon-California border, but Simpson Timber Company's ownership in that area only included coastal redwood stands.

Figure 1. Location of track plate segments with and without fisher detections.

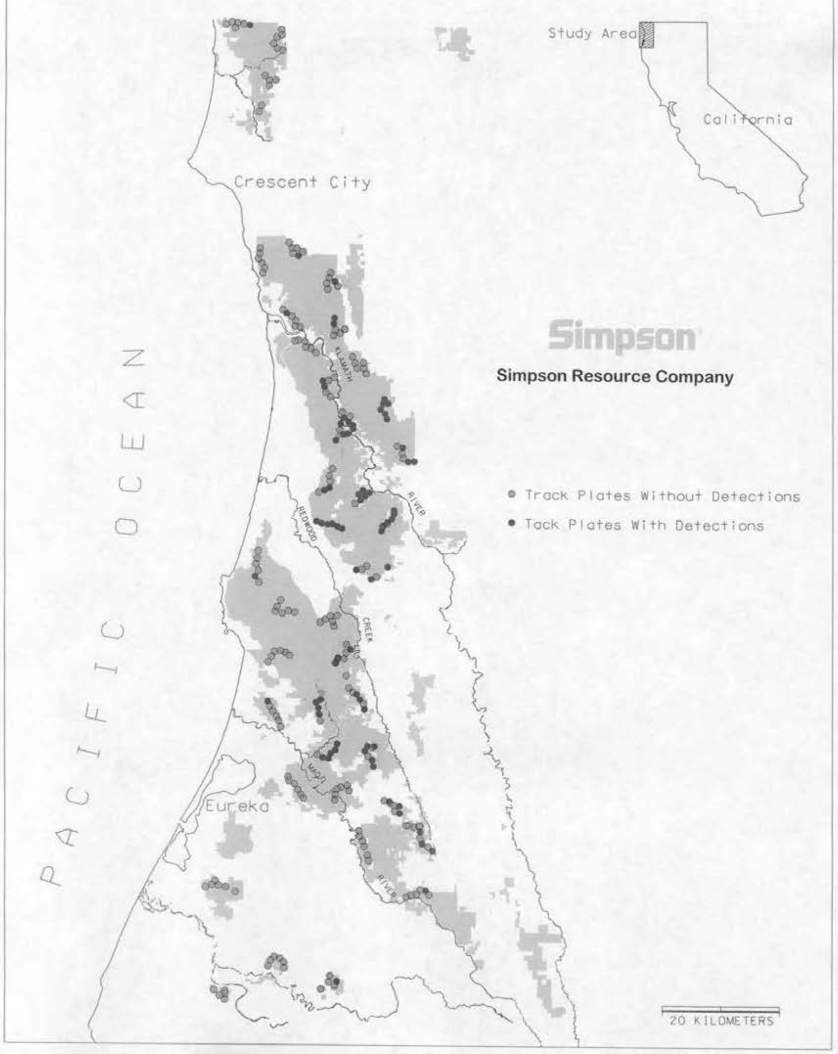
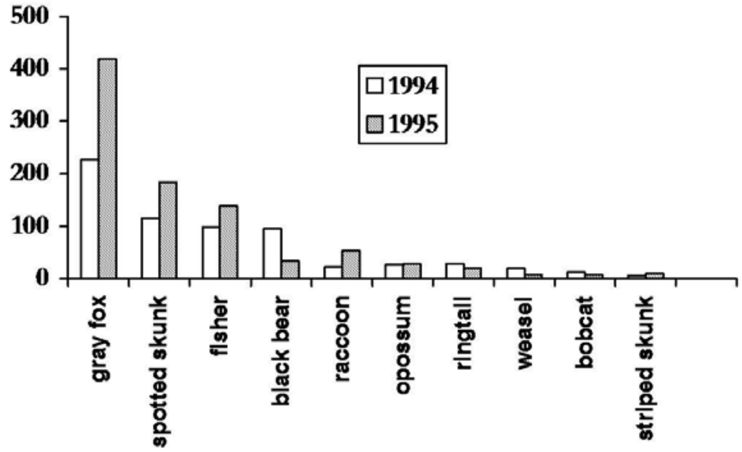
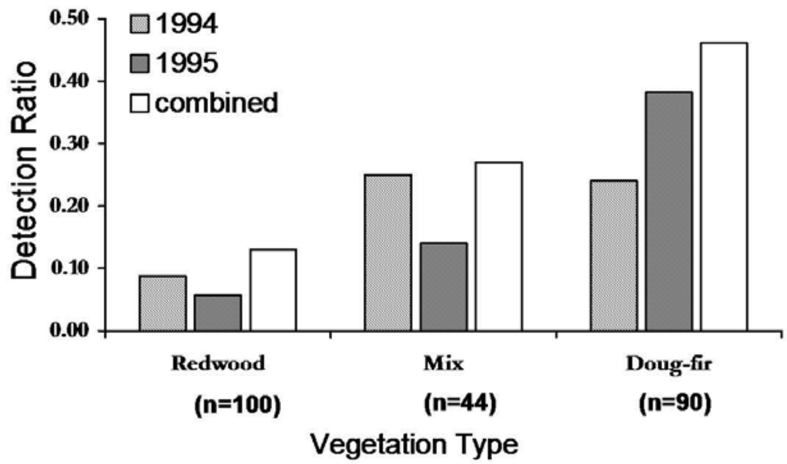


Figure 2. Total detections of different species from track plate surveys in 1994 and 1995.



Vegetation type was the only variable to be selected by the logistic procedure to predict fisher occurrence in stands. Figure 3 illustrates this relationship with the highest detection ratios (roughly equivalent to fisher population density) in the Douglas-fir zone followed by the mixed Douglas-fir/redwood and redwood zone We found no relationship between fisher detections and stand age, canopy cover, or topographic position. The average age of stands in which fishers were detected was 42.6 years compared to 43.6 years of stands in which they were not detected. A forward stepwise logistic procedure indicated that presence of fishers at the station level was best predicted by elevation, volume of logs, basal area of conifer 52-90 cm, percent slope and distance to the coast.

Figure 3. Detection ratios of fishers in three coastal vegetation types.



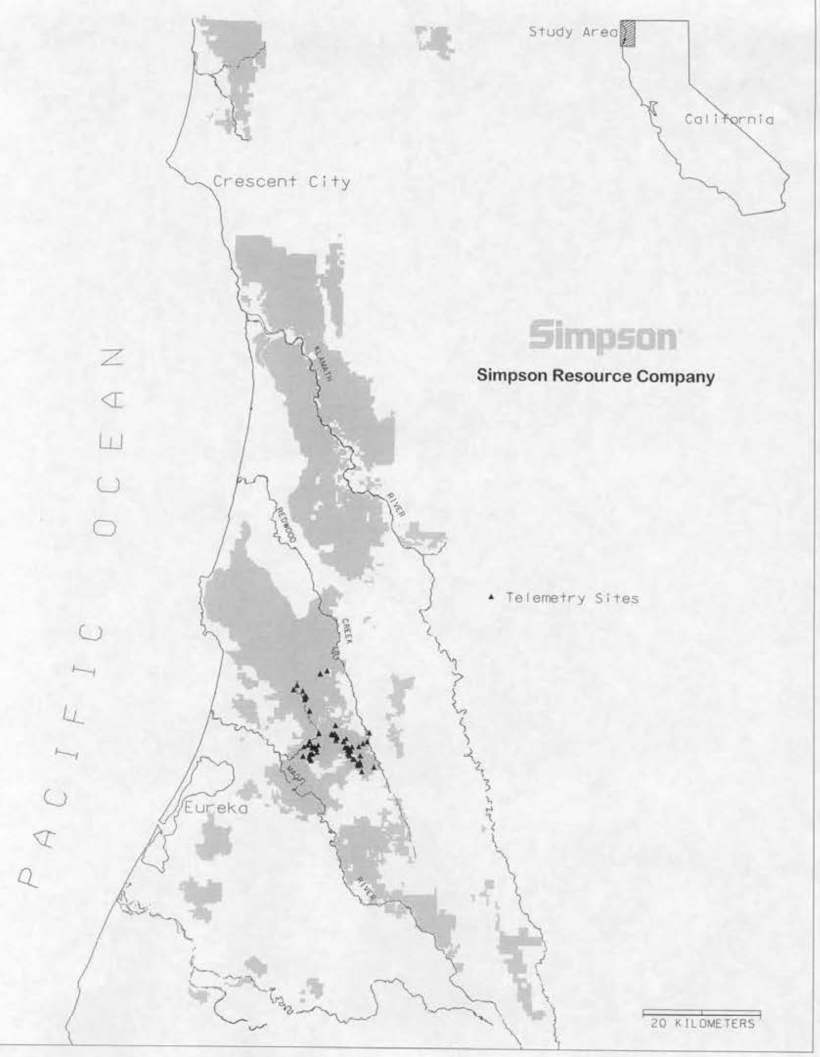
Conclusion: This study indicated that although fishers were generally well distributed across Simpson's ownership, detections occurred more frequently at higher elevations, further from the coast and in stands with a predominant Douglas-fir component. Greater amounts of hardwood and greater volume of logs were also associated with the occurrence of fishers. Another study over a similar but larger geographic region including Redwood State and National Park and Humboldt Redwood State Park also indicated that fishers were generally less frequently detected in areas closer to the coast (Beyer and Golightly 1996). In addition, this broader survey also showed a pattern with few fishers detected in the northernmost (Smith River watershed) and southernmost (Eel River watershed) portions of the study area. Contrary to the notion that fishers are associated with late successional forests, the mean stand age in which fishers were detected in this study was 42.6 years and there was no difference in stand age between stations with and without fisher detections. A survey of Redwood National and State Parks provided corroboration relative to fisher habitat selection in the redwood region (Slauson et al. 2003). An analysis of track plate surveys throughout old growth and second growth portions of the park indicated that fishers were found more than expected in second growth and less than expected in old growth. However, this study also found that fishers were associated with structurally complex portions of the second growth stands.

DEN AND REST SITE SELECTION
(in-house telemetry study)

1996 and 1997: Simpson Timber conducted a radio telemetry study to quantify denning and resting areas used by fishers. The specific objectives of the study were to (1) capture and radio collar fishers to locate rest and den sites, (2) quantify the structures used for resting and denning, (3) quantify the vegetation around the sites, and (4) compare the vegetation at rest and den sites to vegetation data collected at track plate stations where fishers were detected. This information was used to evaluate management practices currently being applied under the northern spotted owl habitat conservation plan (HCP) to determine if habitat provided under the HCP might also be beneficial for fishers.

For logistical reasons, the study was conducted on a portion of the ownership within the North Fork Mad River sub-basin and over the ridge to the east into a portion of the Redwood Creek watershed (Figure 4). We captured fishers using Tomahawk live traps equipped with a nest box to provide shelter and minimize stress. We located radio-collared fishers using hand-held yagi antennas, and if collared fishers' were inactive (no variation in signal strength between signal pulses), we determined their approximate location through triangulation. After triangulation, we located resting or denning fishers by walking to the source of the signal. Cavities that were repeatedly used by females in early spring were classified as den sites.

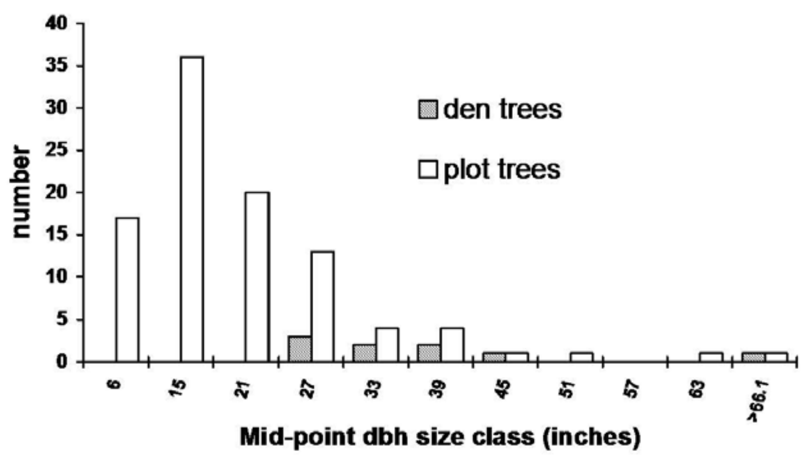
Figure 4. Location of telemetry study area.



A total of 24 individual fishers (10 males and 14 females) were captured during the study. Twelve individuals (6 males and 6 females) were outfitted with radio transmitters and followed to determine rest and den sites.

Nine of 11 adult females captured showed evidence of having been reproductive based on lactating or swollen teats when captured, or they were located in natal or maternal dens. A total of 9 dens were found for 5 of 6 females outfitted with radio transmitters. These consisted of 4 natal (where the young were born) and 5 maternal (temporary refuge sites for the kits) dens. The dens were located in 4 "highly decadent" live hardwoods, 1 "sound" hardwood and 4 conifer snags. Natal dens were all in cavities in 2 tanoaks, 1 chinquapin and 1 Douglas-fir snag. Mean dbh was 76.5 cm (SD = 15.6, range 62.5 - 95.3 cm). Maternal dens were also all cavities: 3 appeared to be cavities excavated by pileated woodpeckers and 2 appeared to have been created by fire. The cavities were in 2 tanoaks, 2 Douglas-fir snags and 1 western red cedar snag with a mean dbh of 112.0 cm (sd = 45.8, range 62.5 - 184.4 cm). Figure 5 indicates that the den trees tended to be the largest trees available in the stand. In addition to this study, the study described below on estimating fisher population density resulted in locating 7 maternal or natal dens. These were also cavities in 2 tanoaks, 2 chinquapins and 3 redwoods with a mean dbh of 185.7 cm (SD = 78.02, range 74-295 cm).

Figure 5. Size class distribution of den versus surrounding plot trees.



A total of 35 rest sites were located in a variety of tree species and structures. Live hemlock was the most common tree species in which rest sites were located followed by live Douglas-fir and cedar (Figure 6). The most common structures used as rest sites were dwarf mistletoe clumps in hemlocks (10), lateral branches and other mammal nests in Douglas-fir trees (7) and mostly cavities in cedars (6) (Figure 7). Although Simpson Timber did not collect specific data on use versus availability, general observations throughout the ownership indicate that hemlock with dwarf mistletoe is not a major component of most stands. This suggests that fishers were showing high selectivity for hemlock with its propensity to be infected with dwarf mistletoe. Other rest sites were found in fir snags and logs, a variety of structures in hardwood species and broken top redwoods (Figure 7). The mean dbh of trees with rest sites was 33.3 inches with a range from 8.8 to 68.9 inches. Trees with rest sites spanned the full range of available dbh size classes, but the smaller trees were less likely to have suitable rest structures compared to larger trees (Figure 8).

Figure 6. Distribution of tree species used as rest sites.

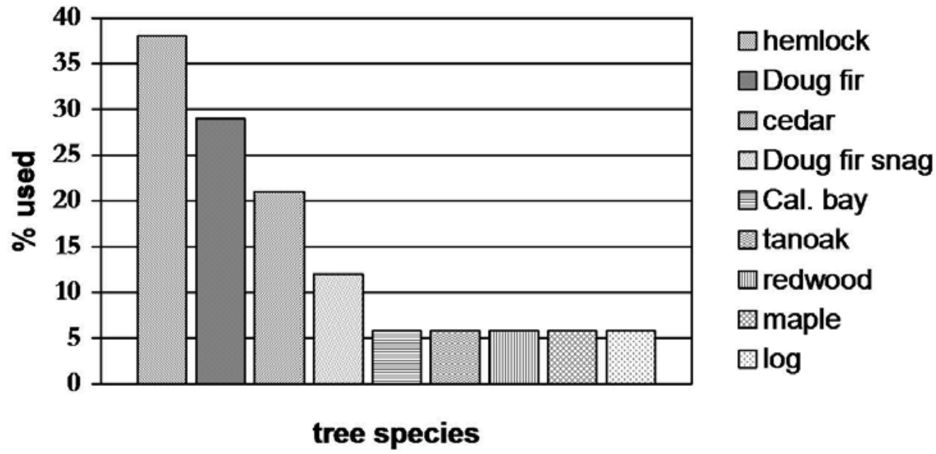


Figure 7. Distribution of structures used as rest sites.

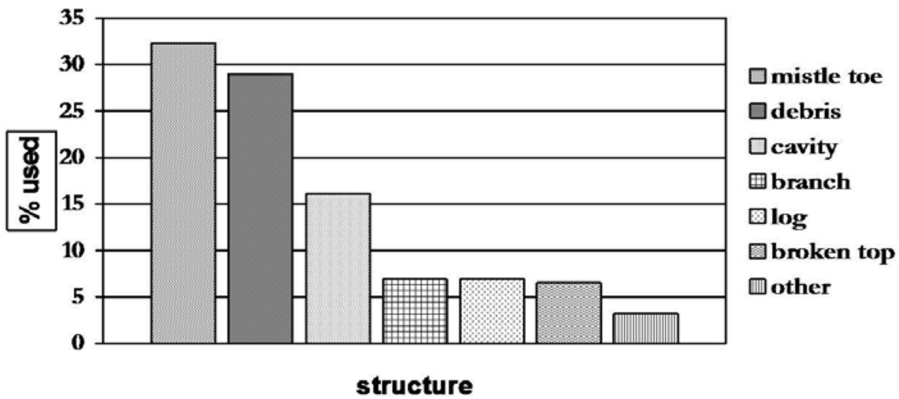
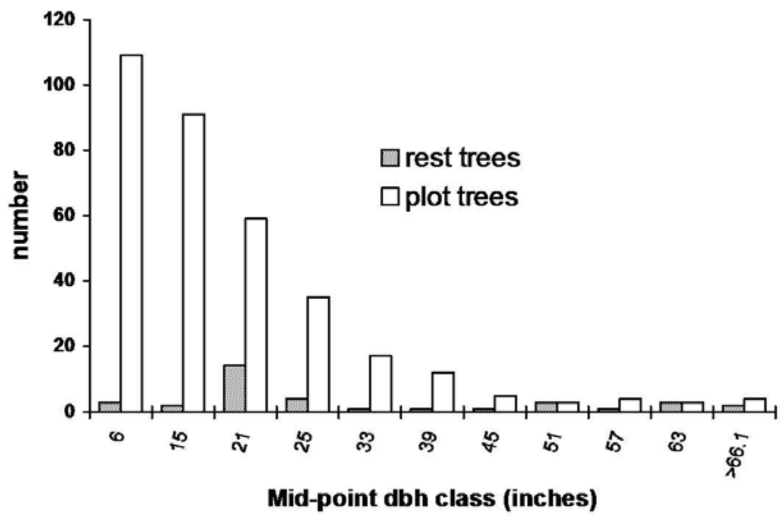


Figure 8. Size class distribution of rest versus surrounding plot trees.



Conclusion: Larger hardwood and conifers with cavities were particularly important to fishers for den sites. Fishers use a wider range of structures for rest sites and these can be found in a broad range of tree sizes compared to den trees. In contrast to den sites that occur in cavities, rest sites tend to be in open structures such as mistletoe or debris platforms. In general, fishers were using the same types of structures in trees for den and rest sites as those used by northern spotted owls for roosting and nesting on Green Diamond's ownership. The primary difference is that fishers show a strong selection for cavities for reproductive sites, while spotted owls show relatively little use of cavities for nesting.

POPULATION DENSITY
(MS graduate study)

2002-2003: Joel Thompson, Department of Wildlife, Humboldt State University, major advisor, Rick Golightly, – "*Abundance and density of fishers on managed timberlands of north coastal California*." The following sections are excerpted from the thesis.

This study employed a capture-resight technique to quantify the abundance and density of fisher on two separate 100 km^2 study sites in north coastal California. Given the problems associated with estimating density of animals that roam over large areas, radio telemetry was used to determine the proportion of time individual marked fishers spent in the study area. The proportional use of the study area by each marked individual was considered an animal equivalent, with full time occupancy equaling a full time animal equivalent. Animal equivalents were then summed and used in a mark-recapture population estimator in place of the number of marked animals

STUDY AREA

Two study areas were defined by two contiguous blocks of Green Diamond ownership, each area being large enough to contain multiple 100 km^2 potential study sites where sampling would occur. One 100 km^2 study site was chosen in each study area by selecting a random point along a line that bisected each study area lengthwise. The Korbel study site center was located at 422560 E, 4533745 N and the Bald Hills study site center at 427158 E, 4564283 N (Universal Transverse Mercator (UTM) Zone 10, NAD 83) (Figure 9).

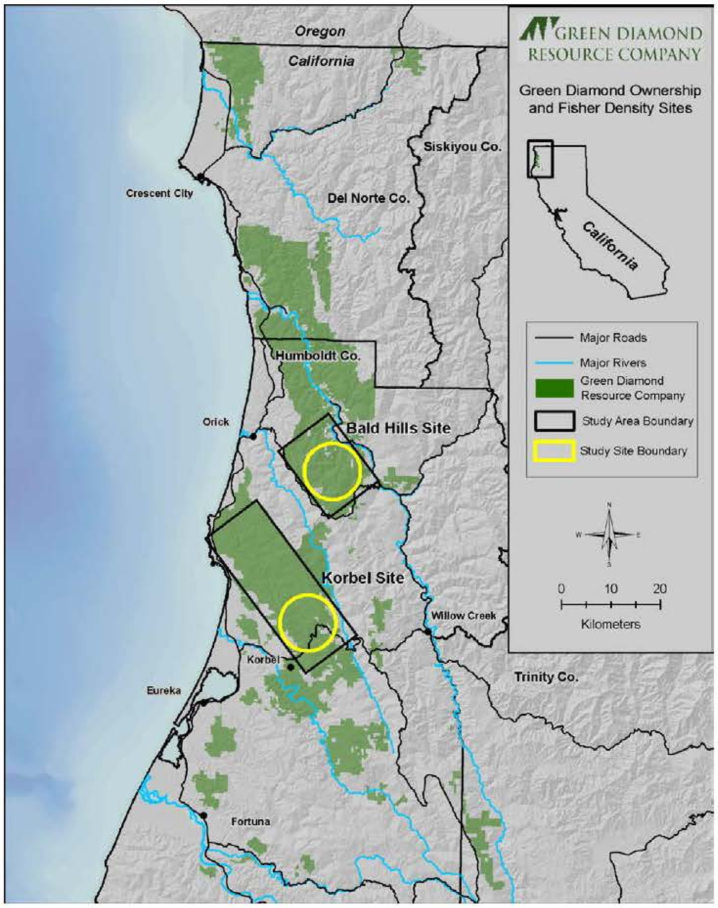


Figure 9. Location of two 100 km^2 study sites (circles) which were randomly selected from two study areas (rectangles) and used to estimate density of fisher on managed timberlands in north coastal California during summers of 2002 and 2003.

The vegetative composition of the study sites was predominately Douglas-fir (*Pseudotsuga menziesii*) and coast redwood (*Sequoia sempervirens*). Other conifers, including hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*) and western red cedar (*Thuja plicata*) were abundant in some locales. Hardwoods, including red alder (*Alnus rubra*), madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflorus*) and California bay (*Umbellularia californica*) were also significant components of the overstory canopy (Tables 1, 2). Due to the intensive management of the timberlands, the forested areas were comprised of "stands" of timber, defined as patches of contiguous forest of similar age and tree species. These stands varied in age from recently harvested to 60-80 year-old second-growth and created a patchwork of young stands scattered among older second-growth stands. Larger residual trees, often left behind due to low merchantability or inaccessibility, were scattered throughout the younger stands. Old growth stands comprised less than one percent of the study areas or study sites.

Table 1. Distribution of forest age classes for two 100 km^2 study sites used to estimate population density of fisher on managed timberlands in north coastal California during summers of 2002 and 2003. The "unknown" age class represents lands not owned by Green Diamond Resource Company.

Study site	Forest age class	% of study site in age class
Bald Hills	unknown	5.5
	0-5	7.9
	6-20	9.0
	21-40	53.1
	41-60	10.0
	61-80	4.3
	81-179	9.1
	180+	1.1
Korbel	unknown	13.1
	0-5	10.3
	6-20	10.9
	21-40	21.4
	41-60	34.9
	61-80	8.8
	81-179	0.6
	180+	0.0

Table 2. Basal area of forest types for two 100 km^2 study sites used to estimate population density of fisher on managed timberlands in north coastal California during summers of 2002 and 2003.

Study Site	Forest type	Basal area (m^2)
Bald Hills	Old growth redwood[a]	51.4
	Old growth white wood[b]	223.1
	Young growth redwood[c]	552.7
	Young growth white wood	2587.4
	Hardwood	5396.4
Korbel	Old growth redwood	85.6
	Old growth white wood	156.2
	Young growth redwood	1926.3
	Young growth white wood	2572.9
	Hardwood	3231.9

[a] Old growth consisted of residual trees exhibiting old-growth characteristics such as large lateral branches, deeply furrowed bark and/or high degree of decadence.
[b] White wood included Douglas-fir, western hemlock and grand-fir.
[c] Young growth included all forest less than 150 yrs of age.

METHODS

Mark-resight methods were used to estimate fisher density at the two study sites in 2002 and 2003. Fishers were trapped and marked in the two 100 km^2 study sites for 3-4 months in late winter and early spring each year. A maximum of 13 traps were used at any one time. Successful traps were often moved to avoid recapturing the same individual. Because trapping was coincident with the spring denning period, traps were checked twice daily to minimize the time a female might be kept away from an active den. Reproductive status was based on signs of nursing (lactating or swollen teats). Radio collars (Model 080, 34-36g, Telonics Inc., Mesa, AZ) were attached to all females. Males captured in the most accessible portions of the study sites were also radio-collared. All fishers were ear-tagged with uniquely colored rototags (Dalton, Nasco Industries, Ft. Atkinson, WI). Hereafter, individuals with radio collars are referred to as “radio-marked animals”, those with ear tags and no collars, as “tagged animals”, and the two groups combined as “marked” animals.

Following trapping, remote cameras (Canon Sureshot Owl pf Date, Canon USA Inc., Lake Success, NY) were used to photograph fishers during three 4-week sampling periods in 2002, (10 June – 30 August) and four 4-week sampling periods in 2003 (5 May – 30 August). Cameras were placed in double-walled black ABS corrugated culvert pipe (120 cm long x 30.5 cm diameter) and were triggered when animals stepped on a pressure sensitive treadle attached to the bottom of the culvert pipe and wired to the camera. This ensured photographs provided a frontal view of the head, allowing ear-tags to be identified. Camera stations were placed at 1.6 km spacing across the study sites in grid formation creating 44 camera stations within each study site. Where access was limited, cameras were placed as close to the grid point as possible. All cameras were placed in vegetation that provided overhead cover and baited with a piece of chicken. Cameras were checked weekly to replace film and bait. The number of cameras was limited to 22; therefore, the 4-week sampling periods were divided into two 2-week sessions, which allowed for one camera at every other grid point on both study sites. Cameras were moved to adjacent grid points every two weeks. Two-week sessions were combined into 4-week sampling periods. Grid spacing allowed for a minimum of three cameras in each home range at all times. Photographs were considered independent if fishers were marked and identified as different individuals or if more than 60 minutes elapsed since the previous fisher was photographed.

Radio-marked fishers were located 1-3 times per week during the sampling periods using a portable receiver and a hand-held H-antenna. Estimated fisher locations were based on the geometric center of the polygons created by azimuths from three different locations used to receive the signal. Each estimated location was plotted on the 1:12000 scale maps and determined to be either in or out of the study site. A single azimuth was used to determine if an animal was in or out of the study site when the signal was received from a location near the perimeter of the site and was in a direction that unambiguously placed the animal in or out of the study site.

I sexed unmarked fishers by measuring head size on photographs along horizontal axes between the eyes and the innermost portion of the ears. Each camera was constructed with a treadle plate of known size, therefore I compensated for the varying distance from the camera to the animal by using a ratio based on head size and treadle width. To test for observer bias, 25 percent of all measured photos were re-measured by a second observer for comparison. I used distance between the eyes, distance between the ears and the sum of these distances to calculate three ratios and used logistic regression to determine the best variable for assigning sex to unmarked individuals. All unmarked individuals were classified as male or female prior to density calculations. Telemetry locations were used to determine the proportion of time each radio-marked fisher spent within each study site. The number of locations within the study site was used to determine the proportion of time each radio-marked fisher was available and was expressed as animal equivalents (Garshelis 1992). Tagged females were assigned an animal equivalent based on the average animal equivalent of radio-marked females. Animal equivalents were summed and considered the number of marked female animal equivalents available for capture during each sample period. Fishers captured and tagged in year one, not captured in year two, but photographed and still identifiable in year two, were considered marked fishers. Individuals found deceased were excluded from estimates for sample periods following their death and from pooled estimates in order to satisfy the assumption of demographic closure. Individuals photographed late in the year and classified as juveniles were also excluded from analyses, therefore all estimates represent non-juvenile fishers.

Since telemetry locations for radio-marked males were limited, I was unable to assign animal equivalents to tagged males using the same method used for females. Instead, I assigned animal equivalents to tagged males that were photographed based on the percentage of their estimated minimum convex polygon home ranges that were contained within the study site boundaries. Because male fishers have larger home ranges than females, I stratified all analyses by sex. I used a modified version of Bowden's estimator (Bowden 1993, Bowden and Kufeld 1995) to calculate separate density estimates for male and female fishers similar to the methods of Matthews et al. (2007). Density estimates were calculated for three sampling periods in 2002 and four sampling periods in 2003. I also calculated annual estimates using pooled data from all periods each year to assess how the estimator functioned with differing levels of information. In place of individual animals, animal-equivalents were substituted, as described by Garshelis (1992), to correct for animals that routinely crossed study site boundaries during the sampling periods. When substituting animal-equivalents, the result of the estimator was a density estimate, which was achieved without adjusting the size of the study sites to compensate for animals that did not reside wholly within the study site boundaries. The modified Bowden estimator, with terms equivalent to Garshelis' animal-equivalents (indicated by *), estimated the density of animals ($\hat{N}^*$) by:

$$\hat{N}^* = \frac{\dfrac{u.+m.}{\bar{f}^*} + \dfrac{S_f^2}{\bar{f}^{*2}}}{1 + \dfrac{S_f^2}{M^*(\bar{f}^{*2})}}$$

where u. was the total number of independent photographs of unmarked fishers, m. was the total number of independent detections of marked fishers, $\bar{f}^*$ was the mean detection frequency of marked animals and S_f^2 was the variance in detection frequency of marked animals. The total animal equivalents residing on the study site during a sampling period (M*) was substituted for the total number of marked animals (M) in the original Bowden equation. Because of this substitution, the end result of the estimator was the number of animal equivalents residing within the defined study site (density) and not the number of animals using the study site and adjacent areas (abundance). Arnason et al. (1991) found that the usual method of constructing a 95 percent confidence interval for N as

$\hat{N} \pm 1.96 * \hat{S}(\hat{N})$ provided poor limits on the estimate. Therefore, an inverse cube root transformation (Arnason et al., 1991) was used to generate 95 percent confidence intervals by substituting the density estimate ($\hat{N}*$) for $\hat{N}$. The resulting 95 percent confidence intervals were generated using the following series of equations, where $\hat{T}$ was the inverse cube root of the density estimate ($\hat{N}*$):

$$\hat{T} = \hat{N}^{*-\frac{1}{3}}$$

with variance;

$$\hat{S}(\hat{T}) = \frac{\hat{T} * S(\hat{N}^*)}{3\hat{N}^*}$$

yielding inverse limits;

$$(T_L, T_U) = \hat{T} \pm 1.96 * \hat{S}(\hat{T})$$

and 95% confidence limits;

$$(\hat{N}^*_L, \hat{N}^*_U) = (\frac{1}{T_U^3}, \frac{1}{T_L^3})$$

where,

$$S(\hat{N}^*) = \sqrt{\frac{\hat{N}^{*2}\left[\frac{1}{M^*} - \frac{1}{\hat{N}^*}\right]\frac{S_f^2}{\bar{f}^{*2}}}{\left[1 + \frac{S_f^2}{M^*\bar{f}^{*2}}\right]^2}}$$

Arnason et al. (1991) found the inverse cube root transformation to be highly effective at improving the approximation to normality for very small samples and small numbers of marked animals, which makes it appropriate for use with wide ranging mammals that occur at low densities, such as fisher.

Home range size was estimated using a combination of telemetry locations, camera detections and capture locations. The computer program CALHOME (Kie et al.1996) was used to generate 100 percent minimum convex polygon (MCP) home range estimates. These home range estimates were used to calculate density estimates based on the number of home ranges that fit within a study site. These estimates were then compared to my mark-resight density estimates and to density estimates generated by other researchers using similar home range techniques. I estimated home range size for all individuals with a minimum of 10 locations. I compared home ranges with 10-15 locations to home ranges with 20 or more locations using ANOVA. Telemetry locations were only

considered for home range analyses if the distance between the farthest receiving location and estimated transmitter location was less than 1.6 km and the view from the receiver locations to the estimated animal location was unobstructed by topography.
Telemetry error was calculated from field tests. Field tests consisted of radio collars being placed in known fisher habitat by one observer and locations being blindly estimated by a second observer. Test location estimates were based on the same criteria used to select points for home range analysis.

RESULTS

I captured 20 fishers in 2002 and 23 fishers in 2003. Of the 23 individual fishers captured in 2003, seven were previously marked in 2002 and 16 were unmarked (Table 3).

Table 3. Fisher captured during late winter and early spring of 2002 and 2003 on managed timberlands in north coastal California.

Year	Fisher captures	Individual fishers	Females	Males	Trap nights
2002	27	20	10	10	1410
2003	36	23	15	8	1356
Total	63	36	19	17	2766

During the two-year period, I obtained 197 independent photographs of marked fishers and 181 independent photographs of unmarked fishers. All males using the study sites were photographed at least once each year. Seven of eight females using the sites were photographed in 2002 and 12 of 13 females in 2003. The one female not photographed in 2002 spent only a small portion of time on the study site before leaving the area. The one female not photographed in 2003 was recovered dead near the end of the first sampling period that year; this female was alive during period one and included in estimates for that period, but excluded from all others periods and the pooled estimate for 2003.

The ratio of ear-width/treadle-width was the first variable to enter the logistic model and determined to be the best predictor of sex for marked individuals. All unmarked individuals with ratios greater than 0.278 were classified as males and all those less than 0.278 were classified as females. Using the 0.278 ratio, 94.7 percent of known females and 82.5 percent of known males were correctly classified. There were six photographs of animals that could not be identified as marked or unmarked. These were considered unknown and not used in the density calculations. There were 16 photographs of unmarked fishers that could not be measured and therefore could not be assigned a sex. These unmarked fishers were allocated according to the estimated male/female ratio (calculated from photographs of known individuals during the same sample period on the same study site) and added to the appropriate unmarked totals for each individual sampling period and for all sampling periods combined each year.

The ratio of marked/unmarked fishers averaged 0.49 ± 0.10 ($\bar{x}$ ± SE) in 2002 and 3.22 ± 0.61 in 2003. Marked fishers were detected an average of 1.59 ± 0.33 times per sample period in 2002 and 2.24 ± 0.21 times per sample period in 2003. Female density estimates ranged from 0.05 - 0.22 fisher/km^2. Male density estimates for the Bald Hills site varied from 0.05 - 0.16 fisher/km^2 (Table 4). Mean population density of male and female fishers was 0.07 ± 0.01 fisher/km^2 and 0.11 ± 0.02 fisher/km^2, respectively for both years and both study sites combined. I was unable to estimate male density on the Korbel study site due to insufficient sightings of marked males. Confidence intervals were extremely small for some estimates because of high proportions of marked to unmarked fisher detections. Differences in upper and lower confidence limits were greater for the means of individual sample periods than for estimates using pooled data.

Home range was calculated for 15 fishers (Table 5). I found no differences in home range size of fishers with 10-15 locations (n=5) compared to fishers with 20 or more locations (n=6), therefore all home range estimates with 10 or more locations were used for comparison purposes. Due to the high density of roads within the study sites, greater than 90 percent of all estimated fisher locations used to calculate home range were within 400 m of the observer. Telemetry error ranged from 12-366 m (119 ± 32; $\bar{x}$ ± SE; n=12). Locations were collected over an average period of 54.3 ± 8.0 weeks. Mean home range size was 602 ± 48 ha for females and 882 ± 400 ha for males. Female home range size was not different across study sites. Density estimates calculated by dividing study site area by mean home range size for both study sites combined resulted in 0.17 female fisher/km^2 and 0.11 male fisher/km^2.

Table 4. Density estimates (fisher/km^2) and 95% confidence intervals for fishers using managed timberlands on two study sites in north coastal California during summers of 2002 and 2003. Fishers captured in 2002, not captured in 2003, but photographed and identified as marked in 2003 were considered marked individuals for density calculations. Pooled estimates used data from all sample periods combined to create a single sample period each year.

Study site	Sex	Year	Sampling period	Density	95% confidence limits: Lower limit	Upper limit
Bald Hills	Female	2002	1	0.11	0.07	0.20
			2	0.22	0.11	0.56
			3	0.14	0.08	0.28
			Pooled	0.17	0.13	0.23
		2003	1	0.10	0.07	0.15
			2	0.08	0.06	0.12
			3	0.08	0.05	0.12
			4	0.07	0.04	0.13
			Pooled	0.09	0.06	0.14
	Male	2002	1	0.06	0.04	0.09
			2	0.07	0.04	0.12
			3	0.05	0.03	0.09
			Pooled	0.06	0.04	0.09
		2003	1	0.09	0.06	0.14
			2	0.08	0.06	0.11
			3	0.07	0.05	0.11
			4	0.07	0.06	0.08
			Pooled	0.08	0.06	0.11
Korbel	Female	2002	1	0.09	0.05	0.17
			2	0.05	0.03	0.12
			3	0.09	0.05	0.18
			Pooled	0.09	0.06	0.15
		2003	1	0.09	0.09	0.09
			2	0.06	0.06	0.06
			3	0.07	0.06	0.07
			4	0.11	0.11	0.11
			Pooled	0.08	0.08	0.08

Table 5. Home range estimates (100% MCP) calculated using 10 or more locations for marked fishers on managed timberlands in north coastal California during summers of 2002 and 2003. Locations included radio triangulations, camera detections, capture sites, rest sites and den sites.

Study site	Animal ID	100% MCP	# locations	Period monitored
Korbel	Female2	513	20.0	2/26/02-05/23/03
	Female7	849	29.0	4/25/02-02/11/04
	Female10	394	33.0	5/20/02-08/27/03
	Female14	555	14.0	2/13/03-02/11/04
	Female16[a]	466	13.0	3/11/03-08/17/03
	Female17	599	10.0	3/12/03-07/02/03
	Male17[a]	816	10.0	4/16/03-07/28/03
Bald Hills	Female4	663	41.0	3/28/02-08/22/03
	Female5	764	45.0	4/02/02-07/14/03
	Female6	613	29.0	3/26/02-11/23/02
	Female9	387	15.0	5/15/02-08/13/03
	Female19	822	12.0	3/27/03-08/13/03
	Male7	320	17.0	4/10/02-12/07/02
	Male8[a]	2036	10.0	4/14/02-07/27/03
	Male11	357	12.0	7/29/02-12/14/04
Bald Hills	Female avg.	650	28.4	-
	Male avg.	904	13.0	-
Korbel	Female avg.	563	19.8	-
	Male avg.	816	10.0	-
Overall	Female avg.	602	23.7	-
	Male avg.	882	12.3	-

[a] Collared as subadult/immature animals

DISCUSSION

Black bear were the most frequently photographed animal followed by fisher, gray fox and spotted skunk. The number of photographs does not necessarily reflect abundance or population density, but it does reflect common mammalian carnivores in the area.

Compared to other study areas in northern California, mean home range size of 11 females in this study was similar to those reported by Buck et al. (1983), more than three times greater than those reported by Yaeger (2005), and 26-47 percent of those reported by Seglund (1994), Dark (1997) and Zielenski et al. (2004). Female home range size on my study sites was very similar to that reported by Zielenski et al. (2004) for their southern Sierra Nevada study area. Male home range size averaged 882 ha in my study and was the smallest mean home range size of male fisher reported in the literature. The difference in home range size among studies further supports the idea that density of fishers differed depending on geographic location. Harestad and Bunnell (1979) found that home range size was correlated with surrogate variables for habitat productivity, suggesting that home range size decreases with increased measures of habitat productivity (i.e. rainfall, latitude, etc.). Zielinski et al. (2004) suggested that higher habitat quality was the main factor influencing the smaller home range size of female fishers in their southern Sierra Nevada study area compared to their northern California study area. Weir and Corbould (2006) stated that distance between home ranges, in addition to home range size, was related to the quality and spatial distribution of habitats. Golightly et al. (2006) found the diet of fishers residing in coastal forests to be more diverse than those of more interior forests. Woodrats (*Neotoma fuscipes*) often occur at high densities in the coastal forests of northern California (Hamm 1995) and have been found to be the most common species in the diet of fishers in the coastal region (Golightly et al. 2006). This may be due to the greater understory complexity of coastal forests compared to drier, more interior forests (Carraway and Verts 1991). The high density of woodrats available to fishers in coastal regions may be at least partially responsible for a positive numerical response in fisher numbers, similar to the positive response of fisher populations to hare densities in Ontario, Canada (Bowman et al. 2006). Increased habitat heterogeneity and productivity generally lead to increased abundance of key habitat elements (e.g. rest and den sites) and potential prey species. With better access to key habitat elements and increased availability of prey, fishers would not require as large an area to survive and reproduce; therefore they would have smaller home ranges. Variation in habitat quality and continuity at various geographic locations are likely the key variables influencing density of fishers.

My estimates of fisher density were very similar to those reported by Fuller et al. (2001) in Massachusetts, roughly twice as great as those reported by Buck (1982) and Mullis (1985) in California, and more than 150 times greater than those reported by Weir and Corbould (2006) in British Columbia (Table 6).

Making direct comparisons among these studies was difficult because estimates were calculated using different methodologies. However, Fuller et al. (2001) presented estimates based on a territory mapping method, with supporting evidence from a mark-recapture estimate. Only the mark-recapture density estimate of Fuller et al. (2001) and the estimates I have presented here, have confidence intervals associated with the estimates. However, Fuller et al. (2001) recognized several problems associated with their mark-recapture estimates, and presented the estimates only as supporting evidence for the accuracy of their territory mapping method. The use of methodologies which generate confidence intervals associated with estimates allows for more meaningful comparisons of estimated density across studies and for comparing density estimates over time.

My density estimates based on home range size were more than three times greater than those reported by Buck (1982) and Mullis (1985) using similar home range size techniques and 22-87 percent greater than my estimates generated using the modified Bowden estimator (Table 4). Estimates calculated using home range size were hampered by edge effects and the assumption that the study sites were fully occupied. However, empirical evidence suggested the study sites were not completely occupied and that this assumption was the most significant factor influencing the inflated home-range based estimates. These two comparisons were examples of how density estimates were affected by methodology as well as temporal-spatial differences and the importance of using consistent methodologies when making comparisons.

Table 6. Fisher density estimates and the methods for estimation from studies across North America.

Study	Location	Density (fisher/km^2)	Estimator type	Confidence intervals associated
This study	California	0.15-0.23	Modified Bowden	Yes
This study	California	0.28	Sample Area/ Mean Home Range	No
Buck 1982	California	0.08	Sample Area/ Mean Home Range	No
Mullis 1985	California	0.08	Sample Area/ Mean Home Range	No
Fuller et al. 2001	Massachusetts	0.19-0.23	Territory Mapping	No
Fuller et al. 2001	Massachusetts	0.21-0.25	Mark-Recapture (Program NOREMARK)	Yes
Wier and Corbould 2006	British Columbia	0.008-0.013	Minimum Number Alive/Sample Area[a]	No

[a] Minimum number of animals alive based on capture and telemetry data divided by the effective sample area.

LITERATURE CITED

Arnason, A. N., C. J. Schwarz, and J. M. Gerrard. 1991. Estimating closed population size and number of marked animals from sighting data. Journal of Wildlife Management 55:716-730.

Bowden, D. C. 1993. A Simple technique for estimating population size. Department of Statistics, Colorado State University, Fort Collins, USA.

Bowden, D. C., and R. C. Kufeld. 1995. Generalized mark-sight population size estimation applied to Colorado moose. Journal of Wildlife Management 59:840-851.

Bowman, J., D. Donovan, and R. C. Rosatte. 2006. Numerical response of fishers to synchronous prey dynamics. Journal of Mammalogy 87:480-484.

Buck , S. G. 1982. Habitat utilization by fisher (Martes pennanti) near Big Bar, California. Thesis, Humboldt State University, Arcata, California, USA.

Buck, S. G., C. Mullis, and A. S. Mossman. 1983. Corral-Bottom/Hayfork Bally fisher study. Unpublished final report. U.S. Forest Service and Humboldt State University, Arcata, California, USA.

Carraway, L. N., and B. J. Verts. 1991. Neotoma fuscipes. Mammalian Species 386:1-10.

Dark, S. J. 1997. A landscape-scale analysis of mammalian carnivore distribution and habitat use by fisher. Thesis, Humboldt State University, Arcata, California, USA.

Fuller, T. K., E. C. York, S. M. Powell, T. A. Decker, and R. M. DeGraaf. 2001. An evaluation of territory mapping to estimate fisher density. Canadian Journal of Zoology 79:1691-1696.

Garshelis, D. L. 1992. Mark-recapture density estimation for animals with large home ranges. Pages 1098-1111 in D. R. McCullough, and R. H. Barrett, editors. Wildlife 2001: Populations. Elsevier Applied Science, New York, New York, USA.

Golightly, R. T., T. F. Penland, W. J. Zielinski, and J. M. Higley. 2006. Fisher diet in the Klamath/north coast bioregion. Unpublished report. Department of Wildlife, Humboldt State University, Arcata, California, USA.

Hamm, K. A. 1995. Abundance of dusky-footed woodrats in managed forests of north coastal California.Thesis, Humboldt State University, Arcata, California, USA.

Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight – a reevaluation. Ecology 60:389-402.

Kie, J. G., J. A. Baldwin and C. J. Evans. 1996. CALHOME: A home range analysis program. Electronic Users Manual.

Matthews, S. M., R. T. Golightly, and J. M. Higley. 2007. Mark-resight density estimation for American black bears in Hoopa, California. Ursus 19: *in press*.

Mullis, C. 1985. Habitat utilization by fisher (Martes pennanti) near Hayfork Bally, California. Thesis, Humboldt State University., Arcata, California, USA.

Seglund, A. E. 1995. The use of resting sites by the Pacific fisher. Thesis, Humboldt State University, Arcata, California, USA.

Weir, R. D., and F. B. Corbould. 2006. Density of fishers in the sub-boreal spruce biogeoclimatic zone of British Columbia. Northwestern Naturalist 87:118-127.

Yaeger, J. S. 2005. Habitat at fisher resting sites in the Klamath province of northern California. Thesis, Humboldt State University, Arcata, California, USA.

Zielinski, W. J., R. T. Truex, G. A. Schmidt, F. V. Schlexer, K. N. Schmidt, and R.G. Barrett. 2004. Home range characteristics of fishers in Califonia. Journal of Mammalogy 85:649–657.

MONITORING CHANGES IN FISHER DISTRIBUTION AND RELATIVE ABUNDANCE (In-house study)

1994, 1995, 2004 and 2006: As noted above, Green Diamond Resource Company (formerly Simpson Timber Company) supported a Humboldt State University MS study that utilized sooted track plates to determine the distribution and habitat associations of fishers throughout its ownership. The specific objectives of that study were to use sooted track plates to: 1) determine the distribution of fishers across the ownership, 2) assess differences in fisher occurrence among three major vegetation types (redwood, *Sequoia sempervirens*, Douglas-fir, *Pseudotsuga menziesii*, and mixed redwood-Douglas-fir) and 3) to identify habitat attributes associated with stands where fishers were and were not detected. While the track plate surveys were not specifically designed for monitoring long term trends, we saw the opportunity to repeat the surveys at 10-year intervals to provide an estimate of potential changes in distribution or abundance of fishers throughout the ownership.

The objective in 2004 was to repeat the exact survey as was conducted in 1994 and 1995. Therefore, three complete surveys of the 40 segments were conducted from 19 January to 21 July in 1994, 1995 and 2004. In addition, 10, 11 and 8 segments were randomly selected in 1994, 1995 and 2004, respectively, and re-sampled following completion of the initial surveys to test for seasonal effects in detection rates. In 2006, we randomly selected 18 of the 40 original segments and surveyed them from 14 January to 1 March. This additional survey in 2006 was prompted when the Hoopa Tribal forestry's fisher study reported a potential decline in fisher numbers (M. Higley, pers. comm.).

Detection ratios were calculated using the station as the sample unit by dividing the number of stations with ≥1 fisher detection by the total number of stations sampled. We also calculated detection ratios based on segments by dividing the number of segments with ≥1 detection by the number of segments sampled. These detection ratios were used to assess trends in detection ratios over time and by region. Regional effects were assessed by grouping segments in localized regions with similar habitat characteristics. Regional groupings contained 2-6 segments each. We compared detection ratios for initial visits to detection ratios of revisits to assess seasonal effects. Only segments sampled during the initial visit and during the re-visit were used for this comparison.

RESULTS

Fishers were detected throughout Green Diamond's ownership even in close proximity to the coast (Figure 1). The one exception was that no fishers were detected in the coastal areas near Humboldt Bay and in the Eel River drainage. The greatest number of incidental sightings occurred in areas where fishers were present that also had higher levels of timber management activities (e.g. surveys for spotted owls, timber harvest layout and etc.).

Mean detection ratios during the 4 sample periods from 1994-2006 varied from 0.40 to 0.67 (Figure 2) at the segment level and 0.14 to 0.33 at the station level (Figure 3). Detection ratios varied among initial visits and revisits of the same segments. At the station level, detection ratios during initial visits varied from 0.15-0.21 (mean = 0.16 ± 0.19) compared to 0.10-0.21 (mean = 0.17 ± 0.03) for revisits (Figure 4). At the segment level, ratios varied from 0.27 – 0.50 (mean = 0.42 ± 0.08) during initial visits and 0.50-0.64 (mean = 0.58 ± 0.04) during revisits (Figure 5).

Figure 1. Distribution of fisher detections as the result of track plate surveys and incidental sightings. Track plate surveys conducted in 1994, 1995, 2004 and 2006 with incidental sightings from 1993-2007.

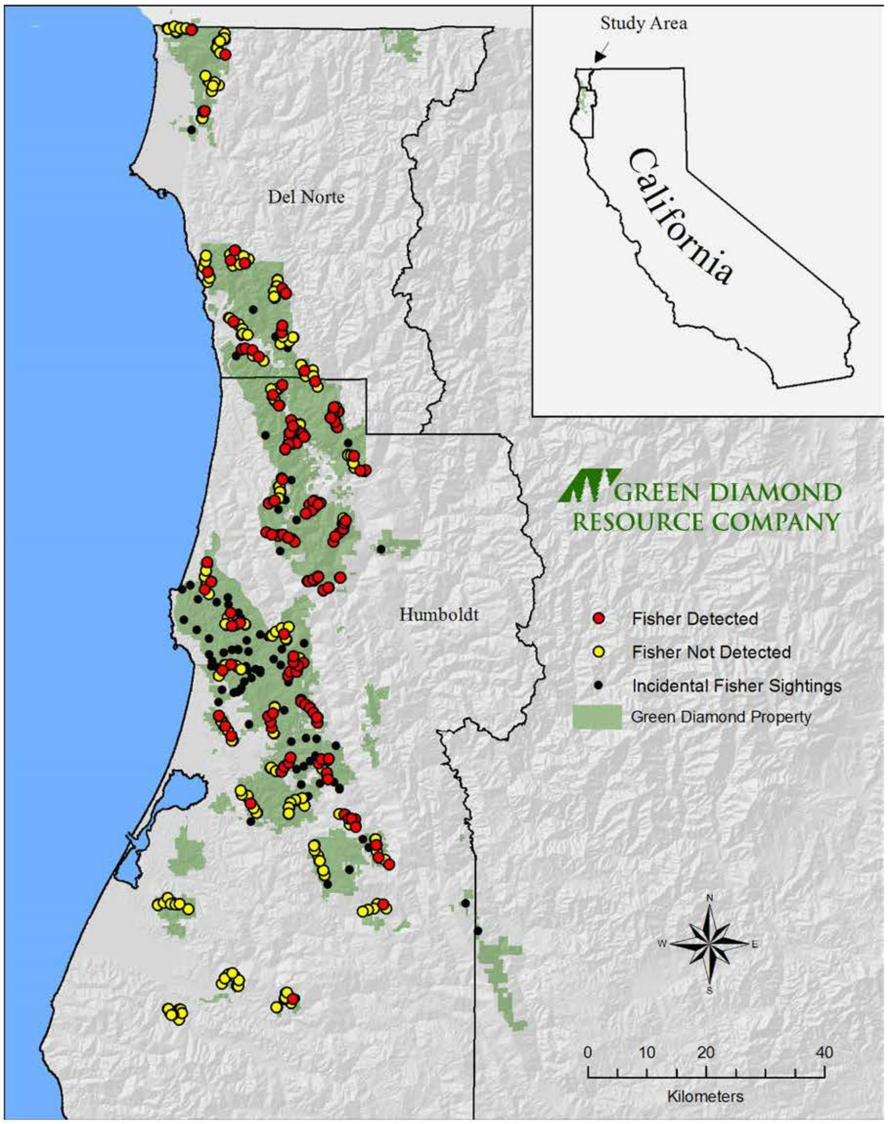


Figure 2. Detection ratio of fisher at sooted-track plate segments consisting of 4-6 track plate stations sampled from January - July 1994, 1995, 2004 and 2006 on managed timberlands in north coastal California. Detection ratios equal the proportion of segments sampled with ≥1 fisher detection. Segments were sampled every other day for 22 consecutive days.

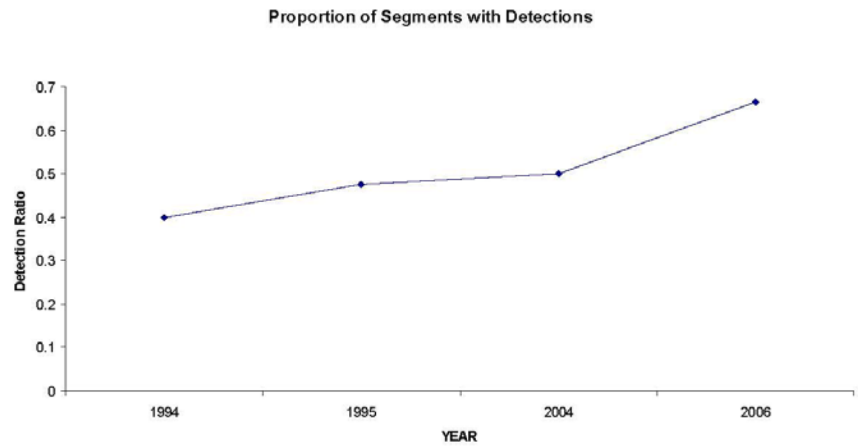


Figure 3. Detection ratio of fishers at sooted-track plate stations sampled from January - July 1994, 1995, 2004 and 2006 on managed timberlands in north coastal California. Detection ratios equal the proportion of all stations sampled with ≥1 fisher detection. Individual stations were sampled every other day for 22 consecutive days.

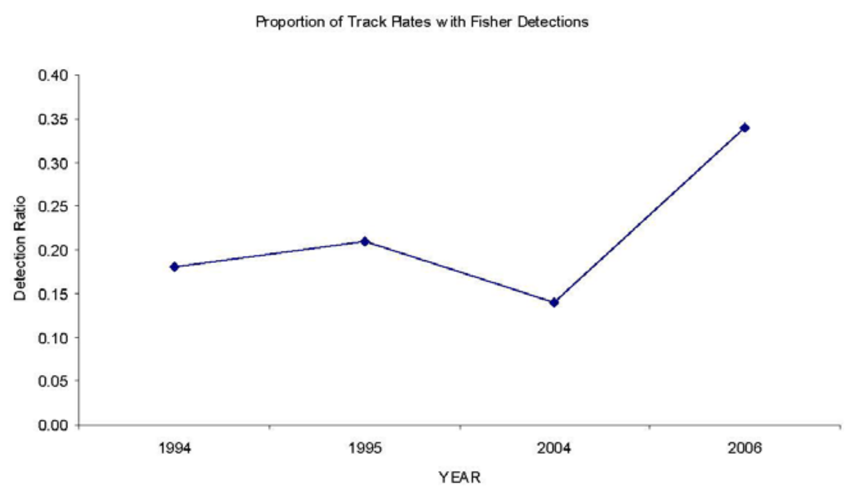


Figure 4. Detection ratio of fisher at sooted-track plate stations sampled from January - July 1994, 1995, 2004 and revisited during late summer. Ratios for initial visits represent only the stations which were revisited. Detection ratios equal the proportion of all stations sampled which had ≥1 fisher detection.

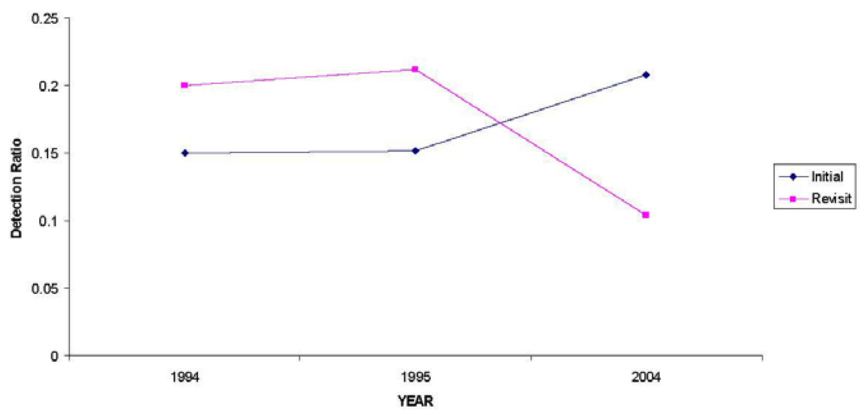
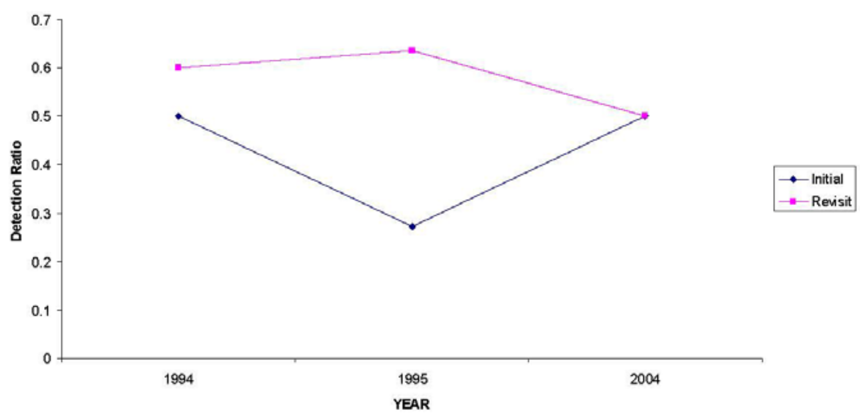


Figure 5. Detection ratio of fisher at sooted-track plate segments consisting of 4-6 track plate stations sampled from January - July 1994, 995, 2004 and 2006. Ratios for initial visits represent only the segments which were revisited. Detection ratios equal the proportion of all segments sampled which had ≥1 fisher detection.



DISCUSSION

There has been no long term monitoring of fisher abundance to generate quantitative estimates of fisher population trends in the north coastal region of California. However, repeated track plates surveys across Green Diamond's ownership in 1994, 1995, 2004 and 2006 provide an indication of potential trends in both distribution and abundance of fishers. Although the specific location of fisher detections varied temporally, overall, there was no evidence for any major shifts in the distribution of fishers in the study area. There also was variation in detections ratios within specific regions of Green Diamond's ownership, there were too few track plate segments per region to allow any meaningful analysis of annual detection ratios. Lacking more survey segments per region, we believe the best assessment of the impacts of management activities on local fisher populations is best addressed in the following section using patch occupancy models.

The detection ratios of survey segments appeared to increase from 1994 through 2006 (Figure 2). The apparent trend was somewhat more complicated based on detection ratios of individual track plate stations with an apparent drop in 2004 followed by a subsequent increase in 2006 (Figure 3). Comparisons between initial and revisit surveys (Figures 4 and 5) provide an indication of the variation of detection rations within a single year. While the difference between initial and revisits may have been due to seasonal variation in detectability, the lack of a pattern between these two sampling periods suggests that the differences were due to sampling variation. Assuming these differences were due to sampling variation, it was unlikely that the apparent trends among years represented statistically significant trends.

While it lacks in statistical and methodological rigor, the trend in incidental observations of fishers by field biologists and foresters may provide an index of fisher abundance through time. However, certain assumptions must be met before this index can be accepted as a reasonable approximation of the actual trend. Some of the key assumptions are that the number of observers was constant through time and that these observers put equal effort into observing fishers. It is also important that the incidental sightings were collected over the same area through time. While none of these assumptions were likely to have been strictly met, we can assess the manner in which the assumptions were likely violated. To begin with, prior to the first graduate study and survey for fishers in 1994, there was little awareness of fishers throughout the forestry and wildlife staff within Simpson Timber Company. As more work was done on the fisher, awareness increased and more of the staff was alert to and capable of identifying a fisher. The petitions to list the fisher in 1994 and 2000 also probably increased awareness of the fisher. Presumably, fisher awareness should have reached a peak by 2000 and has remained high to the present. Records kept by

Green Diamond biologists of incidental sightings from 1993-2008 reflects a pattern of relatively few sightings from 1993-1999 (0-3 sighting per year) with an overall increase from 2000-2008 (5-15 sightings per year). The pattern since 2000 when observer awareness should have reached a peak shows a drop in sightings from 2002-2004 (5 sighting per year) with an increase from 2005-2008 (5-15 sightings per year). While caution should be taken in direct interpretation of these apparent trends, the incidental sightings do corroborate the track plate data suggesting either an upward or at least no evidence for a downward trend.

FORAGING HABITAT ASSOCIATIONS OF FISHERS BASED ON OCCUPANCY MODELS OF TRACK PLATE DATA (In-house study)

August 2009: As noted above, sooted track-plate surveys were conducted in 1994, 1995 as part of a Humboldt State University graduate study to determine distribution and habitat associations of fishers. Later in 2004 and 2006, these same survey segments were repeated to identify potential trends in fisher distribution and abundance. The habitat associated with track plates could best be described as foraging habitat, because the fisher was most likely moving through its environment foraging when it detected the scent and entered the track plate box to eat the bait. All of these individual track plate stations provided presence/absence data from which we estimated site occupancy models (MacKenzie et al. 2006) that characterized foraging habitat affinities of an "average" fisher on Green Diamond's ownership. These models can also be used to predict the probability of occupancy by a fisher at locations where fishers were not detected or where surveys have not been conducted.

METHODS

The occupancy modeling was done by Ryan Nielson, Trent McDonald and Jim Griswold of Western EcoSystems Technology (WEST, Inc.).

Track plate stations:

During all surveys in 1994, 1995, 2004 and 2006 a total of 975 individual track plate stations were operated. We eliminated from analysis 161 track plate stations that were at the northern and southern limits of the ownership. These areas were on the periphery of the fishers' range within the north coast area and including them would confound analyses of habitat associations (i.e., lack of detections due to being outside the range of the fisher would be confounded with lack of detections due to unsuitable habitat). We also eliminated an additional 106 track plates that were off Green Diamond's ownership (mostly on private in-holdings). Since Green Diamond's GIS coverage did not extend beyond its ownership boundaries, we used only the remaining 708 sites to develop the site occupancy models. For similar reasons, a second site occupancy model was developed using 577 sites that were located a sufficient distance from the property boundary to meet an "interior" criterion. A site was defined to be interior if at least 75% of buffers with radii of 656ft (200m), 1312ft (400m), 1969ft (600m), and 2625ft (800m) were on the ownership (i.e., covered by GIS forest inventory data).

Covariates:

We required covariates of interest be known for all stations and included covariates that characterized both physiographic and habitat features representative of the study area. With the exception of the physiographic variables, which were by definition scaled to sum to 1, all variables were standardized so they had mean 0 and variance equal to 1.

Information available at each track plate station consisted of yearly GIS data on stand characteristics (e.g., age, height, tree species) and data from a digital elevation model. We computed covariates, such as percentage of the surrounding area in a particular age class, from the GIS using custom "fragstat" software, (Leitao et al. 2006). We derived values for each covariate (Table 2) from values at the track plate's location, or by calculating an average, proportion, density, or similar metric in a buffer centered on the track plate station. We evaluated some covariates on buffers of different sizes due to the potential for fishers to select these factors differently at different scales. We evaluated multiple-scale covariates on buffers with radii of 200, 400, 600 and 800m.

We calculated the slope position covariate for every track plate as the change in elevation from the valley to the station divided by the change in elevation from the valley to the ridge top, expressed as a percentage. Higher values of slope position (i.e., closer to 100%) indicated locations closer to the top of a ridge or hill, and lower values (i.e., closer to 0%) indicated points closer to the valley or ravine bottom.

We computed interior area for every station as the amount of area covered by the stand containing the track plate station. For this and other calculations, we defined stands as forested areas of uniform age class, where age class 1 was trees 0-5 years old, age class 2 was trees 6-20 years old, age class 3 was 21-40 years old, age class 4 was 41-60 years old, age class 5 was 61-80 years old, age class 6 was trees 81 years old or older, and age class 7 was non-forested areas. For consistency, any portion of a stand more than 800m from the track plate station of interest was ignored when calculating covariates.

We hypothesized that physiographic variables influenced heterogeneity in fisher occupancy; therefore, we included the following variables as potential covariates: elevation (*elev*), distance to coast (*coastdist*) and northing (*north*). Since non-linear relationships could exist between occupancy and these physiographic variables, the following sets of b-splines , (Wright and London 2009), were constructed for each physiographic variable: elev_bs (elev1, elev2, elev3, elev4), coastdist_bs (coastdist1, coastdist2, coastdist3, coastdist4), and north_bs (north1, north2, north3, north4). Thus we entered 6 physiographic variables into the stepwise forward-backward modeling process, 3 physiographic variables (elevation (elev), distance from the coast (coast_dist), northing (north) and 3 corresponding b-splines. We required each set of 4 b-splines for each physiographic variable to come into the model as a group but not singly. Thus, if the north b-spline set entered into the model, we estimated 4 occupancy coefficients for that set, 1 coefficient for each of north1, north2, north3 and north4.

We analyzed two sets of models. One included the indicator variable for year as a candidate variable and the other set excluded year from the candidate pool of potential covariates. For each set we also modeled all 708 track plate sites within GDRCo ownership and the constrained set of 577 that satisfied the interior criterion at all four buffer sizes. This resulted in estimation of four models.

Estimation:

Methods for estimating probability of occupancy by mobile animal species are often used when logistics or time make it difficult to estimate or count every individual within a sample site due to imperfect detection (MacKenzie et al. 2006). Imperfect detection of organisms can bias estimates of status, trends, and habitat relationships. MacKenzie et al. (2002) introduced a method of modeling site occupancy, or the proportion of sites occupied by a species, based on repeated surveys at a sample of sites where probabilities of detection are < 1. This technique evolved from established mark-recapture methods for estimation of the size of closed populations of mobile animals. A comprehensive review of methods for the study of site occupancy by animal species can be found in MacKenzie et al. (2006), and a recent special section in the Journal of Wildlife Management (2006, No. 2).

Our site occupancy models related physiographic and habitat variables to probability of occupancy while accounting for imperfect detection of fishers with a zero-inflated beta-binomial (BB) model (MacKenzie et al. 2006, Royle 2006). The BB model is a mixed effects model that allows probability of detection to vary randomly from site to site. Using this model eliminated the need to model probability of detection as a function of habitat or survey specific covariates in order to account for variability in detections. The BB modeled probability of detection at each site as a random variable from a beta distribution. The beta distribution is a continuous probability distribution defined on the interval [0,1], and is often used as a prior distribution for binomial proportions in Bayesian analysis (Agresti 2002).

The coefficients of the BB model and the site-specific predictions of probability of occupancy by a fisher were estimated by maximizing the likelihood

$$L(\psi,\beta,\alpha,\delta)=\prod_{i=1}^{N}\psi_i\pi_{bb}(k_i,T;\alpha,\delta)+I(k_i=0)(1-\psi_i), \qquad (1)$$

where N was the number of sites, ψ_i is the probability of occupancy for site i, $\pi_{bb}(k_i,T;\alpha,\delta)$ was the probability of k_i successful detection events (k = 0, 1, 2, ... T; T = 11) at the i^{th} track plate based on a beta-binomial mixture distribution with parameters α and δ, and $I(k_i=0)$ was an indicator function that equaled 1 for k_i = 0 (i.e., 11 unsuccessful capture events) and 0 otherwise. Site-specific probabilities of occupancy in equation 1 were modeled as a logistic function of habitat covariates

$$\psi_i = \frac{1}{1+\exp(-x_i\beta)}, \tag{2}$$

where x_j was the vector of characteristics associated with the i^{th} track plate station, and β was a vector of unknown coefficients. The beta-binomial probabilities $\pi_{bb}(k_i, T; \alpha, \delta)$ were computed as

$$\pi_{bb}(k,T;\alpha,\delta) = \frac{beta(k+\alpha, T-k+\delta)\binom{T}{k}}{beta(\alpha,\delta)}. \tag{3}$$

where α and δ were unknown shape parameters to be estimated. Based on this parameterization of the beta-binomial mixture, the mean and variance of the number of expected detections out of T surveys at one track plate in an occupied site was $\mu = T\alpha/(\alpha+\delta)$ and $\sigma^2 = T\alpha\delta(T+\alpha+\delta)/\left((\alpha+\delta)^2(1+\alpha+\delta)\right)$, respectively. The R software package (R Development Core Team 2006) was used to estimate the site occupancy models.

<u>Model Building:</u>

Prior to model building, we used a colinearity (Neter et al. 1985) analysis to estimate a correlation coefficient for every pair of covariates under consideration. During this analysis, we identified relatively high colinearity ($|r| > 0.6$) between many pairs of covariates. To break these colinearities, covariates were either dropped from the analysis prior to model building, or model building was performed in such a manner as to not allow colinear covariates in the same model.

Relatively high colinearity was identified between linear age of stand and both tree height and the percentage of a 200 m buffer in age class 6. Linear age of stand was dropped from the analysis to break these colinearities because age of stand was also represented as indicators for age classes and in percentages of buffers of various age classes. Relatively high colinearity was identified between interior area and edge density, patch density, and mean patch size within all 4 buffer sizes, so interior area was dropped from the analysis. The coefficient of variation (CV) of patch sizes within various buffers and distance to nearest edge were highly correlated with edge density, patch density, and mean patch size, so CV of patch sizes calculated in the 4 buffers around each track plate location and distance to nearest edge were dropped from the analysis.

We found relatively high colinearity between mean patch size, patch density, and edge density. Because all of these variables were deemed potentially important explanatory variables, we chose to not allow 2 or more of these variables in the same site occupancy model. In addition, edge density and open edge density were highly correlated and were not allowed in the same model, as were edge density and percentage of a buffer in age class 1. Finally, indicators for redwood and whitewood dominated stands were correlated with percent redwood and percent whitewood, respectively, so either the indicator or the percentage was allowed in a model, but not both.

Quadratic terms were considered during model building for all continuous variables in Table 2. We required the linear term in the model when the quadratic term was selected. In addition to requiring lower order terms when higher order terms were present, we also required that no variable be represented at two different scales in the final models.

We used a forward stepwise model building approach based on Schwartz's Bayesian Criterion (SBC) (Schwartz 1978) to select the final models. At each forward step, a covariate (or pair of linear and quadratic terms for a covariate) was selected to enter the model if its inclusion resulted in the largest reduction of the model's SBC value. SBC was defined as,

$$-2\log(Likelihood) + p(\log(n)),$$

where *p* was the number of variables in the model, *n* was the number of sites (capture histories), *Likelihood* was the value of the site occupancy likelihood evaluated at the maximum likelihood estimates, and *log* was the natural logarithm. After each forward step, a backwards look evaluated whether any covariates already in the model should be removed to obtain an even lower SBC value. Model building was terminated when the SBC value could not be reduced further.

Once a final model was determined, estimates of coefficients, odds ratios and confidence intervals were computed for variables in the model. Because of the difficulty interpreting these ratios for b-splines and quadratic effects, odds ratios were not computed for b-spline variables or variables involved in quadratic terms. An odds ratio measures the multiplicative change in the odds of a site being occupied when a variable increases by one unit and all other variables remain constant. Odds ratios were computed as *exp(coefficient)*. Ninety-percent confidence intervals (CIs) were calculated by bootstrapping (Manly 2005) the track plate sites and their detectionn histories 1,000 times. The lower 5^{th} and upper 95^{th} percentiles of the 1,000 bootstrap estimates were reported as the lower and upper limits of 90% CIs. An odds ratio whose confidence interval did not contain 1.0 was considered significant. Ninety-percent CIs are conservative compared to intervals of higher levels (e.g., 95%), and were chosen to increase the power of detecting trends and important associations between habitat types and fisher occupancy.

In addition, the average estimated probability of occupancy was calculated based on all sites in the final models, along with 90% confidence intervals calculated using the method described above. Plots of the predicted probability of site occupancy by a fisher were created based on the final models. Variables not included in a plot were held constant at their median values.

Investigation of Annual Variation in Occupancy:

We considered variables that quantified annual changes in occupancy (*year_1994*, *year_1995*, *year_2004*, *year_2006*, and *replicate*) during model building. Temporal changes in occupancy were a primary objective of this study and considered vitally important to fisher management.

RESULTS

The initial model building procedure resulted in selection of a year covariate that indicated a decrease in occupancy for year 2004 relative to the other years that were surveyed. This model contained the same suite of covariates as the final model plus amount of non-forest within a 600m radius buffer. Since we could not account for a year effect in future landscape projections of occupancy, the final site occupancy model of fisher track plate detections did not include a year covariates and was based on 577 sites that satisfied the interior criterion for all buffer sizes (Table 2). The following variables in the order in which they entered the model were: elevation (positive coefficient), percentage of an 800 m (2624 ft) buffer containing stands of trees 6-20 years old (negative coefficient) and the percentage of whitewood tree species within the stand (positive coefficient). No variables were removed from the model at backward looks during the model building process. Based on this final model, the average probability of occupancy by a fisher was 0.646 (90% CI from 0.537 to 0.754). Holding other variables constant, the odds of occupancy by a fisher was estimated to increase with increasing elevation at the site, decrease with increasing amounts of 6-20 year old stands in the 800 m buffer and increase with increasing percentage of whitewood tree species within the stand where the track plate was located (Figures 1 to 3).

The site occupancy model of fisher track plate detections based on all 708 sites on Green Diamond ownership was similar to the final model. We did not consider this model for predictive purposes since it included track plate sites for which we had limited habitat data at some or all buffer sizes. This model contained the following variables in the order in which they entered the model: percentage of whitewood trees (positive coefficient), percentage of an 800 m (2624 ft) buffer containing stands of trees 6-20 years old (negative coefficient), elevation (positive coefficient), percentage of a 400 m radius buffer in non-forest (negative coefficient) and percentage of a 200 m radius buffer in stands 61-80 years old (negative coefficient). Holding other variables constant, the odds of occupancy by a fisher under this model was estimated to increase with increasing elevation, decrease with increasing amounts of 6-20 year old stands in the 800 m buffer, increase with increasing elevation, decrease with increasing amount of non-forest within a 400m buffer, and decrease with increasing amounts of 61-80 year old forest within a 200 m radius buffer.

DISCUSSION

The assumptions underlying the application of the site occupancy model used in this analysis include: (1) there were no changes to occupancy of individual sites for the duration of the survey (the so-called "closure" assumption); (2) probability of occupancy (ψ) was constant across sites or correctly modeled using covariates; and (3) individuals were never falsely detected (MacKenzie et al. 2006). The closure assumption (1) means that a species was either always present or always absent within some area around each site during the 11 surveys. This does not mean the same fisher has to stay in close proximity to a particular site for a specified period of time, but simply that if a fisher was identified during one survey occasion, there was a non-zero probability of identifying a fisher on the track plate at that site during all other survey occasions. This non-zero probability of capture assumption was satisfied at sites with >1 capture if, between every check, at least 1 fisher uses or passes through an area where it would be possible for them to detect the presence of the track plate.

It should also be noted that for logistical reasons track plate stations were located along roads on Green Diamond's ownership. Therefore, statistical inference from this analysis was limited to some undefined areas along similar roads on the ownership. Given the high density of roads on this managed landscape, the area of inference probably applies to most of the ownership.

The initial model building procedure included selection of a year covariate along with the same suite of covariates as the final model plus amount of non-forest within a 600m radius buffer. We did not consider this model for predictive purposes since we could not account for a year effect in future landscape projections of occupancy, but it provided support for a reduction in occupancy for year 2004 relative to the other years that were surveyed. While there are other potential explanations for a reduction in occupancy, the simplest explanation is that the fisher population was reduced in 2004 relative to the other years. This corresponds to an apparent reduction in the fisher population on the Hoopa Reservation immediately to the east of the Green Diamond study area. Higley and Matthews (2009) estimated the fisher population density in 2004-05 was less than half what the previous estimate had been during 1998-99. They also noted a change in the sex ratio from approximately 2F:1M to 0.6F:1M. While they had no direct evidence to explain the cause of this apparent reduction in fisher numbers, they postulated that it may have due to changes in fisher predator numbers, disease or changes in prey populations. In addition, Higley and Matthews (2009) also reported that the fisher population was rebounding from the 2004-05 decline, which is consistent with our increase in occupancy in 2006. Clearly these comparisons are strictly circumstantial, but it does suggest that fisher populations are dynamic and that they may fluctuate at a regional level.

Although the models with the full suite and constrained (interior) set of track plate sites were similar, we believe it is most appropriate to consider the model that only included the interior set of track plate sites for which we had adequate habitat coverage in our GIS layers. We developed both sets of models to assess the potential impact of a high percentage of the stations (18.5%) being close to the property boundary with missing habitat data. Fortunately, the top three covariates to enter both models were the same, which suggests these covariates had the greatest impact on the probability that fishers occupied a given location. However, since we can not assess the missing habitat data for the track plates near the property boundary, we have little confidence in the relevance of the other variables that entered the model with the complete suite of track plates.

The positive relationship between the probability of fisher detection (occupancy), elevation, and amount of whitewood tree species was consistent with previous studies on Green Diamond that showed increasing detections with increasing elevation and amount of Douglas-fir forest (Klug 1997). The increase in occupancy rates with increasing elevation and whitewood tree species is likely a result of various factors such as increased prey diversity and potentially greater abundance of sites for resting and denning. Studies of fisher prey base have not been done locally to document this assumption, but anecdotal observations indicate a wider variety of potential prey species at higher elevations in Douglas-fir/hardwood areas of the ownership. The whitewood stands on Green Diamond ownership are also represented by a greater hardwood and hemlock/cedar component which has been shown to be important for denning and resting sites.

Previous studies of fishers on Green Diamond's ownership did not evaluate the spatial component of forest age classes at a variety of scales as was done in this study. We constructed the age class covariates in the occupancy model from resource selection modeling done for northern spotted owls (Green Diamond, unpublished report). We used the same age class breaks for the fisher occupancy model since we believe these age classes represent biologically significant stages in the development of forest structure. Hamm (1995) and Hughes (2005) documented that the young forests have high densities of dusky-footed woodrats (*Neotoma fuscipes*), a key prey species for northern spotted owls (Courtney et al. 2004) and fishers in the redwood region (Golightly et al. 2006). These young forests also support numerous other prey species utilized by fishers, which suggests young forest may be important as foraging habitat for fishers in a similar manner as they are hypothesized to be used by spotted owls in the southern portion of their range. The older managed stands with late seral structure are the primary areas used for resting and reproduction for both spotted owls and fishers in this region (Courtney et al. 2004). If fishers and spotted owls use managed forests in similar ways in the redwood region, one would not expect the negative relationship between fisher occurrence and increasing amounts of 6-20 year old forests. However, despite the abundance of prey, fishers may be avoiding this age class for reasons not readily applicable to spotted owls. We hypothesize that fishers may be avoiding young stands due to increased risk of predation, increased human activity associated with producing young stands on a managed landscape or other factors that are beyond our current knowledge of fisher ecology.

Habitat analyses from Hoopa are not directly comparable to our results, because their analyses were based on telemetry locations of fishers rather than track plate stations and they used different stand age classes (Higley and Matthews, 2009). They reported that female fisher located significantly closer to older closed-canopy forest (closed canopy stands >30 years old), sapling-brushy pole (cutover areas 10-29 years old), and seedling stands (cutover areas <10 years old) than expected by chance. They speculated that fishers were selecting older closed-canopy forest for resting and denning structures and escape cover, while the sapling-brushy pole and seedling stands were important for foraging. The only remaining habitat types apparently not selected by fishers were young pole stands that had been pre-commercially thinned to remove the shrub layer, oak woodlands, non-forested areas and urban areas. Higley and Matthews (2009) also reported that fishers in the Hoopa study area were subjected to high predation pressures primarily from bobcats and mountain lions. They hypothesized that the young stands with abundant prey attracted these larger predators along with fishers, which put the fishers at risk for predation. This suggests that although predation risks may be high, fishers have not developed avoidance for these young stands where prey species are abundant.

Spotted owls are famous for their tolerance of human activity. They will allow people to approach to very close distance and observations within our study area indicate they show no apparent avoidance of areas with high levels of harvesting activity. The same does not appear to be true for fishers. While doing our fisher telemetry work reported above, it was common to have fishers leave their rest site while an approaching field biologist with a radio receiver was still hundreds of meters away. It appears that fishers simply do not tolerate human activity in close proximity. If fishers avoid areas with high levels of human activity associated with timber harvesting, it would seem that the 0-5 rather than the 6-20 year old age class would enter the top occupancy model with a negative coefficient. We believe the 0-5 year age class likely gets even less use by fishers than the 6-20 yr age class, but because it only spans a 5-year period, the total area within a given sub-basin in this age class tends to be limited. To understand why, it is necessary to understand the pattern of timber harvesting on Green Diamond's ownership. The initial logging of old growth forests in this area tended to create whole watersheds or sub-basins of similar aged stands. As the stands within a given area reach merchantable age, typically Green Diamond initiates even-age harvesting. This harvesting continues within the constraints of the California Forest Practice Rules, which limits harvest unit size and provides "adjacency constraints" (i.e., adjacent timber stands can not be harvested for 3-5 years following the even-age harvest of the first unit). Therefore, once started, logging activities are ongoing at a relatively constant rate for 20-30 years until most of the unconstrained harvest units have been logged in a given area. This steady rate of harvesting results in an initial increase in the amount of young age classes (0-5 and 6-20) until the rate of harvest matches the rate of ingrowth (stands moving from a younger into an older age class). Therefore, the amount of 0-5 age class reaches a plateau at approximately one third the amount of 6-20, which explains why the latter age class is a better covariate for the amount of harvesting activity within a given area. The results from the Hoopa study (Higley and Matthews, 2009) do not appear to support this "disturbance hypothesis", since they found fishers selecting for stands that had been recently harvested. However, Hoopa Tribal Forestry is not subject to California Forest Practice rules and they have developed their own forest management plan. Their timber harvesting is not concentrated in selected sub-basins so presumably their disturbance is more dispersed.

Although it is apparent that there is much we do not understand about habitat selection by fishers, results of this study on Green Diamond's ownership, and the studies in Hoopa, indicate managed landscapes in this region can support high populations of fishers. Our studies suggest that fisher occupancy will decline in regions with high levels of harvesting, but our occupancy model indicates that there will be a high probability of fisher use once most of the stands are >20 years old. The pattern of timber harvesting across Green Diamond's ownership should create a dynamic mosaic of areas with variable levels of occupancy through time. However, fishers apparently are adaptable to such changes since there is still a well distributed population across the ownership after over 100 years of timber harvesting in the region.

LITERATURE CITED

Agresti, A., 2002. *Categorical Data Analysis*. John Wiley & Sons, New York, USA.

Burnham, K. P., Anderson, D. R., 2002. *Model Selection and Multimodel Inference*. Springer, New York, New York, USA.

Courtney, S. P., J. A. Blakesley, R. E. Bigley, M. L. Cody, J. P. Dumbacher, R. C. Fleisher, A. B. Franklin, J. F. Franklin, R. J. Gutiérrez, J. M. Marzluff, L. Sztukowski. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR

Golightly, R. T., T. F. Penland, W. J. Zielinski, and J. M. Higley. 2006. Fisher diet in the Klamath/north coast bioregion. Unpublished report. Department of Wildlife, Humboldt State University, Arcata, California, USA.

Hamm, K. A. 1995. Abundance of dusky-footed woodrats in managed forests of north coastal California.Thesis, Humboldt State University, Arcata, California, USA.

Higley, J. M. and S. Mathews. 2009. Fisher habitat use and population monitoring on the Hoopa Valley Reservation, California. Final Report USFWS TWG U-12-NA-1, Hoopa Tribal Forestry, Hoopa, California.

Hosmer, D. W., Lemeshow, S., 2000. *Applied Logistic Regression, 2nd edition*. John Wiley & Sons, New York, USA.

Hughes, K. D. 2005. Habitat associations of dusky-footed woodrats in managed Douglas fir/hardwood forest of northern California.Thesis, Humboldt State University, Arcata, California, USA.

Klug, R. R. 1997. Occurrence of Pacific fisher (*Martes pennanti pacifica*), and the habitat attributes associated with their detections. Thesis, Humboldt State University, Arcata, California, USA.

Leitao, A.B., J. Miller, J. Ahern, and K. McGarigal. 2006. Measuring Landscapes: A Planners Handbook. Island Press, Washington, D.C.

MacKenzie, D. I., Nichols, J. D., Lechman, G. B., Droege, S., Royle, J. A., Langtimm, C. A., 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248–2255.

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., and Hines, J. E., 2006. *Occupancy Estimation and Modeling*. Academic Press, Amsterdam, NL.

Manly, B. F. J., 2006. *Randomization, Bootstrap and Monte Carlo Methods in Biology, 3rd Edition*. Chapman & Hall, Boca Raton, FL.

Neter, J., Wasserman, W., and Kutner, M. H., 1985. *Applied Linear Statistical Models: Regression, Analysi of Variance, and Experimental Designs, 2nd edition*. Homewood, IL: Richard D. Irwin, Inc.

R Development Core Team, 2006. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Royle, J. A., 2006. Site occupancy models with heterogeneous detection probabilities. *Biometrics* 62:97–102.

Schwarz, G., 1978. Estimating the dimension of a model. *Annals of Statistics* 6:461–464.

Thome, D. M., C. J. Zabel and L. V. Diller. 1999. Forest stand characteristics and reproduction of northern spotted owls in managed north-coastal California forests. Journal of Wildlife Management 63(1):44-59.

Wright, D. B. and K. London. 2009. Modern Regression Techniques Using R. Sage.

Table 1. Explanatory variables considered for site occupancy models of fisher track plate detections.

Basis	Type	Variable	Description
Stand	Age class indicators	Non-forest	indicator variable for non-forest polygon (age = 0 and non-forest)
		age_0-5_yrs	indicator variable for age class of stand = 0 to 5 years
		age_6-20_yrs	indicator variable for age class of stand = 6 to 20 years
		age_21-40_yrs	indicator variable for age class of stand = 21 to 40 years
		age_41-60_yrs	indicator variable for age class of stand = 41 to 60 years
		age_61-80 yrs	indicator variable for age class of stand = 61 to 80 years
		age_81+ yrs	indicator variable for age class of stand >= 81 years
	Residual	%_residual	% residual trees retained from a previous harvest
	Species composition	%_HW	% hardwood trees (e.g. tanoak, madrone, CA bay, etc.)
		%_RW	% redwood trees
		%_WW	% whitewood trees (e.g. Douglas-fir, grand fir, hemlock, etc.)
		%_RWWW	% redwood + % whitewood (=%_RW + %_WW)
		%_nonfor_stand	% non-forest in stand
		RW_ba	redwood basal area (m/ha)
		WW_ba	whitewood basal area (m/ha)
		predom_RW	indicator variable for predominate species = redwood. If percentage of the stand's redwood basal area ((young growth RW basal area + old growth RW basal area)/ total basal area)) was >50%, predom_RW = 1, otherwise predom_RW = 0.
		predom_WW	indicator variable for predominate species = whitewood. If percentage of the stand's whitewood basal area ((young growth RW basal area + old growth RW basal area)/ total basal area)) was >50%, predom_WW = 1, otherwise predom_WW = 0.

	Linear height	tree_height	height of trees in stand (m)
	Stand shape	interior_area	amount of 'interior' habitat in patch at center (hectares) b
	Linear age	age	age (years) of stand
Point	Slope position	slope_position	slope position (%) with bottom = 0 and top of ridge = 1
Buffer	Age class percentages	%_nonfor_200	percentage of 200 m buffer that is non-forest
		%_0-5_200	percentage of 200 m buffer in age class 0 to 5 years
		%_6-20_200	percentage of 200 m buffer in age class 6 to 20 years
		%_21-40_200	percentage of 200 m buffer in age class 21 to 40 years
		%_41-60_200	percentage of 200 m buffer in age class 41 to 60 years
		%_61-80_200	percentage of 200 m buffer in age class 61 to 80 years
		%_81+_200	percentage of 200 m buffer in age class 81+ years
		%_nonfor_400	percentage of 400 m buffer that is non-forest
		%_0-5_400	percentage of 400 m buffer in age class 0 to 5 years
		%_6-20_400	percentage of 400 m buffer in age class 6 to 20 years
		%_21-40_400	percentage of 400 m buffer in age class 21 to 40 years
		%_41-60_400	percentage of 400 m buffer in age class 41 to 60 years
		%_61-80_400	percentage of 400 m buffer in age class 61 to 80 years
		%_81+_400	percentage of 400 m buffer in age class 81+ years
		%_nonfor_600	percentage of 600 m buffer that is non-forest
		%_0-5_600	percentage of 600 m buffer in age class 0 to 5 years
		%_6-20_600	percentage of 600 m buffer in age class 6 to 20 years

	%_21-40_600	percentage of 600 m buffer in age class 21 to 40 years
	%_41-60_600	percentage of 600 m buffer in age class 41 to 60 years
	%_61-80_600	percentage of 600 m buffer in age class 61 to 80 years
	%_81+_600	percentage of 600 m buffer in age class 81+ years
	%_nonfor_800	percentage of 800 m buffer that is non-forest
	%_0-5_800	percentage of 800 m buffer in age class 0 to 5 years
	%_6-20_800	percentage of 800 m buffer in age class 6 to 20 years
	%_21-40_800	percentage of 800 m buffer in age class 21 to 40 years
	%_41-60_800	percentage of 800 m buffer in age class 41 to 60 years
	%_61-80_800	percentage of 800 m buffer in age class 61 to 80 years
	%_81+_800	percentage of 800 m buffer in age class 81+ years
Fragmentation statistics	dist_to_edge	distance to nearest edge (meters)
	edge_density_200	edge density (m/ha) in 200 m buffer (edge = change in age class)
	edge_density_400	edge density (m/ha) in 400 m buffer (edge = change in age class)
	edge_density_600	edge density (m/ha) in 600 m buffer (edge = change in age class)
	edge_density_800	edge density (m/ha) in 800 m buffer (edge = change in age class)
	mean_patch_size_200	mean patch size (ha) in 200 m buffer (patch = uniform age class)
	mean_patch_size_400	mean patch size (ha) in 400 m buffer (patch = uniform age class)
	mean_patch_size_600	mean patch size (ha) in 600 m buffer (patch = uniform age class)
	mean_patch_size_800	mean patch size (ha) in 800 m buffer (patch = uniform age class)
	patch_density_200	patch density (n/100 ha) in 200 m buffer (patch = uniform age class)

	patch_density_400	patch density (n/100 ha) in 400 m buffer (patch = uniform age class)
	patch_density_600	patch density (n/100 ha) in 600 m buffer (patch = uniform age class)
	patch_density_800	patch density (n/100 ha) in 800 m buffer (patch = uniform age class)
	CV_patch_200	coefficient of variation (%) of patch sizes in 200 m buffer (patch = uniform age class)
	CV_patch_400	coefficient of variation (%) of patch sizes in 400 m buffer (patch = uniform age class)
	CV_patch_600	coefficient of variation (%) of patch sizes in 600 m buffer (patch = uniform age class)
	CV_patch_800	coefficient of variation (%) of patch sizes in 800 m buffer (patch = uniform age class)
	open_edge_density_200	opening edge density (m/ha) in 200 m buffer (opening = age < 6 or nonfor)
	open_edge_density_400	opening edge density (m/ha) in 400 m buffer (opening = age < 6 or nonfor)
	open_edge_density_600	opening edge density (m/ha) in 600 m buffer (opening = age < 6 or nonfor)
	open_edge_density_800	opening edge density (m/ha) in 800 m buffer (opening = age < 6 or nonfor)
Survey Date	year_1994	indicator variabel for year of 11 track-plate surveys = 1994
	year_1995	indicator variable for year of 11 track-plate surveys = 1995
	year_2004	indicator variable for year of 11 track-plate surveys = 2004
	year_2006	indicator variable for year of 11 track-plate surveys = 2006
	replicate	indicator variable for second 11-day survey of track-plate within the year

Table 2. Coefficients, odds ratios, and percentile-based 90% confidence intervals (CI) for odds ratios of variables in the final beta-binomial site occupancy models of fisher track plate detections in which the variable "year" was not included in the candidate set of covariates. The final predictive model was fit using data from 577 sites within the boundaries of Green Diamond Resource Company ownership considered interior based on all four buffer criterion.

Variable	Description	Coefficient	Odds Ratio	Percentile 90% CI Lower	Percentile 90% CI Upper
intercept	intercept	1.314	NA	NA	NA
elev	elevation of site	1.079	2.942	1.766	15.025
%_6-20_800	% 800 m buffer in age class 6 - 20 yrs	-0.823	0.439	0.211	0.640
%_WW	% whitewood trees	1.492	4.446	1.170	21.529
$\hat{E}[p]$	mean detectibility	0.087	NA	NA	NA
$\hat{\sigma}_p$	standard deviation of detectibility	0.140	NA	NA	NA

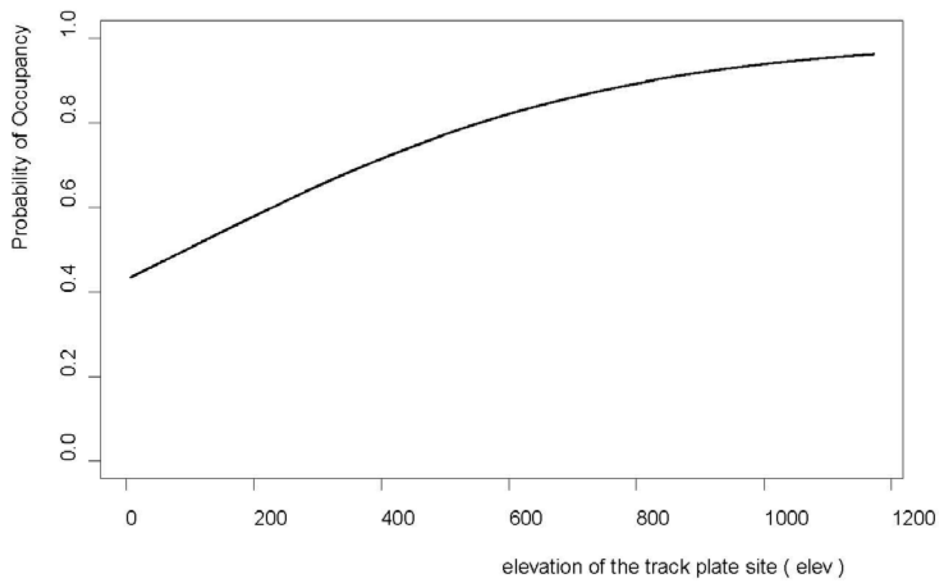


Figure 1. Probability of occupancy as a function of elevation of track plate site (without year effect) based on the final site occupancy model of fisher track plate detections using 557 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for all buffer sizes.

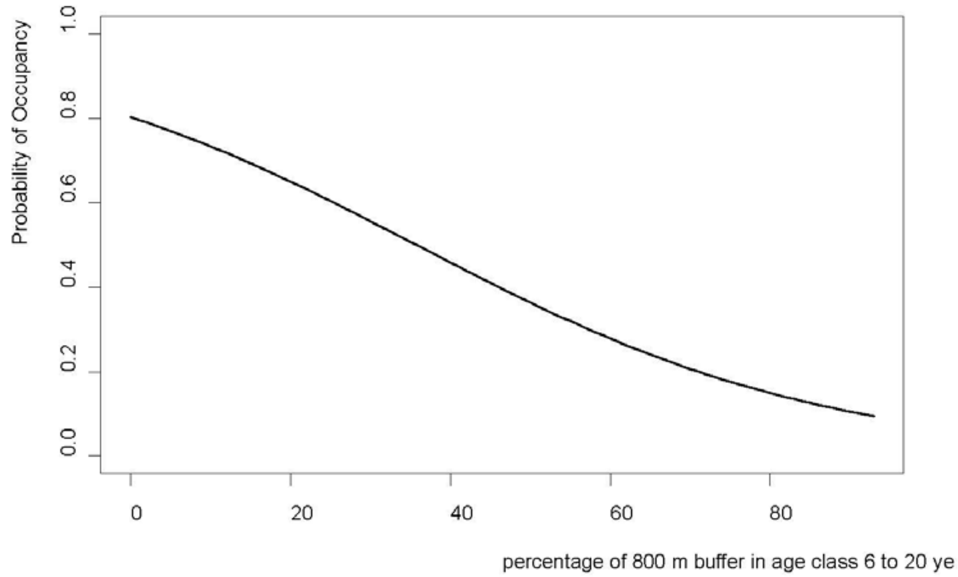


Figure 2. Probability of occupancy as a function of percentage of 800m buffer in forest age class 6 to 20 years based on the final site occupancy model of fisher track plate detections using 557 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for all buffer sizes.

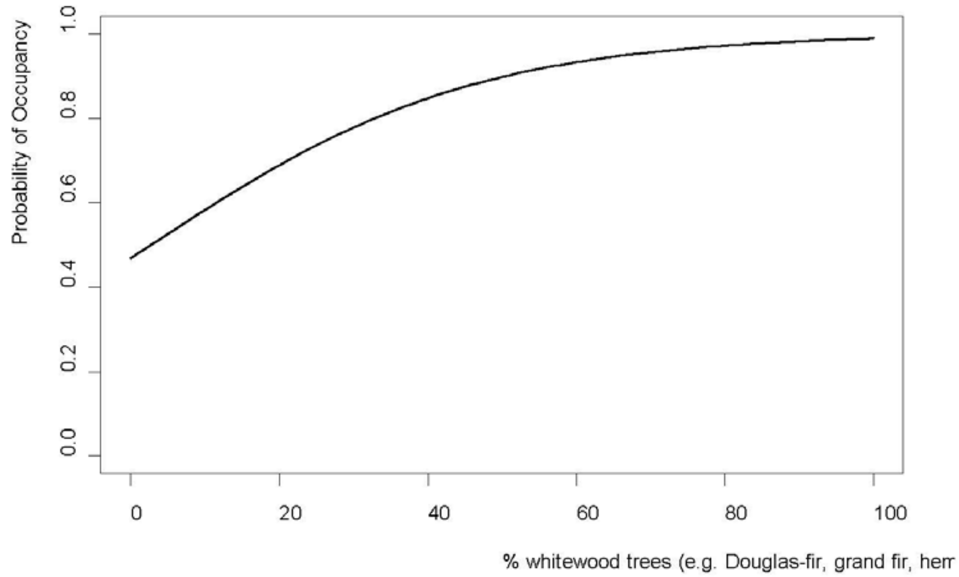


Figure 3. Probability of occupancy as a function of percentage of percent whitewood trees within the stand where the track plate was located based on the final site occupancy model of fisher track plate detections using 557 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for all buffer sizes.

The following is a memo from Western EcoSystems Technology, Inc. to Green Diamond Resource Company an additional analysis of fisher occupancy rates.

West, Inc.

Western EcoSystems Technology
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Date: May 19, 2008
To: Green Diamond Resources Co.
From: Ryan Nielson and Trent McDonald
Re: Site occupancy by fishers

INTRODUCTION

In 1994, 1995, 2004, and 2006 Green Diamond Resources (GD) attempted to identify the presence of fishers (*Martes pennanti*) at various locations on their property using track plates at bait stations. From this presence/absence data we estimate site occupancy models (MacKenzie et al. 2006) that characterize habitat affinities of an "average" fisher on Green Diamond's property. These models can also be used predict the probability of occupancy by a fisher at locations where fishers were not detected or where surveys have not been conducted.

METHODS

Trap Sites

Data provided to WEST, Inc., by Green Diamond Resources consisted of trap locations (sites), dates and outcomes (success or failure) of each track plate survey, along with covariates describing the habitat at each site. Each trap was baited and checked multiple times within a year. All traps were checked 11 times over a short period, and most checks were spaced 2 days apart. A majority of the checks occurred in winter and spring months, but some traps were set and checked later in the summer and fall (Table 1). A subset of trap plates were checked 11 times earlier in the year (January – May), and again later in the year (June – August). Each string of 11 consecutive checks at each trap location were considered independent 'sites', resulting in 975 sites and their associated capture histories. Thus, the capture history for each site was a sting of 1's and/or 0's representing the trapping successes and failures for each of the 11 checks.

Of the 975 sites surveyed for fishers by Green Diamond biologists, 121 were off Green Diamond property (mostly on private in-holdings). Because GD's geographic information system (GIS) coverage did not extend beyond its ownership boundaries, we used only the remaining 854 sites to develop one of the site occupancy models (model 1). For similar reasons, a second site occupancy model (model 2) was developed using only sites that were located a sufficient distance from GD's property boundary to meet an "interior" criterion. This interior requirement insured that GD managed most of the area surrounding the trap and that a large proportion of the area around the trap was covered by GD's GIS. A site was defined to be interior if the location was on GD's property and if at least 75% of buffers with radii of 656ft (200m), 1312ft (400m), 1969ft (600m), and 2625ft (800m) were on GD lands. This requirement left 657 sites for estimating site occupancy model 2.

Covariates

For analysis, it was required that covariates of interest be known for all sites. The environmental information available at each site consisted of yearly GIS data on stand characteristics (e.g., age, height, and type of tree species) and information from a digital elevation map (DEM). From the GIS, covariates such as percentage of the surrounding area in a particular age class were computed using custom "fragstat" software. The full list of covariates considered in the analysis is contained in Table 2. Values for each of these covariates were derived either from values at the trap plate's location, or by calculating an average, proportion, density, or similar metric in a buffer centered on the trap location. Some covariates were evaluated on buffers of different sizes due to the perceived potential for fishers to select these factors differently at different scales. These multiple-scale covariates were evaluated on buffers with radii of 656ft (200m), 1312ft (400m), 1969ft (600m), and 2625ft (800m)

The *slope position* covariate was calculated for every site from the trap plate's elevation and 2 other elevations contained in the DEM. Besides elevation of the site, the 2 other elevations necessary to compute slope position were the elevation of the valley or ravine bottom directly downhill of the point, and the elevation of the ridge or hilltop directly uphill of the trap location. *Slope position* was calculated from these 3 elevations as the change in elevation from the valley to the point divided by the change in elevation from the valley to the ridge top, expressed as a percentage. Higher values of slope position (i.e., closer to 100%) indicated locations closer to the top of a ridge or hill, and lower values (i.e., closer to 0%) indicated points closer to the valley or ravine bottom.

Another covariate, *interior area*, was computed for every site using information from the stand that contained the fisher trap plate. *Interior area* was computed as the amount of area covered by the stand containing the trap location. For this and other calculations, stands were defined as areas of uniform age class, where age class 1 was defined as trees 0-5 years old, age class 2 was defined as trees 6-20 years old, age class 3 was 21-40 years old, age class 4 was 41-60 years old, age class 5 was 61-80 years old, age class 6 was trees 81 years old or older, and age class 7 was non-forested areas. For consistency, any portion of a stand more than 2625 ft (800 m) from the trap location of interest (straight-line distance) was ignored when calculating the covariates.

Estimation

Methods for estimating probability of occupancy by mobile animal species are often employed when logistics or time make it difficult to estimate or count every individual within a sample site due to imperfect detection (MacKenzie et al. 2006). Imperfect detection of organisms can bias estimates of status, trends, and habitat relationships. MacKenzie et al. (2002) introduced a method of modeling site occupancy, or the proportion of sites occupied by a species, based on repeated surveys at a sample of sites where probabilities of detection are < 1. This technique evolved from established mark-recapture methods for estimation of the size of closed populations of mobile animals. A comprehensive review of methods for study of site occupancy by animal species can be found in MacKenzie et al. (2006), and a recent special section in the Journal of Wildlife Management (2006, No. 2).

The site occupancy model estimated here related habitat characteristics to probability of occupancy while accounting for imperfect detection of fishers with a zero-inflated beta-binomial (BB) model (MacKenzie et al. 2006, Royle 2006). The BB is a mixed effects model that allows probability of detection to vary randomly from site to site. Use of this model eliminated the need to model probability of detection as a function of habitat or survey specific covariates in order to account for variability in detections. The BB modeled probability of detection at each site as a random variable from a beta distribution. The beta distribution is a continuous probability distribution defined on the interval [0,1], and is often used as a prior distribution for binomial proportions in Bayesian analysis (Agresti 2002).

The coefficients of the BB model and the site-specific predictions of probability of occupancy by a fisher were estimated by maximizing the likelihood

$$L(\psi,\beta,\alpha,\delta)=\prod_{i=1}^{N}\psi_i\pi_{bb}(k_i,T;\alpha,\delta)+I(k_i=0)(1-\psi_i), \qquad (1)$$

where N was the number of sites, ψ_i is the probability of occupancy for site i, $\pi_{bb}(k_i,T;\alpha,\delta)$ was the probability of k_i successful trapping events ($k = 0, 1, 2, \ldots T$; $T = 11$) at the i^{th} trap based on a beta-binomial mixture distribution with parameters α and δ, and $I(k_i=0)$ was an indicator function that equaled 1 for $k_i = 0$ (i.e., 11 unsuccessful capture events) and 0 otherwise. Site-specific probabilities of occupancy in equation (1) were modeled as a logistic function of habitat covariates

$$\psi_i=\frac{1}{1+\exp(-x_i\beta)}, \qquad (2)$$

where x_j was the vector of characteristics associated with the i^{th} trap site, and β was a vector of unknown coefficients. The beta-binomial probabilities $\pi_{bb}(k_i,T;\alpha,\delta)$ were computed as

$$\pi_{bb}(k,T;\alpha,\delta)=\frac{beta(k+\alpha,T-k+\delta)\binom{T}{k}}{beta(\alpha,\delta)}. \qquad (3)$$

where α and δ were unknown shape parameters to be estimated. Based on this parameterization of the beta-binomial mixture, the mean and variance of the number of expected detections out of T surveys at one track plate in an occupied site was $\mu=T\alpha/(\alpha+\delta)$ and $\sigma^2=T\alpha\delta(T+\alpha+\delta)/\left((\alpha+\delta)^2(1+\alpha+\delta)\right)$, respectively. The R software package (R Development Core Team 2006) was used to estimate the site occupancy models.

Model Building

Given the covariates of interest (Table 2), some type of model selection procedure was needed to identify a reasonable subset of covariates that explained a large portion of the variation in the probability of a site being occupied by a fisher. Prior to model building, a colinearity (Neter et al. 1985) analysis estimated a correlation coefficient for every pair of covariates under consideration. During this analysis, relatively high colinearity ($|r| > 0.6$) was identified between many pairs of covariates. To break these colinearities, covariates were either dropped from the analysis prior to model building, or model building was performed in such a manner as to not allow colinear covariates in the same model.

Relatively high colinearity was identified between linear age of stand and both tree height and the percentage of a 200 m buffer in 81+ years old age class. Linear age of stand was dropped from the analysis to break these colinearities because age of stand was also represented as indicators for age classes and in percentages of buffers of various age classes (Table 2). Relatively high colinearity was identified between *interior area* and edge density, patch density, and mean patch size within all 4 buffer sizes, and so *interior area* was dropped from the analysis. The coefficient of variation (CV) of patch sizes within various buffers and distance to nearest edge were also found highly correlated with edge density, patch density, and mean patch size, and so the CV of patch sizes calculated in the 4 buffers around each trap location and distance to nearest edge were dropped from the analysis.

Relatively high colinearity was found between mean patch size, patch density, and edge density. Because all three of these variables were deemed potentially important explanatory variables, we chose not to allow 2 or more of these three variables in the same site occupancy model. In addition, edge density and open edge density were found to be highly correlated and so were not allowed in the same model, as were edge density and percentage of a buffer in the 0 to 5 years age class. Finally, indicators for redwood or whitewood dominated stands were correlated with percent redwood and percent whitewood, respectively, and so either the indicator or the percentage was allowed in a model, but not both.

Quadratic terms were considered during model building for all of the continuous variables in Table 2. As usual, we required the linear term in the site occupancy model when the quadratic term was selected for inclusion. In addition to requiring lower order terms when higher order terms were present, we also required that no variable be represented at two different scales in one of the final models. For example, we did not allow mean patch size measured in a buffer of radius 1312 ft to be in the model at the same time as mean patch size measured in a buffer of radius 1969 ft.

A forward stepwise model building approach based on Schwartz's Bayesian Criterion (SBC) (Schwartz 1978) was used to select the final models. At each forward step, a covariate (or pair of linear and quadratic terms for a covariate) was selected to enter the model if inclusion of that covariate resulted in the largest reduction of the model's SBC value. SBC was defined as,

$$-2log(Likelihood) + p(log(n)),$$

where *p* was the number of variables in the model, *n* was the number of sites (capture histories), *Likelihood* was the value of the site occupancy likelihood evaluated at the maximum likelihood estimates, and *log* was the natural logarithm. After each forward step to add a covariate, a backwards look evaluated whether any covariates already in the model should be removed to obtain an even lower SBC value. Model building was terminated when the SBC value could not be further reduced.

Once a final model was determined, estimates of coefficients, odds ratios and confidence intervals were computed when appropriate for variables in the final model. Because of the difficulty interpreting these ratios for quadratic effects, odds ratios were not computed for variables involved in quadratic terms in the final model. An odds ratio measures the multiplicative change in the odds of a site being occupied that occurs when a variable increases by one unit and all other variables in the model remain constant. Odds ratios were computed as *exp(coefficient)*. Ninety-percent confidence intervals (CIs) were calculated by bootstrapping (Manly 2005) the sites and their capture histories 1,000 times. The lower 5^{th} and upper 95^{th} percentiles of the 1,000 bootstrap estimates were reported as the lower and upper limits of 90% CIs. An odds ratio whose confidence interval did not contain 1.0 was considered significant. Ninety-percent CIs are conservative compared to intervals of higher levels (e.g., 95%), and were chosen to increase the power of detecting trends and important associations between habitat types and fisher occupancy as measured by track plate detections. If a significant trend or habitat association is not identified using a 90% CI, that trend or association would not be identified as significant using a higher confidence level.

In addition, the average estimated probability of occupancy was calculated based on all sites in the final models, along with 90% confidence intervals calculated using the method described above. In addition, plots of the predicted probability of site occupancy by a fisher were created based on the final model. Variables not included in a plot were held constant at their median values.

Investigation of Trends

Variables that quantified temporal changes in occupancy (*year_1994*, *year_1995*, *year_2004*, *year_2006*, and *replicate;* Table 2) were considered during model building. However, temporal changes in occupancy were vitally importance to fisher management and were a primary objective of this analysis. Due to their importance, temporal changes in occupancy were estimated even when none of the variables that quantified temporal changes were selected for inclusion in either of the final models of site occupancy. If variables for temporal changes in fisher occupancy rates were not in either of the final models, we fit three variations of final model 2. Model 2a included indicator variables for discrete years (*year_1995*, *year_2004*, and *year_2006*), along with all other effects in model 2. Model 2b included a continuous covariate for date (Julian day = number of days since January 1, 1970) to estimate a linear trend in occupancy rates, along with all other effects in model 2. Model 2c included an indicator variable for discrete years and *replicate* within year along with all other variables in model 2. After estimating coefficients in models 2a-2c, we bootstrapped sites and their capture histories 1,000 times to estimate 90% confidence intervals for odds ratios.

RESULTS

The final site occupancy model of fisher track plate detections based on all 854 sites within GD property (model 1; Table 3) contained variables for percentage of a 200 m buffer containing stands of trees 21 to 40 years old, the indicator variable for redwood dominated stands, and the percentage of an 800 m buffer containing stands 81+ years old. No variables were removed from the model at backward looks during the model building process. Estimates of coefficients and odds ratios are given in Table 4. Based on this final model, the average probability of occupancy by a fisher across all sites was 0.675 (90% CI from 0.560 to 0.754); the proportion of the 854 sites used to fit model 1 that had known occupancy (i.e., ≥ 1 detection) was 0.207. Based on this final model and holding other variables constant, the odds of a site being occupied by a fisher was estimated to increase by 10.4% for every 1-unit increase in percentage of a 200 m buffer surrounding the site containing stands of trees 21 to 40 years old. Based on this final model and holding other variables constant, the odds of a site being occupied by a fisher was estimated to be 97.1% lower for stands where the predominate species was redwood. Based on this final model and holding other variables constant, the odds of a site being occupied by a fisher was estimated to decrease by 5.2% for every 1-unit increase in percentage of an 800 m buffer surrounding the site containing stands of trees 81+ years old. Probability of site occupancy by a fisher as a function of each variable in this model is shown in Figures 1 and 2. The shape parameters estimated for the BB model estimate that on average, the expected number of track plate detections (out of 11 surveys) at a site occupied by a fisher was $T\hat{\alpha}/(\hat{\alpha}+\hat{\delta}) = 0.757$.

The final site occupancy model of fisher track plate detections based on 657 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for all 4 buffer sizes (model 2; Table 3) contained the indicator variable for predominate species equals redwood along with the variable for percentage of an 800 m buffer containing stands of trees 21 to 40 years old. No variables were removed from the model at backward looks during the model building process. Because this model only contained 1 variable based on a metric computed within the 800 m radius buffer, we re-fit this final model using the 662 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for a 2625 ft (800 m) radius buffer. The results from the re-fit of this final model are reported in Table 4 and Figure 3, and are nearly identical to the results from the original model 2 fit using 5 fewer sites.

Based on the re-fit of final model 2, the average probability of occupancy by a fisher across all sites was 0.654 (90% CI from 0.519 to 0.757); the proportion of the 662 sites used to fit model 2 that had known occupancy (i.e., ≥ 1 detection) was 0.216. Based on this final model and holding other variables constant, the odds of a site being occupied by a fisher was estimated to increase by 4% for every 1-unit increase in percentage of an 800 m buffer surrounding the site containing stands of trees 21 to 40 years old. Based on this final model and holding other variables constant, the odds of a site being occupied by a fisher was estimated to be 92.4% lower for stands where the predominate species was redwood. Probability of site occupancy by a fisher as a function of each variable in this model is shown in Figure 3. The shape parameters estimated for the BB model estimate that on average, the expected number of track plate detections (out of 11 surveys) at a site occupied by a fisher was $T\hat{\alpha}/(\hat{\alpha}+\hat{\delta}) = 0.827$.

Because neither model 1 or 2 included variables that quantified temporal changes in occupancy, temporal change variables were not important predictors of variation in occupancy probabilities. When temporal variables were forced into model 2, model 2a had a SBC value of 2227.37 (14.7 SBC units from the minimum), and none of the coefficients for indicator variables for discrete year were statistically significant – all 90% CIs for odds ratios for discrete year effects included 1.0. The likelihood maximization routine used to estimate coefficients for Model 2b would not converge, indicating little or no unexplained linear trend in occupancy. Model 2c had a SBC value of 2233.87 (21.2 SBC units from the minimum), but again all 90% CIs for odds ratios for discrete year and replicate effects included 1.0. Predictions of site occupancy probabilities for all 662 sites used to fit 2c are plotted in Figure 4, along with average site occupancy probabilities and 90% CIs for each year-by-replicate combination (Table 5).

DISCUSSION

The assumptions underlying the application of the site occupancy model used in this analysis include: (1) there are no changes to occupancy of individual sites for the duration of the survey (the so-called "closure" assumption); (2) probability of occupancy (ψ) is constant across sites or correctly modeled using covariates; and (3) individuals are never falsely detected (MacKenzie et al. 2006). The closure assumption (1) means that a species is either always present or always absent within some area around each site during the 11 surveys. This does not mean the same fisher has to stay in close proximity to a particular site for a specified period of time, but simply that if a fisher is identified during one survey occasion, there is a non-zero probability of identifying a fisher on the track plate at that site during all other survey occasions. This non-zero probability of capture assumption is satisfied at sites with >1 capture if, between every check, at least 1 fisher uses or passes through an area where it would be possible for them to sense the presence of the trap (by smell, assumably).

Track plate stations were located along roads on GD ownership. Statistical inference from this analysis is therefore limited to areas along similar roads on GC ownership.

REFERENCES

Agresti, A., 2002. *Categorical Data Analysis*. John Wiley & Sons, New York, USA.

Burnham, K. P., Anderson, D. R., 2002. *Model Selection and Multimodel Inference.* Springer, New York, New York, USA.

Hosmer, D. W., Lemeshow, S., 2000. *Applied Logistic Regression, 2nd edition.* John Wiley & Sons, New York, USA.

MacKenzie, D. I., Nichols, J. D., Lechman, G. B., Droege, S., Royle, J. A., Langtimm, C. A., 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology* 83:2248–2255.

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., and Hines, J. E., 2006. *Occupancy Estimation and Modeling.* Academic Press, Amsterdam, NL.

Manly, B. F. J., 2006. *Randomization, Bootstrap and Monte Carlo Methods in Biology, 3rd Edition.* Chapman & Hall, Boca Raton, FL.

Neter, J., Wasserman, W., and Kutner, M. H., 1985. *Applied Linear Statistical Models: Regression, Analysi of Variance, and Experimental Designs, 2nd edition.* Homewood, IL: Richard D. Irwin, Inc.

R Development Core Team, 2006. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Royle, J. A., 2006. Site occupancy models with heterogeneous detection probabilities. *Biometrics* 62:97–102.

Schwarz, G., 1978. Estimating the dimension of a model. *Annals of Statistics* 6:461–464.

TABLES

Table 1. Number of trap sites sampled in each month. The month associated with each trap site was the median month for 11-day consecutive trapping events.

Month	1994	1995	2004	2006	Total
January	0	48	24	60	132
February	42	42	42	43	169
March	42	48	24	0	114
April	54	0	48	0	102
May	30	30	48	0	108
June	34	38	50	0	122
July	36	24	48	0	108
August	48	48	0	0	96
September	0	12	0	0	12
October	0	0	0	0	0
November	0	12	0	0	12
Total	286	302	284	103	975

Table 2. Explanatory variables considered for site occupancy models of fisher track plate detections.

Basis	Type	Variable	Description
Stand	Age class indicators	*Non-forest*	indicator variable for non-forest polygon (age = 0 and non-forest)
		age_0-5_yrs	indicator variable for age class of stand = 0 to 5 years
		age_6-20_yrs	indicator variable for age class of stand = 6 to 20 years
		age_21-40_yrs	indicator variable for age class of stand = 21 to 40 years
		age_41-60_yrs	indicator variable for age class of stand = 41 to 60 years
		age_61-80 yrs	indicator variable for age class of stand = 61 to 80 years
		age_81+ yrs	indicator variable for age class of stand >= 81 years
	Residual	*%_residual*	% residual trees retained from a previous harvest
	Species composition	*%_HW*	% hardwood trees (e.g. tanoak, madrone, CA bay, etc.)
		%_RW	% redwood trees
		%_WW	% whitewood trees (e.g. Douglas-fir, grand fir, hemlock, etc.)
		%_RWWW	% redwood + % whitewood (=%_RW + %_WW)
		%_nonfor_stand	% non-forest in stand
		RW_ba	redwood basal area (m/ha)
		WW_ba	whitewood basal area (m/ha)
		predom_RW	indicator variable for predominate species = redwood. If percentage of the stand's redwood basal area ((young growth RW basal area + old growth RW basal area)/ total basal area)) was >50%, *predom_RW* = 1, otherwise *predom_RW* = 0.
		predom_WW	indicator variable for predominate species = whitewood. If percentage of the stand's whitewood basal area ((young growth RW basal area + old growth RW basal area)/ total basal area)) was >50%, *predom_WW* = 1, otherwise

			predom_WW = 0.
	Linear height	*tree_height*	height of trees in stand (m)
	Stand shape	*interior_area*	amount of 'interior' habitat in patch at center (hectares) [b]
	Linear age	*age*	age (years) of stand
Point	Slope position	*slope_position*	slope position (%) with bottom = 0 and top of ridge = 1
Buffer	Age class percentages	*%_nonfor_200*	percentage of 200 m buffer that is non-forest
		%_0-5_200	percentage of 200 m buffer in age class 0 to 5 years
		%_6-20_200	percentage of 200 m buffer in age class 6 to 20 years
		%_21-40_200	percentage of 200 m buffer in age class 21 to 40 years
		%_41-60_200	percentage of 200 m buffer in age class 41 to 60 years
		%_61-80_200	percentage of 200 m buffer in age class 61 to 80 years
		%_81+_200	percentage of 200 m buffer in age class 81+ years
		%_nonfor_400	percentage of 400 m buffer that is non-forest
		%_0-5_400	percentage of 400 m buffer in age class 0 to 5 years
		%_6-20_400	percentage of 400 m buffer in age class 6 to 20 years
		%_21-40_400	percentage of 400 m buffer in age class 21 to 40 years
		%_41-60_400	percentage of 400 m buffer in age class 41 to 60 years
		%_61-80_400	percentage of 400 m buffer in age class 61 to 80 years
		%_81+_400	percentage of 400 m buffer in age class 81+ years
		%_nonfor_600	percentage of 600 m buffer that is non-forest
		%_0-5_600	percentage of 600 m buffer in age class 0 to 5 years

	%_6-20_600	percentage of 600 m buffer in age class 6 to 20 years
	%_21-40_600	percentage of 600 m buffer in age class 21 to 40 years
	%_41-60_600	percentage of 600 m buffer in age class 41 to 60 years
	%_61-80_600	percentage of 600 m buffer in age class 61 to 80 years
	%_81+_600	percentage of 600 m buffer in age class 81+ years
	%_nonfor_800	percentage of 800 m buffer that is non-forest
	%_0-5_800	percentage of 800 m buffer in age class 0 to 5 years
	%_6-20_800	percentage of 800 m buffer in age class 6 to 20 years
	%_21-40_800	percentage of 800 m buffer in age class 21 to 40 years
	%_41-60_800	percentage of 800 m buffer in age class 41 to 60 years
	%_61-80_800	percentage of 800 m buffer in age class 61 to 80 years
	%_81+_800	percentage of 800 m buffer in age class 81+ years
Fragmentation statistics	*dist_to_edge*	distance to nearest edge (meters)
	edge_density_200	edge density (m/ha) in 200 m buffer (edge = change in age class)
	edge_density_400	edge density (m/ha) in 400 m buffer (edge = change in age class)
	edge_density_600	edge density (m/ha) in 600 m buffer (edge = change in age class)
	edge_density_800	edge density (m/ha) in 800 m buffer (edge = change in age class)
	mean_patch_size_200	mean patch size (ha) in 200 m buffer (patch = uniform age class)
	mean_patch_size_400	mean patch size (ha) in 400 m buffer (patch = uniform age class)
	mean_patch_size_600	mean patch size (ha) in 600 m buffer (patch = uniform age class)
	mean_patch_size_800	mean patch size (ha) in 800 m buffer (patch = uniform age class)

	patch_density_200	patch density (n/100 ha) in 200 m buffer (patch = uniform age class)
	patch_density_400	patch density (n/100 ha) in 400 m buffer (patch = uniform age class)
	patch_density_600	patch density (n/100 ha) in 600 m buffer (patch = uniform age class)
	patch_density_800	patch density (n/100 ha) in 800 m buffer (patch = uniform age class)
	CV_patch_200	coefficient of variation (%) of patch sizes in 200 m buffer (patch = uniform age class)
	CV_patch_400	coefficient of variation (%) of patch sizes in 400 m buffer (patch = uniform age class)
	CV_patch_600	coefficient of variation (%) of patch sizes in 600 m buffer (patch = uniform age class)
	CV_patch_800	coefficient of variation (%) of patch sizes in 800 m buffer (patch = uniform age class)
	open_edge_density_200	opening edge density (m/ha) in 200 m buffer (opening = age < 6 or nonfor)
	open_edge_density_400	opening edge density (m/ha) in 400 m buffer (opening = age < 6 or nonfor)
	open_edge_density_600	opening edge density (m/ha) in 600 m buffer (opening = age < 6 or nonfor)
	open_edge_density_800	opening edge density (m/ha) in 800 m buffer (opening = age < 6 or nonfor)
Survey Date	*year_1994*	indicator variabel for year of 11 track-plate surveys = 1994
	year_1995	indicator variable for year of 11 track-plate surveys = 1995
	year_2004	indicator variable for year of 11 track-plate surveys = 2004
	year_2006	indicator variable for year of 11 track-plate surveys = 2006
	replicate	indicator variable for second 11-day survey of track-plate within the year

Table 3. Details of model building using SBC forward stepwise selection for 2 site occupancy models of fisher track plate detections. Model 1 was fit using data from 854 sites within the boundaries of Green Diamond Resource Company ownership. Model 2 was fit using data from 657 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for all 4 buffer sizes.

Model	Step Selected	Variable	SBC
1	0	*intercept*	2839.80
	1	*%_21-40_200*	2814.61
	2	*predom_RW*	2793.07
	3	*%_81+_800*	2790.87
2	0	*intercept*	2239.93
	1	*predom_RW*	2222.13
	2	*%_21-40_800*	2212.64

Table 4. Coefficients, odds ratios, and percentile-based 90% confidence intervals (CI) for odds ratios of variables in the final site occupancy models of fisher track plate detections. Model 1 was fit using data from 854 sites within the boundaries of Green Diamond Resource Company ownership. Model 2 was fit using data from 662 sites within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for a 2625 ft (800 m) radius buffer.

				Odds	Percentile 90% CI	
Model	Variable	Description	Estimate	Ratio	Lower	Upper
1	*intercept*	intercept	1.617	NA	NA	NA
	%_21-40_200	percentage of 200 m buffer in age class 21 to 40 years	0.099	1.104	1.029	1.174
	predom_RW	indicator for predominate species = redwood	-3.540	0.029	0.014	0.115
	%_81+_800	percentage of 800 m buffer in age class 81+ years	-0.053	0.948	0.931	0.982
	α	shape parameter 1 for the beta-binomial distribution	0.191	NA	NA	NA
	δ	shape parameter 2 for the beta-binomial distribution	2.584	NA	NA	NA
2	*intercept*	intercept	0.736	NA	NA	NA
	predom_RW	indicator for predominate species = redwood	-2.578	0.076	0.019	0.191
	%_21-40_800	percentage of 800 m buffer in age class 21 to 40 years	0.039	1.040	1.019	1.089
	α	shape parameter 1 for the beta-binomial distribution	0.223	NA	NA	NA
	δ	shape parameter 2 for the beta-binomial distribution	2.742	NA	NA	NA

Table 5. Mean predicted probability of site occupancy based on fisher track plate detections for each year and replicate, along with 90% percentile confidence intervals.

			90% CI	
Year	Replicate	Mean	LL	UL
1994	1	0.633	0.485	0.898
	2	0.630	0.390	0.864
1995	1	0.626	0.490	0.922
	2	0.616	0.396	0.886
2004	1	0.482	0.312	0.922
	2	0.320	0.146	0.770
2006	1	0.847	0.605	0.997

FIGURES

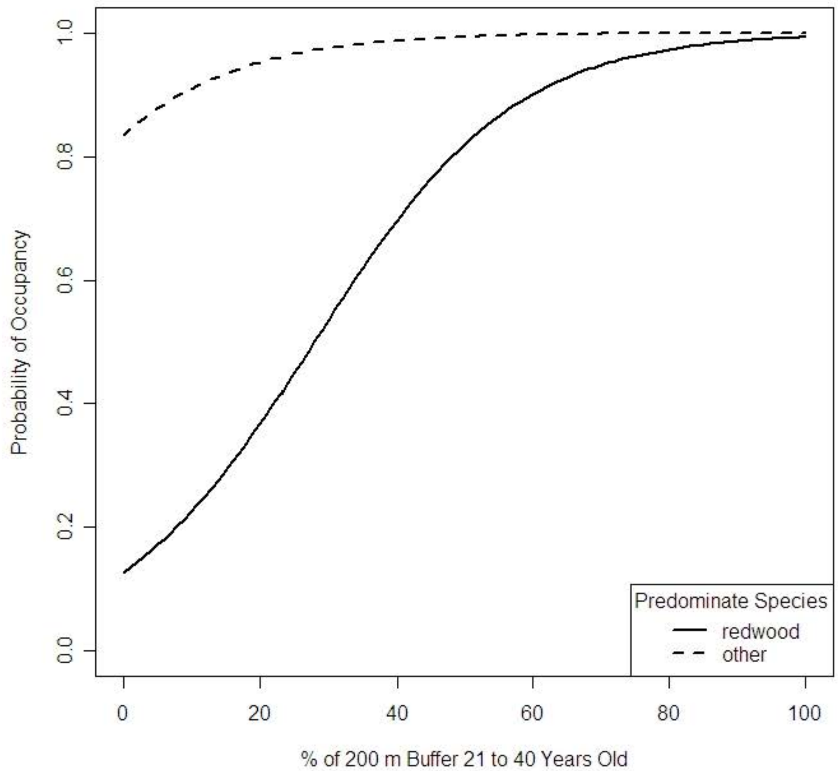

Figure 1. Probability of occupancy as a function of percentage of 200 m buffer 21 to 40 years old and predominate species = redwood, based on the final site occupancy model of fisher track plate detections using 854 sites (model 1) within the boundaries of Green Diamond Resource Company ownership. The other variable in this model was held constant at its median value.

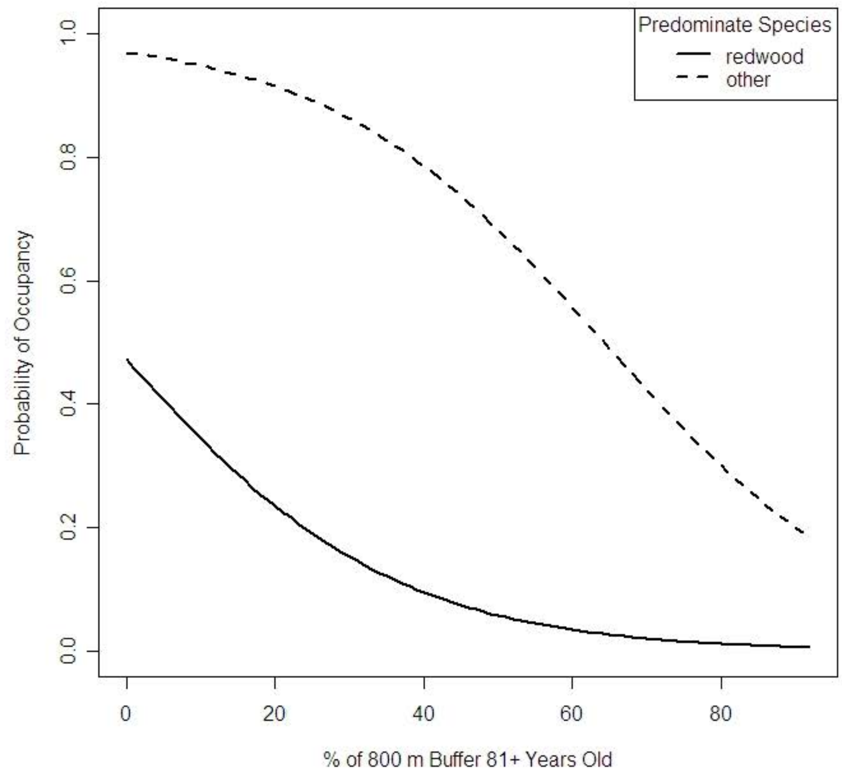

Figure 2. Probability of occupancy as a function of percentage of 800 m buffer in 81+ years old and predominate species = redwood, based on the final site occupancy model of fisher track plate detections using 854 sites (model 1) within the boundaries of Green Diamond Resource Company ownership. The other variable in this model was held constant at its median value.

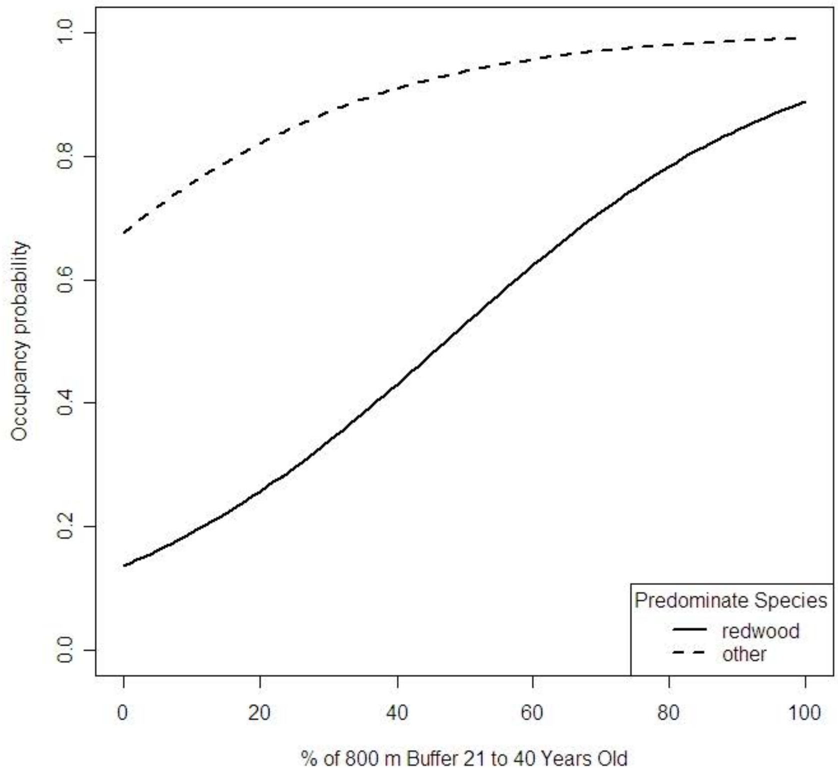

Figure 3. Probability of occupancy as a function of percentage of 800 m buffer 21 to 40 years old and predominate species = redwood, based on the final site occupancy model of fisher track plate detections using 662 sites (model 2) within the boundaries of Green Diamond Resource Company ownership that satisfied the interior criterion for a 2625 ft (800 m) radius buffer.

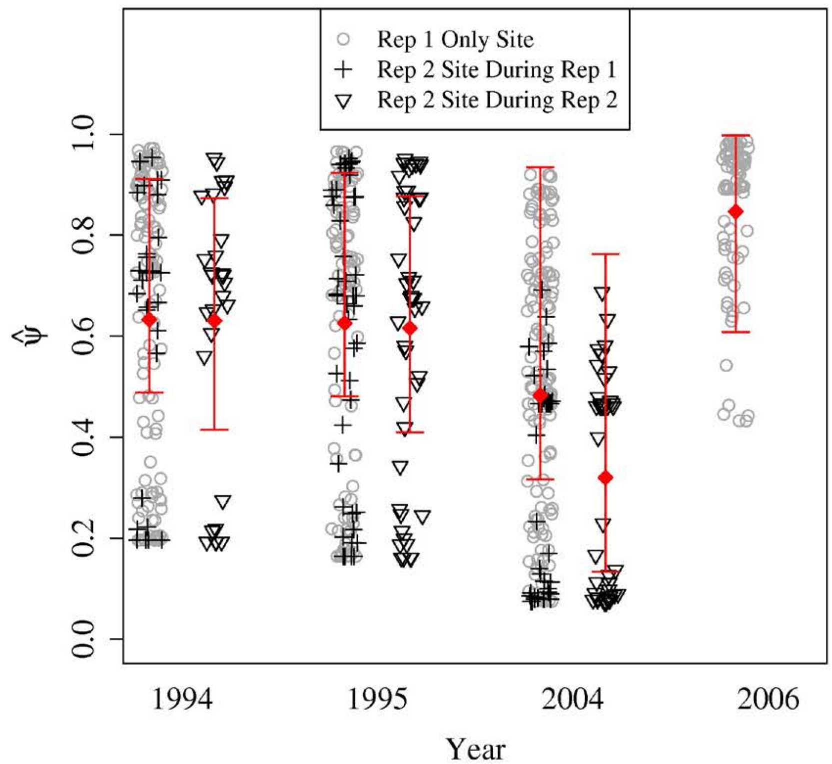

Figure 4. Predicted site occupancy rates based on model 2c for fisher track plate detections which contained indicator variables for discrete year and replicate effects. Red diamonds represent average predictions for year-by-replicate combinations, and red lines show 90% confidence intervals based on the percentile method and 1,000 bootstrap samples of sites and their detection histories.

C.4 TREE VOLE STUDIES

Section C.4 is a copy of a published study of the relative abundance, nest site characteristics and nest dynamics of red tree voles on managed timberlands in coastal northwest California.

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RELATIVE ABUNDANCE, NEST SITE CHARACTERISTICS, AND NEST DYNAMICS OF SONOMA TREE VOLES ON MANAGED TIMBERLANDS IN COASTAL NORTHWEST CALIFORNIA

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ABSTRACT—Tree voles (*Arborimus* spp.) are arboreal rodents that are endemic to the Pacific Northwest. Little is known about their population structure or population trends due to the lack of a reliable capture method suited to mark-recapture studies. We used a line transect approach to determine density of active Sonoma tree vole (*A. pomo*) nests in 6 stand-age categories in a managed forest landscape. Median density varied from 0 to 6.21 active nests/ha, with an increasing trend relative to stand age ($P = 0.003$). Nest tree diameter at breast height ($P < 0.001$) and nest height ($P < 0.001$) increased significantly with stand age. Nest placement, relative to the bole of the tree, also differed significantly ($P = 0.045$), with more nests being placed out on branches in older stand-age categories. We also monitored Sonoma tree vole nests to quantify the characteristics of nest dynamics. The mean proportion of nests that were occupied from 1 checking period to the next ranged from 0.4 to 0.6 in the different aged stands. Median persistence time of a nest was 28.6 months (95% CI = 25.8 to 34.8 months) and the probability of a nest persisting beyond 60 months was <0.1.

Key words: *Arborimus pomo*, Sonoma tree vole, managed forests, nest dynamics, timber harvest, northern California

Tree voles (*Arborimus* spp.) are the smallest and least studied arboreal rodents found in Douglas-fir (*Pseudosuga menziesii*) forests of the Pacific Northwest (Carey 1991). Although they are endemic to forests of coastal Oregon and California, few studies have attempted to elucidate their population structure, population trends or general ecology (Verts and Carraway 1998). Because they are arboreal, nocturnal, and apparently feed only on conifer needles (Maser and others 1981), tree voles are exceptionally difficult to observe or trap (Johnson and George 1991; Huff and others 1992; Murray 1995). In spite of the inherent difficulties associated with doing field studies on the species, it has been suggested that tree voles have a close association with old-growth Douglas-fir forests and could be vulnerable to local extirpations due to the loss or fragmentation of these forests (Gillesberg and Carey 1991; Ruggiero and others 1991; Huff and others 1992). In California, the Sonoma tree vole (*Arborimus pomo*) is considered a "species of special concern" by the California Department of Fish and Game (CDFG 2000).

Recent genetic studies have established 2 distinct species of tree voles: the red tree vole (*A. longicaudus*), which is distributed from near the Columbia River in northwestern Oregon south to Del Norte county in northern California, and the Sonoma tree vole found in northwestern California from Del Norte county south to Sonoma county (Johnson and George 1991; Murray 1995). The species differ genetically and show subtle morphometric differences (Johnson and George 1991).

Tree voles are found almost exclusively in forests that have Douglas-fir in the canopy (Huff and others 1992). Tree vole populations appear to have a patchy distribution (Carey and others 1991). Areas of activity are most easily determined by the presence of nests, which are constructed of fine twigs, feces, conifer needles, lichens, and discarded resin ducts (Carey 1991). These resin ducts remain after voles consume the fleshy part of conifer needles (Benson and Borell 1931). Carey (1991) states that tree voles also use nests of other species. Nests are located throughout the canopy, although they are more common in the lower third (Vrieze 1980; Gillesberg and Carey 1991; Meiselman and Doyle 1996). Meiselman and

Doyle (1996) found nests only in Douglas-fir trees. Nests are usually located near the trunk of the tree, but can be found out on branches as well (Gillesberg and Carey 1991; Meiselman and Doyle 1996). The primary food of tree voles is Douglas-fir needles, although they will consume needles of grand fir (*Abies grandis*), sitka spruce (*Picea sitchensis*), and western hemlock (*Tsuga heterophylla*) (Howell 1926; Benson and Borell 1931).

Although tree vole nests are often found in aggregations that could be described as colonies, it is generally thought that individual nests are inhabited by a single adult vole or an adult female with young (Jewett 1920; Benson and Borell 1931). After examining approximately 70 nests and collecting 23 specimens, Benson and Borell (1931) found only 1 nest that was occupied by 2 adults and observed no difference in the appearance of nests occupied by males compared to those occupied by females. If a single adult vole occupies a nest, then the number of active nests could provide a reliable index of the abundance of voles in a stand. If individual voles have multiple nests, the index could still be useful if the number of nests/vole remains constant with varying vole densities.

Potential tree vole nests can be located by visually searching trees from the ground. Nest materials can often be found below nests. The nest can be confirmed as that of a tree vole if resin ducts are found in this accumulation of material. If nest material is not found, climbing and inspecting the nest is required for confirmation of a tree vole nest.

Line transects provide a systematic approach for counting tree vole nests within occupied forest stands. Burnham and others (1985) suggested that line transects are more efficient and less biased than strip transects when the probability of detection decreases dramatically with increased distance from the line. Nest search results have the potential to be used as an index to actual population sizes, although the relationship between number of nests and number of individuals is not known (Carey and others 1991). Corn and Bury (1986, 1988) have captured tree voles in pitfall traps with limited success. Others, including us, have captured tree voles by climbing nest trees and raiding active nests (Benson and Borell 1931). Although animals can be captured using these methods, they are not well suited for mark-recapture studies due to the potential destruction of nests (nest raiding) or death of the individual animals (pitfall traps). Because no reliable method of capture has been developed for the tree voles, no direct relationship between the number of active nests and number of individuals has been established. This means that using the number of active nests as indicators of relative abundance must be done with caution. Counts of active nests cannot be used to estimate actual population size.

We studied the relative abundance and nest site characteristics of Sonoma tree voles in managed Douglas-fir forests within Simpson Timber Company's (STCO) ownership in northwestern California. In addition, we conducted an observational study of Sonoma tree vole nests to determine patterns of nest dynamics. This included estimates of nest permanence, abandonment, occupancy, and re-occupancy.

Study Area and Methods

The study area was confined to the lower Mad River and Redwood Creek drainages within STCO ownership in Humboldt County, northwest California (Fig. 1). The predominant overstory species on the study area was Douglas-fir, although the western portion included a significant amount of coastal redwood (*Sequoia sempervirens*). Hardwoods, such as tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), and California bay (*Umbellularia californica*) added significantly to the overstory of some stands. Almost all forests on STCO property have been logged at least once using even-age silvicultural practices, leaving young 2nd- and 3rd-growth stands. The oldest stands were from 80 to 100 yr old, although some younger stands contained scattered residual trees that were left during past logging operations (due to low merchantability and inaccessibility).

Forest stands were randomly selected using STCO's GIS timber inventory database from each of the following stand-age categories: 10 to 19, 20 to 29, 30 to 39, 40 to 49, 50 to 59 and 60+ yr old. The selected stands were searched for Sonoma tree vole nests using a line transect approach (Anderson and others 1979). The line transect approach was well suited for counting tree vole nests in managed forests because tree height and structural complexity were less rel-

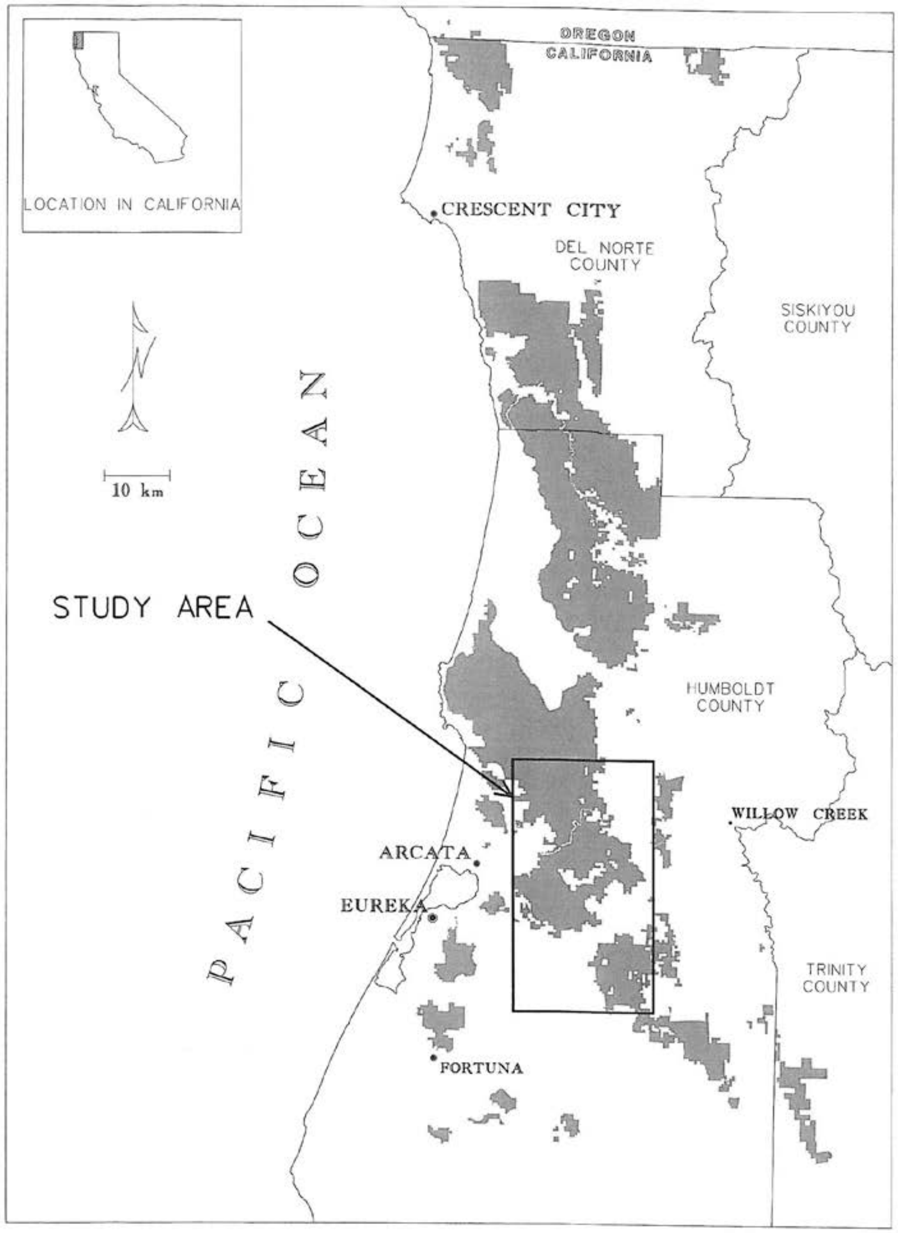

FIGURE 1. Sonoma tree vole study area in northwestern California. Shaded area denotes Simpson Timber Company ownership.

ative to mature or old-growth forests. We used density of active nests as an indicator of relative abundance of tree voles in different aged stands. This study was based on the following assumptions: 1) individual nests were used by a single adult vole and 2) if individual voles used more than 1 nest, the number of nests used was independent of vole density. Transect distances were recorded using a hip-chain with perpendicular distances to nests measured with a hand-held tape measure. Transect lengths were dependent on the shape and area of the individual stands. Transects varied from 200 to 750 m with most transects approximately 500 m in length.

We distinguished tree vole nests from avian and other mammalian nests by observing resin ducts (old or new) on the nest or on the ground below the nest (Benson and Borell 1931; Maser 1966). Occupancy was established using 1 of the following 3 criteria: 1) the presence of freshly discarded (green) resin ducts on the nest or on the ground below the nest (Benson and Borell 1931), 2) small, fresh conifer boughs on top of the nest (Benson and Borell 1931), or 3) sighting a tree vole at the nest. Other data collected at each nest included the species and diameter at breast height (dbh) of the tree containing the nest, height of the nest, and the location of the nest relative to the bole of the tree.

Due to small sample sizes, active and inactive nests were combined and stratified by age category. They were then analyzed using program DISTANCE (Thomas and others 1998) to determine the detection function and effective strip width (ESW) for each age category. Model selection was done automatically by DISTANCE based on Akaike's Information Criterion (AIC). Following DISTANCE analysis, we calculated the density of active nests for each stand using the ESW for the appropriate age category produced by DISTANCE. Density of active nests was compared among stand-age categories using ANOVA (Hintze 2000). Nest height and nest tree dbh were square root transformed and compared among stand-age categories using ANOVA (Hintze 1997). Post-hoc comparisons of nest height and dbh were completed using Fisher's LSD Multiple-Comparison test. Chi-square tests were used to compare nest placement among stand-age categories.

To compare nest trees to the trees immediately surrounding the nest tree, we randomly selected vole nests in each of the sampled stands and recorded the dbh of every tree >7.5 cm dbh within a 0.04-ha circular plot centered on the tree containing the nest. Only trees >7.5 cm dbh were included because no vole nests were located in trees <7.5 cm dbh. The average diameter of all plot trees was then compared to the nest tree diameter in an attempt to look for tree size selection for nest building.

We also conducted an observational study of nest use patterns in which we monitored 10 forest stands from 5 different age classes (2 each: 20 to 29, 30 to 39, 40 to 49, 50 to 59, and 60+ yr old) that were known to have high densities of tree vole nests. Although our nonrandom selection of stands prevented us from making inferences beyond the area of study, it was necessary to observe stands with large numbers of tree vole nests to quantify differences in nest occupancy through time. We laid out a 100- × 100-m grid with 10-m spacing between grid points in each stand and searched the stands intensively for active and inactive nests in an attempt to locate every nest in the grid. Because the majority of tree vole nests are found within the lower ⅓ of the canopy (Zentner 1977; Vrieze 1980; Gillesburg and Cary 1991; Meiselman 1992), and we were able to view the uppermost portion of most trees, we believe that we were successful in detecting a very high proportion of the nests in our study grids. We flagged all nest trees and noted the location of nests within each 10-m grid so that nest trees could be relocated on subsequent visits. We collected data during fall of 1994; winter, spring, and fall of 1995; and winter and fall of 1996.

We recorded the total number of tree vole nests in each grid and examined nests to determine occupancy using the same visual observations of sign described previously. Nests were not disturbed or altered during the observational study. We tested the hypotheses that tree vole nest occupancy (nest inhabited by a vole), re-occupancy (formerly abandoned nest subsequently inhabited by a vole), persistence (length of time a nest remained intact), abandonment (nest vacated due to movement or death of the occupant), and new nest construction (occupied nest not observed on the previous visit) were not different among various stand-age classes. Nests were considered destroyed if the nest was completely gone or

TABLE 1. Summary data and median density of active Sonoma tree vole nests across a range of stand age categories.

Parameter	Stand age category (yr)					
	10–19	20–29	30–39	40–49	50–59	≥60
Number of stands searched	6	7	9	8	8	8
Number of stands with nests	0	4	9	6	7	7
Total transect distance (m)	3250	3850	4300	3900	3870	3550
Total number of nests	0	11	40	45	44	45
Number of active nests	0	7	29	33	22	39
Median density of active nests (number/ha)	0	1.00	3.40	3.99	2.01	6.21

enough material had been lost that the nest would no longer provide shelter for a vole. To control for differences in nest density among stands, the 5 dependent variables (newly constructed, occupancy, re-occupancy, abandonment, and destruction) were expressed as proportions based on the total number of nests recorded for each sampling period.

Univariate repeated measures analyses were run on the 5 nest turnover variables to detect differences among age classes and sample periods. For the repeated measures analysis, observed proportions were transformed using the empirical logistic transformation (McCullagh and Nelder 1989) prior to analysis to achieve additivity and allow analysis using standard methods. The empirical logistic transformation proceeded as follows: if n is the number of nests in a certain category during a stand survey (for example, n = the number of active nests in a certain stand during a certain visit), and t is the total number of nests in the stand during that visit, the empirical logistic transformation of the proportion n/t was

$$y = \log\left(\frac{n + 0.5}{t - n + 0.5}\right).$$

By the nature of binomial data, the variance of observed proportions was small when n/t was near 0 or 1, and larger when n/t was near 0.5. Consequently, the reciprocals of y's estimated variance,

$$w = 1/v = [(n + 0.5)^{-1} + (t - n + 0.5)^{-1}]^{-1},$$

were used as weights in the repeated measures analysis. In addition, the univariate repeated measures analysis assumed that transformed proportions were equally correlated through time. Effects due to age class, period, and the age class-by-period interaction were fit.

It was not possible to directly estimate the mean persistence time of vole nests without knowing when each nest was 1st constructed and then following the nest until it was destroyed. Therefore, we conducted a "survival analysis" to determine the distribution of "life times" of vole nests (Hintze 1997). This analysis was based on the elapsed time between initiation of observations on the nests and destruction of the nest or cessation of the study. The data values were a mixture of complete (nests destroyed) and censored observations (vole nests are still intact at the end of the study). The distribution of nest "life time" was assumed to follow a Weibull distribution (Hintze 1997). To test the appropriateness of the Weibull distribution, we plotted log[-logS(t)] vs log t, where S(t) is the product-limit (Kaplan-Meir) estimate of nest survival and t is the time interval. Allison (1995) suggests that if the Weibull distribution provides a good fit, this plot will be a straight line. This survival analysis provided estimates of expected "life time" or average time to nest destruction.

RESULTS

A total of 46 stands were searched in 6 stand-age categories, yielding 185 Sonoma tree vole nests. Nests were identified in all but the youngest stand-age category (Table 1). Although nests were documented in 8 species of tree and on the ground, 80.5% of the nests were located in Douglas-fir trees. Tanoak was the next most commonly used tree for nesting. Density of active nests increased significantly with stand age (ANOVA, $F = 4.422$, df = 5,39, $P = 0.003$). Median density estimates of active nests increased from 0 to 6.21 nests/ha with increased stand age, with the exception of the 50 to 59 yr-old stands (Table 1). This trend held true even

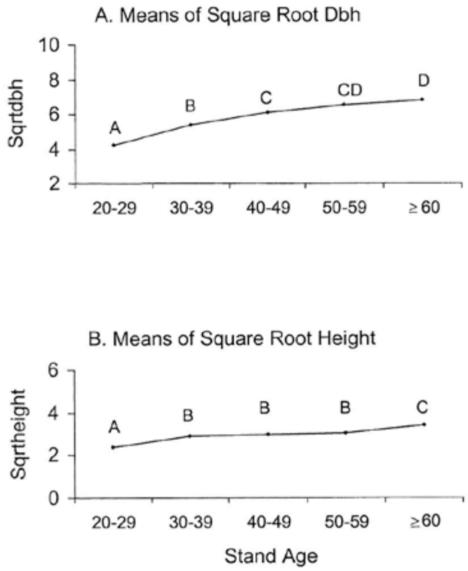

FIGURE 2. Differences in the square root of nest tree diameter at breast height (sqrtdbh) and nest height (sqrtheight) relative to stand age. Means labeled with the same letter did not differ significantly based on Fisher's LSD Multiple-Comparison test.

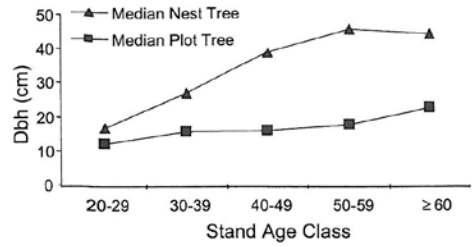

FIGURE 3. Median diameter at breast height (dbh) of Sonoma tree vole nest trees and surrounding trees (0.04 ha plot centered on nest tree) relative to stand age.

if the 10 to 19 yr-old age category (in which we found no vole nests) was dropped from the analysis (ANOVA, $F_{4,34} = 2.904$, $P = 0.036$).

There were significant differences in nest tree dbh ($F_{4,179} = 9.56$, $P < 0.001$, Fig. 2a) and nest height ($F_{4,179} = 8.30$, $P < 0.001$, Fig. 2b) among the 5 stand-age categories in which vole nests were found. Nests were located higher and in larger diameter trees as stand age increased. The median dbh of nest trees increased to a maximum of about 46 cm with increasing stand age, while plot trees increased only slightly with stand age (Fig. 3). Voles constructed nests in small (≤11 cm dbh) trees in all age classes of stands, but the range of tree sizes increased with increasing stand age (Fig. 4). Nest placement also differed significantly among stand-age categories ($\chi^2 = 9.75$, df = 4, $P < 0.05$), with an increased proportion of nests located on branches away from the bole in older stands.

During the nest observation study, the mean number of Sonoma tree vole nests/100- × 100-m grid/yr for stand-age classes 20 to 29, 30 to 39, 40 to 49, 50 to 59, and 60+ yr throughout the 6 study periods was 9.7, 9.7, 14.1, 16.3, and 14.2, respectively. Results from the repeated measures analysis (Table 2) demonstrate that the age class-by-period interaction was significant for the proportion of destroyed nests, proportion of reoccupied nests, and proportion of abandoned nests ($P = 0.0014$, 0.0223, 0.018, respectively). The proportion of destroyed nests in the 30 to 39 yr-old and 40 to 49 yr-old age classes was unusually high during fall 1996, while the remaining 3 age classes had unusually high proportions of destroyed nests in winter of 1997. In addition to the high proportion of destroyed nests in fall 1996, the 40 to 49 yr-old age class also exhibited a high proportion of abandoned nests. We documented a high proportion of reoccupied nests in the 40 to 49 yr-old age class in winter 1997 and a high proportion of reoccupied nests in the 60+ yr-old age class during spring 1995.

Nest persistence did not differ among stand age classes ($\chi^2 = 16.9$, df = 12, $P = 0.154$);

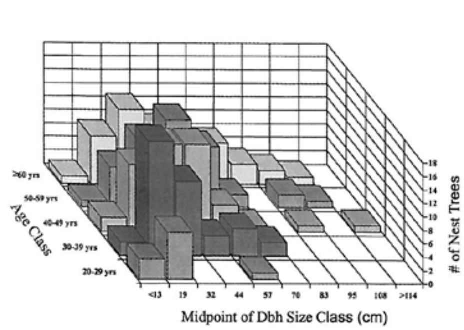

FIGURE 4. Number of Sonoma tree vole nest trees in a range of dbh (diameter at breast height) size classes relative to stand age.

TABLE 2. *F*-ratios and *P*-values from the repeated measures analysis of the empirical logistic transformation of five responses measured during the tree vole nest observation study. 'Agecat' represents the age class of the surveyed stand and 'Period' represents the date of the survey.

		Empirical logistic response			
Response variable	Effect	Numerator degrees of freedom	Denominator degrees of freedom	*F*	*P*
Newly active	Agecat	4	5	0.64	0.658
	Period	5	22	4.16	0.008
	Agecat by period	20	22	0.81	0.682
Active	Agecat	4	5	2.91	0.136
	Period	6	26	7.35	<0.001
	Agecat by period	24	26	0.60	0.893
Destroyed	Agecat by period	20	22	3.86	0.001
Recolonized	Agecat by period	20	22	2.44	0.022
Abandoned	Agecat by period	20	22	2.54	0.018

therefore, data from all age classes were lumped together to calculate nest persistence time. After lumping, the persistence time (survival time) of 113 nests was estimated over 42 mo (fall 1994 through spring 1998). The linear regression of log[-logS(t)] vs. log t was highly significant ($F = 219.59$, $P < 0.001$, $r^2 = 0.9821$). These results indicated that the Weibull distribution was appropriate to use for the distribution of nest persistence. The Weibull-based survival analysis indicated that the probability of a nest being destroyed was nearly linear over the duration of the study (Fig. 5). Median persistence time of a nest was 28.6 mo (95% CI = 25.8 to 34.8 mo), and the probability of a nest persisting beyond 60 mo (5 yr) was <10%.

DISCUSSION

It has been suggested that tree voles are associated with mature and old-growth forests

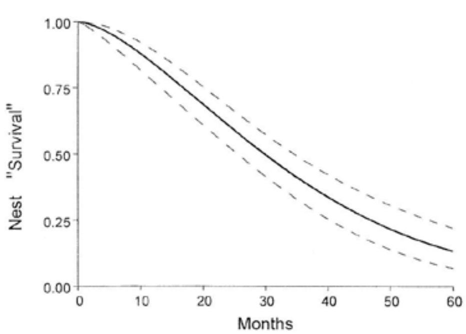

FIGURE 5. Weibull survival distribution of Sonoma tree vole nests with the 95% confidence interval.

(Franklin and others 1981; Meslow and others 1981; Corn and Bury 1986). In our study area, we hypothesize that voles begin colonizing stands at about 20 yr old. This is based on the assumptions that voles did not persist in openings following clearcut timber harvesting and that the vole nests currently found in these regenerating stands resulted from voles that colonized the stand from adjacent areas. It is unknown if the time required for apparent colonization is due to the need for the development of suitable stand structure to support vole populations or if it is related to the time necessary for voles to disperse from adjacent stands. We have made anecdotal observations of vole nests in stands 10 to 16 yr old, which suggests that source distance of colonizing voles may increase the time for colonization beyond the age when the stand is structurally suitable for occupation.

Density of active vole nests increased significantly as stands matured beyond 20 yr old, with the exception of the 50 to 59 yr-old age class (Table 1). It is unknown whether or not the increase in active vole nests would have continued if older stands had been available for sampling. It is also unknown if the increased number of active vole nests accurately reflected increased vole numbers. As stated earlier, the relationship between number of voles and number of vole nests is unknown. In relating active nest densities to relative abundance, we assumed that the number of nests a vole used did not vary as vole density changed. Based on this assumption, we would assume there were more voles in stands with more active nests.

The increase in nest height and nest tree dbh (Fig. 2) was presumably attributed to fundamental growth characteristics of a developing young-growth stand. The available trees for nesting become larger with age, and as a young conifer grows, its lower branches die and fall away. To find suitable platforms for nest construction, tree voles would be forced to nest higher in the tree or move to another tree. This increase in height also keeps the vole closer to its food source, the needles of the living branches. Nest placement also differed among stand-age categories. As stand age increased, voles built more nests out on branches away from the bole. Perhaps this was associated with the more developed branch systems, which provided good supporting structure for the nests. In addition, nests on limbs were closer to the vole's food source.

Because the primary food of tree voles is Douglas-fir needles (Benson and Borell 1931), one would expect to find nests more often in Douglas-fir trees. Meiselman and Doyle (1996) found tree vole nests only in Douglas-fir. We located nests in 8 tree species and on the ground, although 80% of the nests were in Douglas-fir trees. Tanoak was the next most frequently used tree for nest construction, which was presumably due to its common occurrence in many stands. The majority of nests found in tanoak appeared to have initially been made by other species, most likely western gray squirrels (*Sciurus griseus*) and Douglas squirrels (*Tamiasciurus douglasii*). We did locate 1 nest in a 38 yr-old stand that was on the ground. It was below a small Douglas-fir that contained a small, active vole nest. After close inspection, it was obvious that this nest had not fallen from the tree above. The ground nest was approximately 0.5 m across, and was covered with fresh fir clippings. Under the clippings, we found masses of fresh resin ducts and a system of tunnels. We did not locate a vole at this nest; therefore, we do not know if it was occupied by a male or female.

In the youngest stands occupied by voles, there was little difference between trees with vole nests versus trees in a plot immediately surrounding the nest tree. As stands increased in age, the median size of trees with nests increased at a greater rate than plot trees. This could be an indication that most of the trees in these stands were suppressed and not growing due to being over-stocked. However, because each plot was centered on a tree with a vole nest, we believe this indicated that voles tended to select for the dominant or co-dominant trees in a stand, and the trees immediately surrounding nest trees tended to be suppressed and were smaller in diameter than the dominant over-story trees. Even though the majority of vole nests were located in dominant and co-dominant trees, small trees ($\leq$11 cm dbh) continued to be used for nesting and contained 2 to 4% of all vole nests located in each of the 4 oldest age categories (Fig. 4).

The inability to conduct traditional mark-recapture studies with tree voles precludes any type of quantitative population assessment. The results of this study cannot be used to directly estimate the age or structural characteristics associated with a stand that is capable of supporting a viable population of voles. Our findings do indicate that old forest is not required in the vicinity of a younger stand for it to become occupied by voles. Although dispersal distances of tree voles have not been documented, we assume they are not effective at dispersing long distances. Where there were mature stands in close proximity to young-growth stands, we would assume that increases in numbers of active vole nests could be attributed to local recruitment as well as dispersal from adjacent mature stands. However, in the more isolated young-growth stands (>7 km from mature forests), we suspect that increases in the number of active nests were not influenced by dispersal from distant mature stands, but were due to inherent increases in the local vole populations through time.

When considering use patterns of vole nests, we hypothesized that dynamics of Sonoma tree vole nests were not different among stands of different age classes. Because of the interaction between age class and check period, we could not assess differences due to age class alone; however, we did find differences for 3 of the dependent variables (destroyed, abandoned, and reoccupied) when considering age class-by-check period interactions (Table 2). Considered together, it appears that the trajectories of the proportions destroyed, abandoned, and reoccupied were approximately the same in the 30 to 39 and 40 to 49 yr-old age classes, but were different from the same trajectories in the 20 to 29, 50 to 59, and 60+ yr-old age classes. The lack of a consistent trend among all stand ages made a biological interpretation of these differences problematic.

We expected to find differences in nest permanence (reflected in the proportion of nests destroyed) relative to stand age, but found no clear trend. Presumably, a nest was more likely to be destroyed through passive processes, such as windstorms, after the occupant had died. It also seemed likely that inclement weather would affect vole nests differently in various stand-age classes, with nests in older stands being better protected. Since our data were not consistent with these hypotheses, one might suggest that nest destruction may be primarily due to stochastic events, such as the direct actions of predators. Because of the patchy distribution of tree vole nests, discovery of 1 nest by a predator would enhance the likelihood of discovering others, thereby increasing the chances of having a high proportion of nests destroyed in a given colony. The variation among the proportions of nests destroyed supports this hypothesis. The lack of a clear trend among stand-age classes supports the theory that the colonies might have been hit by predators, causing high proportions of nests to be destroyed in individual colonies over relatively short periods of time. Depending on the type of predator, the effect could be similar on nest abandonment. A mammalian predator might be more inclined to destroy a number of nests while searching for prey, while an avian predator might focus on a colony and take voles without destroying the nests, causing increases in nest abandonment but not destruction.

Zentner (1977) speculated that succeeding generations of voles occupied a single nest and that some nests could be 30 yr old. Contrary to Zenter (1977), we did not find evidence of vole nests persisting for long periods of time in our managed forests. Our data indicated that most nests persisted just over 2 yr and <10% of nests persisted >5 yr (Fig. 5). The relatively linear nature of the estimated survival of nests suggested that nest destruction was a stochastic event with approximately equal probabilities through time. It is possible that Zentner's (1977) observations were the result of nests constructed in structural deformities of large, older trees that would not be as highly susceptible to destruction by passive processes or predatory actions as would nests in younger trees with fewer deformities. This could lead to the accumulation of large amounts of nest material over long periods of time as the site is repeatedly occupied by successive generations of voles. This suggests that large trees with structural deformities may be important habitat elements for this species, especially in regenerating forests that typically have less structural diversity than mature forests. We recommend that large trees with deformities and low commercial value be retained during harvesting operations to maintain important wildlife value while having minimal commercial impact on timber harvest operations. However, additional research will be required to fully understand the dynamics of tree vole nests and the importance of different types of nesting structure.

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LITERATURE CITED

ALLISON PD. 1995. Survival analysis using the SAS system: a practical guide. Cary, NC: SAS Institute Inc. 292 p.

ANDERSON DR, LAAKE JL, CAIN BR, BURNHAM DP. 1979. Guidelines for line transect sampling of biological populations. Journal of Wildlife Management 43:70–78.

BENSON SB, BORELL AE. 1931. Notes on the life history of the red tree mouse, *Phenacomys longicaudus*. Journal of Mammalogy 12:226–233.

BURNHAM KP, ANDERSON DR, LAAKE JL. 1985. Efficiency and bias in strip and line transect sampling. Journal of Wildlife Management 49:1012–1018.

[CDFG] CALIFORNIA DEPARTMENT OF FISH AND GAME. 2000. California natural diversity database: special animals. Sacramento, CA: California Department of Fish and Game. 52 p.

CAREY AB. 1991. The biology of arboreal rodents in Douglas-fir forests. In: Huff MH, Holthausen RS, Aubry KB, technical coordinators. Biology and management of old-growth forests. Portland, OR: USDA Forest Service. General Technical Report PNW-276. p. 6–8.

CAREY AB, BISWELL BL, WITT JW. 1991. Methods for measuring populations of arboreal rodents. Portland, OR: USDA Forest Service. General Technical Report PNW-273. 18 p.

CORN PS, BURY RB. 1986. Habitat use and terrestrial activity by red tree voles (*Arborimus longicaudus*) in Oregon. Journal of Mammalogy 67:404–406.

CORN PS, BURY RB. 1988. Distribution of the voles *Arborimus longicaudus* and *Phenacomys intermedius* in the central Oregon Cascades. Journal of Mammalogy 69:427–429.

FRANKLIN JF, CROMACK K JR., DENISON W, MCKEE A, MASER C, SEDELL J, SWANSON F, AND JUDAY G. 1981. Ecological characteristics of old-growth Douglas-fir forests. Corvallis, OR: USDA Forest Service. Portland, OR: General Technical Report PNW-118. 48 p.

GILLESBERG A, CAREY AB. 1991. Arboreal nests of *Phenacomys longicaudus* in Oregon. Journal of Mammalogy 72:784–787.

HINTZE JL. 1997. NCSS 97: Number cruncher statistical system for windows. Kaysville, UT: NCSS.

HINTZE JL. 2000. NCSS 2000: Number cruncher statistical system for windows. Kaysville, UT: NCSS.

HOWELL AB. 1926. Voles of the genus *Phenacomys* II. Life history of the red tree mouse *Phenacomys longicaudus*. North American Fauna 48:39–64.

HUFF MH, HOLTHAUSEN RS, AUBRY KB. 1992. Habitat management for red tree voles in Douglas-fir forests. Portland, OR: USDA Forest Service. General Technical Report PNW-GTR-302. 16 p.

JEWETT SG. 1920. Notes on two species of *Phenocomys* in Oregon. Journal of Mammalogy 1:165–168.

JOHNSON ML, GEORGE SB. 1991. Species limits within the *Arborimus longicaudus* species complex (Mammalia: Rodentia) with a description of a new species from California. Natural History Museum of Los Angeles County: Contributions in Science, Number 429:1–16.

MASER C. 1966. Life histories and ecology of *Phenacomys albipes*, *Phenacomys longicaudus*, *Phenacomys silvicola* [thesis]. Corvallis, OR: Oregon State University. 221 p.

MASER C, MATE BR, FRANKLIN JF, DYRNESS CT. 1981. Natural history of Oregon coast mammals. Portland, OR: USDA Forest Service. General Technical Report PNW-GTR-133. 496 p.

MCCULLAGH P, NELDER JA. 1989. Generalized linear models, 2nd ed. London, UK: Chapman and Hall. 511 p.

MEISELMAN N. 1992. Nest-site characteristics of red tree voles in Douglas-fir forests of northern California [thesis]. Arcata, CA: Humboldt State University. 60 p.

MEISELMAN N, DOYLE TA. 1996. Habitat and microhabitat use by the red tree vole (*Phenacomys longicaudus*). American Midland Naturalist 135:33–42.

MESLOW EC, MASER C, VERNER J. 1981. Old-growth forests as wildlife habitat. Transactions of the North American Wildlife and Natural Resources Conference 46:329–335.

MURRAY MA. 1995. Biochemical systematics of the genus *Arborimus* [thesis]. Arcata, CA: Humboldt State University. 46 p.

RUGGIERO LF, JONES LLC, AUBRY KB. 1991. Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: an overview. Portland, OR: USDA Forest Service. General Technical Report PNW-GTR-285:447–462.

THOMAS L, LAAKE JL, DERRY JF, BUCKLAND ST, BORCHERS DL, ANDERSON DR, BURNHAM KP, STRINDBERG S, HEDLEY SL, BURT ML, MARQUES FFC, POLLARD JH, FEWSTER RM. 1998. Distance 3.5. St. Andrews, UK: Research Unit for Wildlife Population Assessment, University of St. Andrews.

VERTS BJ, CARRAWAY LN. 1998. Land mammals of Oregon. Berkeley, CA: University of California Press. 720 p.

VRIEZE JM. 1980. Spatial patterning of red tree mouse nests [thesis]. Arcata, CA: Humboldt State University. 37 p.

ZENTNER PL. 1977. The nest of *Phenacomys longicaudus* in northwestern California [thesis]. Sacramento, CA: California State University Sacramento. 57 p.

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Appendix D. Summary of Green Diamond Resource Company's Forest Habitat Conservation Plan Riparian and Geologic Measures.

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D.1 INTRODUCTION

The Forest Habitat Conservation Plan (FHCP) includes enforceable Riparian Management Zone (RMZ) prescriptions and protection of geologically unstable areas beneficial to the Covered Species as a landscape management commitment to promote retention and development of late seral habitat in a dendritic network across the Plan Area. Although initially created through the Aquatic Habitat Conservation Plan that currently mandates their implementation, these prescriptions are also incorporated as enforceable commitments of this FHCP to promote protections for terrestrial Covered Species within riparian zones where only a single light selection harvest (variable 0-30% canopy removal) is allowed during the life of the Plan. Prescriptions for RMZs and geologically unstable areas provide a substantial conservation benefit for the Covered Species and they encumber over 25% of the Plan Area through extremely limited or no timber harvest. Accordingly, they are an important factor in the Service's consideration of whether this FHCP minimizes and mitigates take to the maximum extent practicable.

D.1.1 Riparian Management Measures

D.1.1.1 Class I RMZ Width

Green Diamond will apply a riparian management zone (RMZ) of at least 150 feet (slope distance) on each bank of all Class I watercourses. The width will be measured from the watercourse transition line or from the outer Channel Migration Zone (CMZ) edge where applicable.

Where the floodplain is wider than 150 feet on one side, the outer zone of the RMZ will extend to the outer edge of the floodplain. An additional buffer will be added to the RMZ immediately adjacent to a floodplain, as follows:

Side Slopes	Additional Floodplain Buffer
0-30%	30 feet
30-60%	40 feet
>60%	50 feet

D.1.1.1.1 Inner Zone RMZ Width

Green Diamond will establish an inner zone within the RMZ, the width of which will depend upon the streamside slope in accordance with the following:

Side Slopes	Inner Zone Width
0-30%	50 feet
30-60%	60 feet
>60%	70 feet

D.1.1.1.2 Outer Zone RMZ Width

Green Diamond will establish an outer zone of the RMZ within the RMZ, which will extend from the outside limit of the inner zone edge to at least 150 feet from the bankfull channel (or CMZ edge) with the additional floodplain buffer set forth above.

D.1.1.2 Conservation Measures within Class I RMZs

During the life of the Plan, Green Diamond will carry out only one harvest entry into Class I RMZs, which will coincide with the even-aged harvest of the adjacent stand. Green Diamond will apply the restrictions in this subsection of Section D.1.1 during such entry. If cable corridors through RMZs are necessary to conduct intermediate treatments (e.g., commercial thinning) in adjacent stands prior to even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stands. These Class I RMZs will be subject to the restrictions identified in Section D.1.1.2.

D.1.1.2.1 Overstory Canopy Closure

1. Green Diamond will retain at least 85% overstory canopy closure within the inner zone.
2. At least 70% canopy overstory closure will be retained within the outer zone.
3. CDF protocol in effect as of the date of the Plan will be used for sampling overstory canopy cover to determine compliance with the overstory canopy closure requirements.

D.1.1.2.2 Retention Based on Bank Stability

1. Within the RMZ, Green Diamond will harvest no trees that contribute to maintaining bank stability.
2. Redwoods will be preferentially harvested over other conifers.

D.1.1.2.3 Conifer Density Requirements

1. If the inner zone is predominantly composed of hardwoods (it contains <15 conifer stems per acre that are >16 inches dbh), Green Diamond will take no conifers from the inner zone.
2. No harvesting within the RMZ will be undertaken that would reduce the conifer stem density within the RMZ to <15 conifer stems that are >16 inches dbh per acre.

D.1.1.2.4 Retention Based on Likelihood to Recruit

The following criteria will be used to identify trees within the RMZ as potential candidates for marking to harvest due to their low likelihood of recruitment to the watercourse. (The determination of trees to be marked within the RMZ will be predicated on ensuring that overstory canopy retention standards and slope stability measures are met (Sections D.1.1 and D.2.2), as well as ensuring that trees that are likely to recruit to the watercourse are not marked for harvest.)

Criteria for trees that have a low likelihood of recruiting are:

1. Tree has an impeded “fall-path” to the stream (e.g., upslope family members of a clonal group blocked by downslope stems); or
2. Tree or the majority of the crown weight of the tree is leaning away from stream and the tree is not on the stream bank or does not have roots in the stream bank or stream; or
3. The distance of the tree to the stream is greater than the height of the tree; or
4. Tree is on a low gradient slope such that gravity would not carry the fallen tree into the stream or objects such as trees and large rocks impede its recruitment path; or
5. Tree is not on an unstable area or immediately downslope of an unstable area; or

6. Harvesting of the tree will not compromise the stream bank or slope stability of the site or directly downslope of the site.

D.1.1.2.5 Tree Falling for Safety Purposes

Trees may be felled within RMZs to create cable yarding corridors as needed to ensure worker safety, subject to the canopy closure requirements set forth above. Such trees will be part of the harvest unit. This measure supersedes Section D.1.1.2.4 (retention based on likelihood to recruit) when required by law.

D.1.1.2.6 Equipment Exclusion Measures

The Class I RMZ is an equipment exclusion zone (EEZ), except for a) existing roads and landings; b) construction of new spur roads to extend operations outside the RMZ; c) road watercourse crossings; d) skid trail watercourse crossings; e) designated skid trail intrusions; and f) an outside edge of a road that partially intrudes into the RMZ either along the top margin of the RMZ at the head of a watercourse or into the lateral margin of the RMZ to avoid crossing a watercourse (e.g. for the construction of a switch-back).

The exception for skid trail watercourse crossings is only applicable when the following conditions are met:

1. Construction and use of skid trail watercourse crossings within the RMZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trail watercourse crossing sites in the RMZ over establishing new skid trail watercourse crossing sites in the RMZ.
2. Skid trail watercourse crossings shall not be constructed or used in the RMZ to provide access to RMZs for the purpose of their harvest.
3. Within the Class I RMZ, trees may be felled to facilitate skid trail watercourse crossing construction and use. All such felled trees will be retained as downed wood in the RMZ and will be counted towards estimated reductions in full tree equivalent (FTE) values and reductions in potential recruitment of LWD.
4. Green Diamond will submit to the Service an explanation, justification, and map of any proposed skid trail watercourse crossings as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for skid trail intrusions is only applicable when the following conditions are met:

1. RMZ hillslopes are <25%.
2. Construction and use of skid trails within the RMZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trails in the RMZ over construction of new skid trails in the RMZ.
3. Skid trails will not be constructed or used in the RMZ to provide access to RMZs for the purpose of their harvest.
4. Within the RMZ, only trees <10 inches in dbh may be felled to facilitate skid trail use. All such felled trees will be retained as downed wood in the RMZ and will be counted towards estimated reductions in FTE values and reductions in potential recruitment of LWD.

5. Green Diamond has submitted to the Services an explanation, justification, and map of the proposed skid trail and use in the RMZ as part of the informational copy of the THP notice of filing.

The exception for a new road to partially intrude into the RMZ is only applicable when the following criteria are considered and conditions are met:

1. Alternatives to constructing the road within the RMZ (such as other road locations, steeper road grades, crossing a watercourse, vegetation removal within the RMZ) have been evaluated.
2. For lateral RMZ intrusions, RPFs must consider and provide a discussion for the management of road runoff, road grade, side slopes, unstable slopes, riparian vegetation removal (comparison of basal area), other road locations and minimization of new watercourse crossings.
3. For intrusions into RMZs at the head of a watercourse, RPFs must consider and provide a discussion for the same issues identified for lateral RMZ intrusions as well as obtain geologic review for evaluation of potential headwall swales, cut slope heights and fill slopes to confirm this exception has lower potential of sediment delivery and slope failure than installing a watercourse crossing.
4. The road intrusion will encroach no more than 50 feet into the RMZ, must retain a minimum 50 foot vegetated filter strip between the road and watercourse, and the total length of the RMZ intrusion will be limited to 300 feet.
5. Road intrusions within the RMZ may occur only if it will have the least amount of impact to the riparian area and aquatic resources compared to the alternatives.
6. Green Diamond will submit to the Services a discussion of each item above and provide an explanation, justification, and map of the proposed road construction intrusion in the RMZ as part of the informational copy of the THP notice of filing.

D.1.1.2.7 Management-related Ground Disturbance Treatment

1. Any ground disturbance caused by management activities that is larger than 100 square feet within an RMZ will be mulched and seeded or otherwise treated to reduce the potential for sediment delivery from sheet and gully erosion.
2. Minimum standards for seeding and mulching operations are 30 pounds per acre of seed and a minimum mulching depth of two inches, covering at least 90% of the surface area.
3. Hand-constructed firelines (established by removing the duff and litter layers to expose, but not disturb, the mineral soil) will not be subject to the 100-square foot ground disturbance standard, but other measures will be applied as necessary to ensure that hand-constructed firelines within a Class I RMZ do not deliver sediment to Class I watercourses.

D.1.1.2.8 Snag Retention Measures

Green Diamond will retain all safe snags within the RMZ, and fall and leave unsafe snags on-site.

D.1.1.2.9 Inner Zone Salvage

Green Diamond will not carry out salvage within the inner zone of the Class I RMZ. If any part of the salvageable piece is in the inner zone, the entire piece will be left.

D.1.1.2.10 Floodplain or CMZ Salvage

Green Diamond will not carry out salvage within an identified floodplain or CMZ.

D.1.1.2.11 Outer Zone Salvage

Within the outer zone of the Class I RMZ Green Diamond will conduct salvage operations only of downed trees and if all of the following criteria is met:

1. The wood is not currently, and is unlikely in the future to be, incorporated into the bankfull channel (including wood located below unstable areas);
2. The wood is not contributing to bank or slope stability; or
3. The wood is not positioned on a slope such that it can act to intercept sediment moving toward the stream.

D.1.1.3 Class II RMZ Width

1. Green Diamond will establish an RMZ of at least 75 or 100 feet on each bank of all Class II watercourses.
2. A 75-foot minimum buffer will be used on the first 1,000 feet of 1st order Class II watercourses (Class II-1 watercourses). Downstream of this first 1000-foot section, the RMZ will be expanded to at least 100 feet.
3. A 100-foot minimum buffer will be used on all 2nd order or larger Class II watercourses (Class II-2 watercourses).
4. Where a 1st order Class II watercourse flows directly into a Class I watercourse, the Class II RMZ will be at least 100 feet on each bank for the first 200 feet of channel upstream of the Class I RMZ boundary, after which the Class II RMZ will be dictated by the length of the stream, as per #2 above.

D.1.1.3.1 Inner Zone RMZ Width

Green Diamond will establish an inner zone within the RMZ, the width of which will be 30 feet measured from the first line of perennial vegetation.

D.1.1.3.2 Outer Zone RMZ Width

Green Diamond will establish an outer zone of the RMZ within the RMZ, which will extend the remaining 45 feet or 70 feet (depending on whether it is a Class II-1 watercourse or a Class II-2 watercourse, respectively).

D.1.1.4 Conservation Measures within Class II RMZs

During the life of the Plan, Green Diamond will carry out only one harvest entry into Class II RMZs, which will coincide with the even-aged harvest of the adjacent stand. Green Diamond will apply the restrictions in this Section D.1.1.4 during such entry. If cable corridors through RMZs are necessary to conduct intermediate treatments (e.g., commercial thinning) in adjacent stands prior to even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the RMZs will be limited to the cable corridors only. Any cable roads established in the RMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stand. These Class II RMZs will be subject to the restrictions identified in Section D.1.1.4.

D.1.1.4.1 Overstory Canopy Closure

1. Green Diamond will retain at least 85% overstory canopy closure within the inner zone.
2. At least 70% overstory canopy closure will be retained within the outer zone.

D.1.1.4.2 Retention Based on Bank Stability

Within the RMZ, Green Diamond will harvest no trees that contribute to maintaining bank stability. Redwoods will be preferentially harvested over other conifers.

D.1.1.4.3 Retention Based on Likelihood to Recruit

Riparian management zones along the first 200 feet of the Class II RMZ adjacent to the Class I RMZ will be subject to the same criteria that are listed in section D.1.1.2.4 to determine possible candidate trees for marking due to their low likelihood of recruitment.

D.1.1.4.4 Tree Falling for Safety Purposes

Trees may be felled within RMZs to create cable yarding corridors as needed to ensure worker safety, subject to the canopy closure requirements set forth above. Such trees will be part of the harvest unit.

D.1.1.4.5 Equipment Exclusion Measures

The Class II RMZ is an EEZ, except for a) existing roads and landings; b) construction of new spur roads to extend operations outside the RMZ; c) road watercourse crossings; d) skid trail watercourse crossings; e) designated skid trail intrusions; and f) an outside edge of a road that partially intrudes into the RMZ either along the top margin of the RMZ at the head of a watercourse or into the lateral margin of the RMZ to avoid crossing a watercourse (e.g. for the construction of a switch-back).

The exception for skid trail watercourse crossings is only applicable when the following conditions are met:

1. Construction and use of skid trail watercourse crossings within the RMZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trail watercourse crossing sites in the RMZ over establishing new skid trail watercourse crossing sites in the RMZ.
2. Skid trail watercourse crossings shall not be constructed or used in the RMZ to provide access to RMZs for the purpose of their harvest.
3. Within Class II-1 RMZs, trees may be felled and harvested to facilitate skid trail watercourse construction and use. All harvested trees will be counted towards estimated reductions in FTE values and reductions in potential recruitment of LWD.
4. Within Class II-2 RMZs, trees may be felled to facilitate skid trail watercourse crossing construction and use. All such felled trees shall be retained as downed wood in the RMZ

and shall be counted towards estimated reductions in FTE values and reductions in potential recruitment of LWD.

5. Green Diamond will submit to the Services an explanation, justification, and map of any proposed skid trail watercourse crossings as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for skid trail intrusions is only applicable when the following conditions are met:

1. RMZ hillslopes are <25%.
2. Construction and use of skid trails within the RMZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the RMZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trails in the RMZ over construction of new skid trails in the RMZ.
3. Skid trails will not be constructed or used in the RMZ to provide access to RMZs for the purpose of their harvest.
4. Within the RMZ, only trees <10 inches in dbh may be felled to facilitate skid trail use. All such felled trees shall be retained as downed wood in the RMZ and shall be counted towards estimated reductions in FTE values and reductions in potential recruitment of LWD.
5. Green Diamond has submitted to the Services an explanation, justification, and map of the proposed skid trail and use in the RMZ as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for a new road to partially intrude into the RMZ is only applicable when the following criteria are considered and conditions are met:

1. Alternatives to constructing the road within the RMZ (such as other road locations, steeper road grades, crossing a watercourse, vegetation removal within the RMZ) have been evaluated.
2. For lateral RMZ intrusions, RPFs must consider and provide a discussion for the management of road runoff, road grade, side slopes, unstable slopes, riparian vegetation removal (comparison of basal area), other road locations and minimization of new watercourse crossings.
3. For intrusions into RMZs at the head of a watercourse, RPFs must consider and provide a discussion for the same issues identified for lateral RMZ intrusions as well as obtain geologic review for evaluation of potential headwall swales, cut slope heights and fill slopes to confirm this exception has lower potential of sediment delivery and slope failure than installing a watercourse crossing.
4. The road intrusion will encroach no more than 50 feet into the RMZ, must retain a minimum 50 foot vegetated filter strip between the road and watercourse, and the total length of the RMZ intrusion will be limited to the total width of the RMZ.
5. Road intrusions within the RMZ may occur only if it will have the least amount of impact to the riparian area and aquatic resources compared to the alternatives.
6. Green Diamond will submit to the Services a discussion of each item above and provide an explanation, justification, and map of the proposed road construction intrusion in the RMZ as part of the informational copy of the THP notice of filing.

D.1.1.4.6 Management-related Ground Disturbance Treatment

1. Green Diamond will mulch and seed any area where ground disturbance caused by management activities is larger than 100 square feet within a Class II RMZ, or otherwise treat the area to reduce the potential for sediment delivery from sheet and gully erosion.
2. Minimum standards for seeding and mulching operations are 30 pounds per acre of seed and a minimum mulching depth of two inches, covering at least 90% of the surface area.
3. Hand-constructed firelines (established by removing the duff and litter layers to expose, but not disturb, the mineral soil) will not be subject to the 100-square foot ground disturbance standard, but other measures will be applied as necessary to ensure that hand-constructed firelines within a Class II RMZ do not deliver sediment to Class II watercourses.

D.1.1.4.7 Snag Retention

Green Diamond will retain all safe snags within the RMZ, and will fall unsafe snags and leave them onsite.

D.1.1.4.8 Inner Zone Salvage

Green Diamond will not conduct salvage on downed trees within the inner zone. If any part of the salvageable piece is in the inner zone, the entire piece will be left.

D.1.1.4.9 Outer Zone Salvage

Green Diamond will carry out salvage operations within the outer zone only of downed trees and if all of the criteria listed in Section D.1.1.2.11 are met.

D.1.1.5 Class III Protections

Green Diamond will apply one of two tiers of protection measures within Class III watercourses in accordance with HPA Groups and slope gradient (the average slope as measured with a clinometer, starting from the watercourse bank and running upslope for a distance of 50 feet), as follows:

HPA Group	Slope Gradient
Smith River	<65%=Tier A
	>65%=Tier B
Coastal Klamath	<70%=Tier A
	>70%=Tier B
Korbel	<65%=Tier A
	>65%=Tier B
Humboldt Bay	<60%=Tier A
	>60%=Tier B

D.1.1.6 Class III Tier A Protection Measures

D.1.1.6.1 Equipment Exclusion Zone

Green Diamond will establish a 30-foot EEZ, except for a) existing roads; b) road watercourse crossings; c) skid trails; and d) skid trail watercourse crossings.

The exception for skid trail watercourse crossings is only applicable when the following conditions are met:

1. Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.
2. Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
3. Green Diamond will submit to the Services an explanation, justification, and map of any proposed skid trail watercourse crossings as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for skid trail intrusions is only applicable when the following conditions are met:

1. EEZ hillslopes are less than 25 percent.
2. The location and use of skid trails within the EEZ may occur only when the use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Intrusion into the EEZ is preferred if the alternative routes would result in greater road length and additional watercourse crossings. Preference will be given to utilizing shovel logging equipment and using existing skid trails in the EEZ over locating new skid trails in the EEZ.
3. Skid trails will not be used in the EEZ to provide access to EEZs for the purpose of their harvest.
4. All bare mineral soil greater than 100 square feet created by management activities within the EEZ, will be mulched or treated with slash to adequately cover the exposed soil area prior to any onset of rain or upon completion of operations, whichever occurs first.
5. Green Diamond has submitted to the Services an explanation, justification, and map of the proposed entry into the EEZ as part of the informational copy of the THP notice of filing.

D.1.1.6.2 LWD Retention

Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ.

D.1.1.6.3 Site Preparation

Green Diamond will not ignite fire during site preparation within the EEZ.

D.1.1.7 Class III Tier A Modified Protection Measures

Green Diamond will apply Modified Tier A Class III protection measures within Known Tracts, which have been determined to contain a high proportion of Highly Erodible Soils, and to areas within Coho Planning Watersheds in the AHCP Planning Area, where Highly Erodible Soils exist.

On areas outside of Known Tracts within Coho Planning Watersheds in the AHCP/CCAA Planning area, when a forester finds soil conditions that may constitute Highly Erodible Soils during THP layout, Green Diamond will consult with a Professional Geologist to confirm the presence and extent of the Highly Erodible Soils on the THP areas. Coho Planning Watersheds are defined by CDFG as all CalWater 2.2 Planning Watersheds where CDFG has documented coho salmon to be present during or after 1990.

Highly Erodible Soils are soils that are prone to surface erosion. These include Tonnini's or Wildcat Group derived soils, or soils with similar properties that are derived from uplifted marine sediments, and that are composed primarily of sands or silts. There are several mapped bedrock units (composed of no competent bedrock material - i.e., gravels, cobbles, or boulders are not present) in the region that are known to possess these characteristics and they include, but are not limited to, uplifted marine terraces, the Hookton formation, the Falor formation, the lower member of the Rio Dell formation, and the upper member of the Eel River formation.

D.1.1.7.1 Equipment Exclusion Zone

Green Diamond will establish a 30-foot EEZ, except for a) existing roads; b) road watercourse crossings; and c) skid trail watercourse crossings.

The exception for skid trail watercourse crossings is only applicable when the following conditions are met:

1. Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.
2. Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
3. Green Diamond will submit to the Services an explanation, justification, and map of any proposed skid trail watercourse crossings as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for skid trail intrusions is only applicable when the following conditions are met:

1. EEZ hillslopes are less than 25 percent.
2. The location and use of skid trails within the EEZ may occur only when the use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Intrusion into the EEZ is preferred if the alternative routes would result in greater road length and additional watercourse crossings. Preference will be given to utilizing shovel logging equipment and using existing skid trails in the EEZ over locating new skid trails in the EEZ.

3. Skid trails will not be used in the EEZ to provide access to EEZs for the purpose of their harvest.
4. All bare mineral soil greater than 100 square feet created by management activities within the EEZ, will be mulched or treated with slash to adequately cover the exposed soil area prior to any onset of rain or upon completion of operations, whichever occurs first.
5. Green Diamond has submitted to the Services an explanation, justification, and map of the proposed entry into the EEZ as part of the informational copy of the THP notice of filing.

D.1.1.7.2 Hardwood Retention

1. Green Diamond will retain a minimum of 15 square feet of basal area of hardwoods per acre where it exists before harvest, including the largest hardwoods available for this purpose.

2. Green Diamond will retain all hardwoods when less than 15 square feet basal area is present before harvest.

D.1.1.7.3 Conifer Retention

1. Green Diamond will retain all sub-merchantable conifers.

2. Green Diamond will retain all channel trees and trees that have boles that overlap the edge of the channel zone.

D.1.1.7.4 LWD Retention

Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ.

D.1.1.7.5 Snag Retention

Green Diamond will retain all safe snags.

D.1.1.7.6 Understory Vegetation Retention

Green Diamond will retain at least 50% of understory vegetation following completion of yarding operations.

D.1.1.7.7 Site Preparation

Green Diamond will not ignite fire during site preparation within the EEZ.

D.1.1.8 Class III Tier B Protection Measures

D.1.1.8.1 Equipment Exclusion Zone

Green Diamond will establish a 50-foot EEZ, except for a) existing roads; b) road watercourse crossings; and c) skid trail watercourse crossings.

The exception for skid trail watercourse crossings is only applicable when the following conditions are met:

1. Construction and use of skid trail watercourse crossings within the Class III EEZ may occur only when construction and use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Preference shall be given to utilizing existing skid trail watercourse crossing sites in the Class III over establishing new skid trail watercourse crossing sites in the Class III.
2. Within Class III EEZs, trees may be felled and harvested to facilitate skid trail watercourse crossing construction and use.
3. Green Diamond will submit to the Services an explanation, justification, and map of any proposed skid trail watercourse crossings as part of the informational copy of the THP notice of filing (Section 5.3.7).

The exception for skid trail intrusions is only applicable when the following conditions are met:

1. EEZ hillslopes are less than 25 percent.
2. The location and use of skid trails within the EEZ may occur only when the use of alternative routes to otherwise inaccessible areas outside of the EEZ would result in substantially greater impacts to aquatic resources. Intrusion into the EEZ is preferred if the alternative routes would result in greater road length and additional watercourse crossings. Preference will be given to utilizing shovel logging equipment and using existing skid trails in the EEZ over locating new skid trails in the EEZ.
3. Skid trails will not be used in the EEZ to provide access to EEZs for the purpose of their harvest.
4. All bare mineral soil greater than 100 square feet created by management activities within the EEZ, will be mulched or treated with slash to adequately cover the exposed soil area prior to any onset of rain or upon completion of operations, whichever occurs first.
5. Green Diamond has submitted to the Services an explanation, justification, and map of the proposed entry into the EEZ as part of the informational copy of the THP notice of filing.

D.1.1.8.2 Hardwood Retention

Green Diamond will retain all hardwoods and nonmerchantable trees within the EEZ except where necessary to create cable corridors or for the safe falling of merchantable trees.

D.1.1.8.3 Site Preparation

Green Diamond will not ignite fire during site preparation within the EEZ.

D.1.1.8.4 Conifer Retention

1. Green Diamond will retain conifers where they contribute to maintaining bank stability or if they are acting as a control point in the channel.
2. A minimum average of one conifer 15 inches dbh or greater per 50 feet of stream length within the EEZ will be retained.

D.1.1.8.5 LWD Retention

Green Diamond will retain all LWD on the ground (not including felled trees) within the EEZ.

D.1.2 Slope Stability Measures

Implementation of the Plan involves and requires close coordination and cooperation between registered professional foresters (RPFs) and professional geologists (PGs) who will work together to accomplish the designated tasks. Any Covered Activities that involve geologic issues and require the expertise of a PG would need to be carried out by, or occur under the supervision of, a PG as required by California law. See Business and Professions Code §§7800 *et seq*. These provisions apply within the Plan Area regardless of Plan approval and permit issuance.

D.1.2.1 Steep Streamside Slopes

D.1.2.1.1 Identification

During THP layout, Green Diamond will identify all steep streamside slopes leading to Class I or II watercourses with the following characteristics within the proposed THP area:

<table>
<tr><th colspan="4">Revised HPA Groups and Slope Gradient Threshold</th></tr>
<tr><th><u>SSS HPA Group</u></th><th colspan="2"><u>HPAs</u></th><th><u>Slope Gradient</u></th></tr>
<tr><td>Smith River (Includes Wilson Creek)</td><td colspan="2">Smith River</td><td>65%</td></tr>
<tr><td>Interior Klamath</td><td colspan="2">Interior Klamath</td><td>65%</td></tr>
<tr><td>Korbel</td><td colspan="2">Coastal Lagoons, Little River, Redwood Creek, North Fork Mad River, Mad River, Humboldt Bay, Eel River</td><td>55%</td></tr>
<tr><td rowspan="2"></td><td colspan="3">Coastal Klamath HPA</td></tr>
<tr><td>Class I</td><td>Class II-2</td><td>Class II-1</td></tr>
<tr><td>Coastal Klamath HPA Group (SSSMU 1)</td><td>65%</td><td>70%</td><td rowspan="2">75%</td></tr>
<tr><td>Coastal Klamath HPA Group (SSSMU 2)</td><td>75%</td><td>85%</td></tr>
<tr><td colspan="4">Note: (a) Coastal Klamath HPA was broken into two distinct Steep Streamside Slope Morphologic Units (SSSMU) based on data from the SSS Delineation project. As a result there are specific slope gradient thresholds for each SSSMU and watercourse Class (except for Class II-1 streams where there was insufficient data to delineate gradients for both SSSMUs). (b) Minimum area assessed; The average slope gradient must exceed the slope threshold for at least 100 feet of lineal stream distance to be considered a SSS zone.</td></tr>
</table>

D.1.2.1.2 Slope Distance

Where steep streamside slopes have been identified in the THP area, Green Diamond will create a Steep Streamside Slope (SSS) zone with the following maximum widths:

	Distance (ft)		
SSS HPA Group	**Class I**	**Class II-2**	**Class II-1**
Smith River (Includes Wilson Creek)	100	75	80
Coastal Klamath (SSMU 1)	240	110	135
Coastal Klamath (SSMU 2)	425	195	
Interior Klamath	195	100	90
Korbel	135	110	105

Note: (a) Coastal Klamath HPA was broken into two distinct Steep Streamside Slope Morphologic Units (SSSMU) based on data from the SSS Delineation project. (b) Minimum area defined; The minimum area defined as SSS must be at least as wide as the inner zone of the corresponding RSMZ (70 feet on Class I's and 30 feet on Class II's).

D.1.2.1.3 SSS Outer and Inner Zone Distances

1. The SSS zone will be comprised of an inner zone (Riparian Slope Stability Management Zone [RSMZ]) and an outer zone (Slope Stability Management Zone [SMZ]).
2. The width of the RSMZ will be the same as the applicable RMZ set forth in Section D.1.1.1, except where a qualifying slope break exists within that distance the RSMZ may only extend to the slope break or where the maximum slope distance for a SSS, set forth in Section D.1.2.1.2, is less than the corresponding RMZ. A "qualifying slope break" is an interruption of slope gradient of sufficient degree and scale to reasonably impede sediment delivery to watercourses from shallow landslides originating above the slope break.
3. The width of the SMZ will be either the remainder of the distance to the default maximum SSS distance for that HPA or to a qualifying slope break, whichever is shorter.

D.1.2.1.4 RSMZ Inner and Outer Zone Distances

1. The RSMZs will be comprised of an inner zone and an outer zone.
2. The inner zone of RSMZs on all Class I watercourses will be 70 feet, except where a qualifying slope break exists within that distance the RSMZ inner zone may only extend to the slope break, and the outer zone, if any, will be the remainder of the applicable RMZ distance except where a qualifying slope break exists within that distance.
3. The inner zone of RSMZs on all Class II watercourses will be 30 feet, except where a qualifying slope break exists within that distance then the RSMZ inner zone may only extend to the slope break, and the outer zone, if any, will be the remainder of the applicable RMZ distance except where a qualifying slope break exists within that distance.

D.1.2.1.5 Prescriptions for RSMZs in the Coastal Klamath HPA

In the Coastal Klamath HPA, Green Diamond will not conduct harvesting in RSMZs.

D.1.2.1.6 Prescriptions for RSMZs in All HPAs except Coastal Klamath

1. On Class I and Class II-2 watercourses, Green Diamond will not conduct harvesting on the inner zone of the RSMZ and there will be 85% overstory canopy retention in the outer zone of the RSMZ.
2. On Class II-1 watercourses, Green Diamond will retain 85% overstory canopy in the inner zone of the RSMZ and 75% overstory canopy in the outer zone of the RSMZ.

D.1.2.1.7 Default Prescriptions for SMZs

1. The silviculture prescription employed within SMZs will be single tree selection, as that term is defined in the Glossary of the Plan.
2. Even spacing of unharvested trees will be provided where the trees are available to allow it, and all hardwoods will be retained. All species and size classes represented in pretreatment stands will be represented post-harvest where feasible.
3. If cable corridors through SMZs are necessary to conduct intermediate treatments (e.g., commercial thinning) in adjacent stands prior to even-aged harvest, Green Diamond will apply the restrictions in this section except harvesting of trees in the SMZs will be limited to cable corridors only. Any cable roads established in the SMZ as part of the intermediate treatment will, to the extent feasible, be reused during the even-aged entry in the adjacent stands. The SMZs will be subject to the restrictions identified in Section D.2.1.1.
4. Where no SMZ is identified, the standard default prescriptions for RMZs will apply.

D.1.2.1.8 Tree Falling for Safety and Cable Yarding

Green Diamond may fall trees within RSMZs and SMZs for worker safety and to create cable yarding corridors of up to 25 feet in width.

D.1.2.1.9 Road Construction

Green Diamond's road construction will avoid RSMZs and SMZs where feasible. Where such zones cannot be avoided or where major road reconstruction is required, the road alignment within a RSMZ or SMZ will be evaluated by a PG and a RPF with experience in road construction in steep forested terrain. In addition, Green Diamond will submit to the Services an explanation, justification, and a map of the proposed exception as part of the informational copy of the THP notice of filing (Section 5.3.7).

D.1.2.2 Headwall Swales

D.1.2.2.1 Identification

During THP layout, Green Diamond will identify all headwall swales within the proposed THP area based primarily on field observations by trained and qualified personnel of slope qualities that are characteristic of the landform. Field review of headwall swale areas will focus on slope characteristics that are considered at present to be most important to landslide processes in such areas. These characteristics include slope steepness (typically >70%) of the slopes, slope composition and structure, slope and soil drainage characteristics, the appearance of a concave or inverted teardrop- or spoon-shaped slope, the relative degree of slope convergence, the presence of a build-up of colluvium or a thick colluvial mantle, various vegetative indicators, and the apparent landslide history of the site and similar sites in the area. Perhaps the most important physical characteristic of a headwall swale is its location at the headwaters of a watercourse. Green Diamond will use the SHALSTAB computer model analysis (>1/4 ac) using a 10m DEM or better and a q/T less than or equal to –2.8) as a screening tool to identify areas that may be more likely to contain headwall swales than the general landscape.

D.1.2.2.2 Default Prescription

The default prescription for headwall swales is uniform across the Plan Area and is not subject to adaptive management.

D.1.2.2.3 Silvicultural Prescription

1. The silviculture prescription employed on a field verified headwall swale will be single tree selection (as defined in the Glossary of the Plan).
2. Even spacing of unharvested trees will be provided where the trees are available to allow it, and all hardwoods will be retained.
3. All species and size classes represented in pretreatment stands will be represented post-harvest where feasible.
4. There will be only one harvesting entry in headwall swales during the term of the Permits.

D.1.2.2.4 Tree Falling for Safety and Cable Yarding

Green Diamond may fall trees on a field verified headwall swale for worker safety and to create cable yarding corridors of up to 25 feet in width.

D.1.2.2.5 New Road Construction

Green Diamond's new road construction will avoid field-verified headwall swales where feasible. Where such areas cannot be avoided or where road reconstruction is required, the terrain will be evaluated by a PG and RPF with experience in road construction in steep forested terrain. In addition, Green Diamond will submit to the Services an explanation, justification, and a map of the proposed exception as part of the informational copy of the THP notice of filing (Section 5.3.7).

D.1.2.3 Deep-Seated Landslides

D.1.2.3.1 Identification

All active deep-seated landslides identified by RPFs within the proposed THP area that meet one of the following two criteria will trigger the conservation measures identified in this subsection:

1. First Criterion: A scarp or ground crack that exhibits at least three inches of horizontal displacement or at least six inches of vertical displacement that typically exposes bare mineral soil, but that may be partially revegetated, and where field observations clearly indicate that the movement occurred within approximately the past 100 years; or
2. Second Criterion: A convex, lobate landslide toe that exhibits indicators of instability that can be interpreted based on ground conditions or forest stand characteristics to have been active within approximately the past 100 years.

D.1.2.3.2 Default Prescription for Active Deep-seated Landslides

1. Where neither criterion in Section D.2.1.3.1 is exhibited, other conservation measures in the Plan may apply and the California FPRs will apply, but no default prescription will be required. The California FPRs will also apply to all parts of deep-seated landslides.
2. The default prescription for deep-seated landslides is uniform across the Plan Area and is not subject to adaptive management.

D.1.2.3.3 Harvesting near Active Deep-seated Landslides Identified by the First Criterion

Where an active deep-seated landslide exhibits the first criterion stated in Section D.2.1.3.1, Green Diamond will not harvest within 25 feet upslope from the identified scarp or ground crack.

D.1.2.3.4 Harvesting near Active Deep-seated Landslides Identified by the Second Criterion

Where an active deep-seated landslide exhibits the second criterion stated in Section D.2.1.3.1, Green Diamond will not harvest on the toe or within 25 feet upslope from the inflection point of the convex, lobate landslide toe.

D.1.2.3.5 Tree Falling for Safety and Cable Yarding

Green Diamond may fall trees on active deep-seated landslides for worker safety and to create cable yarding corridors of up to 25 feet in width.

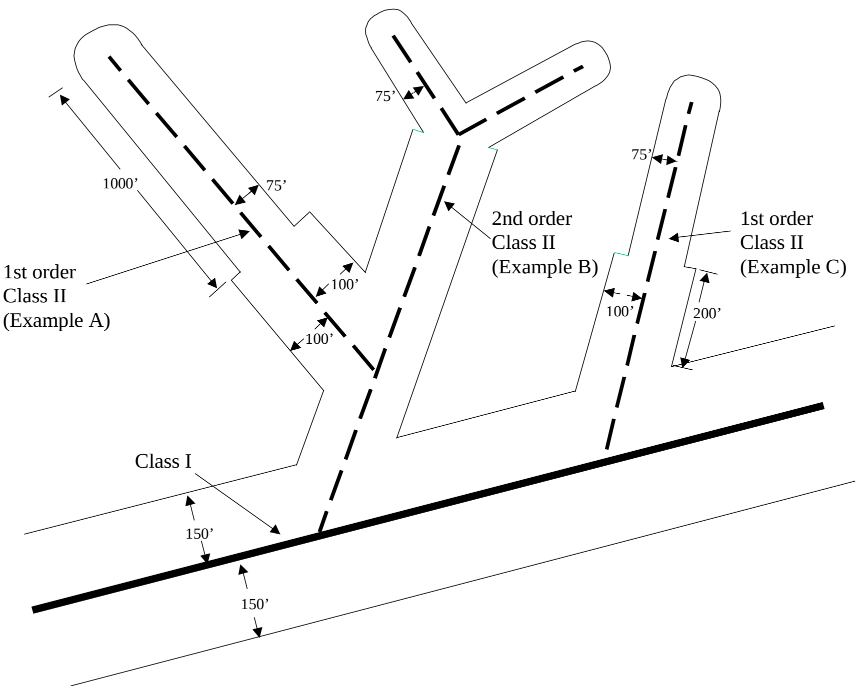
D.1.2.3.6 New Road Construction

Green Diamond will not construct new roads across active deep-seated landslide toes or scarps, or on steep (>50% gradient) areas of dormant slides, without approval by a PG and a RPF with experience in road construction in steep forested terrain.

D.1.2.4 Shallow Rapid Landslides

This conservation measure will apply only to field-verified individual shallow rapid landslides that are at least 200 square feet in plan view and that observably delivered sediment to a watercourse or exhibit indicators of instability with the potential to deliver sediment directly to a watercourse. This conservation measure will not apply to road related failures. Road related failures will be addressed by the road maintenance plan.

1. The default prescription for landslides that do meet the above listed criteria will be no cut within the landslide boundaries, and a minimum of 70% overstory canopy within 50 feet above a slide and 25 feet on the sides of a slide. Site-specific geologic review of this default prescription, pursuant to Section D.1.2, may result in an alternative prescription for shallow rapid landslides.
2. Green Diamond's new road construction will avoid landslides that meet the above listed criteria where feasible. Where such areas cannot be avoided or where major road reconstruction is required, the terrain will be evaluated by a PG and RPF with experience in road construction in steep forested terrain. In addition, Green Diamond will submit to the Services an explanation, justification, and a map of the proposed exception as part of the informational copy of the THP notice of filing (Section 5.3.7).



Example A

The RMZ on the first 1000 feet of a 1st order channel, (a small, typically intermittent, headwater stream with no tributaries), will be at least 75 feet. Downstream of this first 1000-foot section, the RMZ will expand to at least 100 feet.

Example B

All 2nd order or greater Class II watercourses will have a minimum 100-foot RMZ. Example B shows two first order channels, with 75-foot RMZs, joining to form a 2nd order channel, which has a 100-foot RMZ.

Example C

Where a 1st order Class II watercourse flows directly into a Class I watercourse, the Class II RMZ will be at least 100 feet on each bank for the first 200 feet Of channel upstream of the Class I RMZ boundary, after which the Class II RMZ will be dictated by the length of the stream, as per example A.

Figure D-1. Class II riparian management zones.

Appendix E. Terrestrial Retention of Ecosystem Elements (TREE)

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E.1 TERRESTRIAL RETENTION OF ECOSYSTEM ELEMENTS (TREE)

E.1.1 Green Diamond Resource Company Introduction and Background

Green Diamond Resource Company has had a landscape plan for retaining upland forest structure since the implementation of its Northern Spotted Owl Habitat Conservation Plan in 1992 (Green Diamond, 1992). Since that time, field experience related to the efficacy of leaving upland structure has resulted in the evolution of the guidelines and criteria that govern the spatial distribution, type, and amount of retained structure. Implementation of Green Diamond's Aquatic Habitat Conservation Plan (AHCP) in 2007 (Green Diamond, 2007) resulted in additional refinement to the amount and distribution of retained terrestrial habitat. The TREE is focused on habitat areas and habitat elements that are essential to specific behaviors of vertebrate species that reside on Green Diamond's ownership. It discusses the amount, spatial arrangement and types of habitat or habitat elements retained across this dynamic landscape.

The vital role of trees with decay, snags and downed coarse woody debris (CWD) in forest ecosystems has been well documented and Green Diamond recognizes the critical importance of sustaining these elements in the forests that it manages. In addition to the role that these habitat elements play in the ecology of many fungal, nonvascular plant, and invertebrate species, a variety of wildlife species are directly dependent on snags or CWD for nest/den/rest sites and as primary sites for foraging. The primary cavity excavators (woodpeckers) are particularly well known for their connection to snags, but other species (e.g. owls, fishers and others) have vital links through secondary use of snags, CWD and decaying live trees.

Although decaying wood is a vital element in all forest ecosystems, its average abundance varies among forest types and the temporal and spatial distribution of snags and CWD can vary substantially within the same forest type. In addition to the total quantity of dead wood, the size distribution may be important to certain species. All sizes of snags and CWD are likely to be utilized by certain species, but the larger size are more likely to be limiting simply because it takes longer to generate the larger size classes once they are lost from a landscape. Along with considerations of quantity and size class distributions, there is the additional factor that not all tree species have equal potential value as snags or CWD. Trees that are prone to heart rot are generally more valuable as snags and CWD. Such tree species tend to be selected by most primary and secondary cavity users because, during the decay process, they tend to be hard on the outside and soft (decayed) on the inside. Snags that decay from the inside out are suitable for cavity excavation and support a complex detrital-dependent community of species (fungi, saprophytes and invertebrates). In addition, trees that are prone to heart rot are more likely to develop internal cavities while living, which is the only mechanism by which hollow logs are produced. Some species of trees that are resistant to internal rot may have limited value to many of the dead wood-dependent species, but they have the potential to provide long lasting structural forest elements. The high natural variability between and within forest types along with the many other considerations discussed above has made it virtually impossible to establish critical thresholds for the maintenance of snags and CWD.

Throughout Green Diamond's ownership there are differences in the amounts of dead wood even though much of the pattern was produced through management activities rather than natural processes. In spite of the anthropogenic impacts on the distribution of dead wood, there is a sequence of biotic communities (ecocline) as one moves from west to east. In the more coastal areas, forest stands are predominately redwood with relatively few hardwoods other than red alder, which occur primarily in the riparian areas. Since redwood is highly resistant to heart rot, it decomposes very slowly and often contributes large amounts of dead wood in a stand. In addition, because of their longevity, large redwoods develop many structural deformities (e.g. fire scars, broken tops, basal hollows and etc.) that provide an important source of long-lasting structural cover and diversity within the forest. However, the decay resistance of redwood may also have a negative aspect for dead wood associated species. Due to the resistance to heart rot, redwood is likely to produce snags that are difficult to excavate for use by primary and secondary cavity nester. Similarly, redwood logs decompose from the outside inward so they lack the quality of having a hard outer bark with decomposing moist heartwood that is prime habitat for a variety of small mammals, herptiles and invertebrates. Douglas fir and numerous hardwood species become a more dominant component of stands at greater distances inland from the coast. In addition, Douglas fir and many hardwood species are more susceptible to heart rot and produce high quality snags and logs for use by dead wood associated species.

Corresponding with this vegetational west-east transition is a change in the vertebrate species associated with snags and logs. Green Diamond has documented a west-east distributional gradient for fishers, spotted owls and red tree voles. (The pattern associated with the voles is probably more related to direct utilization of Douglas fir for food rather than an association with decadent trees.) Anecdotal observations indicate that the same pattern holds for pileated woodpeckers and other woodpecker species such as the acorn woodpecker. Although Green Diamond's management goals include maintaining dead wood throughout its ownership, the greatest emphasis is placed on those regions where it will have the greatest benefit for the most species. In addition, there are adjacent public lands that can provide an abundance of this wildlife structure in portions of Green Diamond's ownership (e.g. state and national parks or Forest Service late successional reserves), which can partially provide for dead wood values at a landscape level of analysis.

While snags and CWD are important components of forest ecosystems, living trees with decay, hollow living trees, trees with natural cavities, and remnant or legacy trees also play a key role in forest ecosystems. Similar to snag development, structures on living trees often take many decades or centuries to develop and are typically dependent upon natural stochastic events such as lightning, fire, severe storms and natural pathogens. It is important to identify and focus retention on these structures since they are living and will likely persist on the landscape for many years. Living trees with decay are also likely candidates to develop into snags. The living trees with existing structure are prime candidates for retention in harvest units, but other live trees that have low economic value and can be minor stand components should be strongly considered for retention. Examples of these conifer species are hemlock, cedar and grand fir. Hemlock and cedar are known to harbor or develop structures important to wildlife such as mistletoe brooms and complex limb formations. These species are commonly subordinate species in the overstory canopy and will contribute additional vertical diversity to the canopy. A variety of hardwood species within forest stands also contribute to increased wildlife species diversity, and they accommodate essential behaviors of many species. Our data indicates that hardwoods are important stand components of nest groves for spotted owls and data on fishers shows that females frequently select tanoak trees with cavities as their natal and maternal den sites. We also suspect that the positive relationship of successful nest sites of spotted owls with hardwoods is related to increased prey diversity at the nest stand level or the increased canopy diversity from hardwood species contributes to survival of fledged owlets by providing "hiding" or escape cover. A downy owlet is often more difficult to sight within the branches and foliage of evergreen hardwoods relative to exposed lateral branches of conifer trees.

Regardless of the tree species involved, it is important to consider live trees, snags or downed woody debris that have critical or vital conservation value. Primary consideration should be given to live trees, snags and coarse woody debris that currently provide or are most likely to be become critical habitat elements on the landscape. The concept of a “critical habitat element” refers to something that is relatively rare on a managed landscape, takes a long time to develop (greater than a single rotation) and is linked to some behavior (reproduction, foraging) of a vertebrate species in such a way that the loss of the habitat element would likely result in a substantial population reduction of the species on the landscape. This concept is incorporated in the attached live tree retention scorecard, which has been adopted as part of this plan to assist foresters and wildlife biologists in selecting the trees that have the greatest benefit to a variety of wildlife species.

E.1.2 Wildlife Species Positively Influenced by Retention of Green Wildlife Trees, Snags and Coarse Woody Debris

The following are some examples of vertebrate species believed to be dependent on or strongly associated with critical habitat elements found on managed timberlands. Included with each species is the critical habitat element it is known to use. The species are ranked with their approximate relative dependence on these habitat elements.

1. Marbled murrelet – large conifers with large lateral branches (Note: This habitat element on managed lands is not likely to be suitable for maintaining a population of murrelets. All the studies to date indicated that a contiguous stand of old growth is necessary to support murrelets.)
2. Spotted owl – large trees with cavities and structural deformities
3. Fisher – large trees with cavities, internal hollows and mistletoe brooms, downed hollow logs and hardwoods (tanoak) with cavities
4. Several bat species (e.g. Townsend’s bat) – large trees with basal hollows and loose bark with crevices
5. Pileated woodpecker – large live trees and snags with heart rot
6. Tree vole – medium to large trees with structural deformities and “candelabra” tops
7. Bald eagle – large trees above the surrounding canopy with large lateral limbs or structural deformities
8. Peregrine falcon – large green trees or snags with broken tops or fire scar-formed depressions or platforms
9. Vaux’s swift – large fire scarred trees or snags with internal hollows
10. Purple martin – large trees or snags with cavities that are located in open areas
11. Osprey – large trees or snags above the surrounding canopy with broken tops or large lateral branches
12. Marten – large trees with cavities, snags, large hollow logs, brush piles

E.1.3 Guidelines for Green Tree Retention

The guidelines for green tree retention are based on standards initially developed under Green Diamond’s 1992 spotted owl HCP. Although these retention guidelines were initially developed specifically to accelerate the development of future habitat for spotted owls, it is these same trees that will likely contribute to the development of future snags.

The following guidelines apply to clear-cut harvesting of even-age young growth stands. Harvesting using other silvicultural methods not described in this document or in other types of stands will require the site-specific considerations of company wildlife biologists, operational managers and foresters to determine appropriate retention standards. Despite the following guidelines, it is important to remember that the goal is to retain critical habitat elements and promote the development of future spotted owl or other wildlife habitat within a managed landscape, which may best be achieved utilizing a flexible and adaptive approach.

E.1.3.1 Criteria for Establishing the Need for Green Tree Retention in Harvest Units

The original tree retention guidelines were established prior to Green Diamond's Aquatic Habitat Conservation Plan, but this document now serves as the foundation for habitat retention across the ownership. It is essential to understand the provisions of Green Diamond's aquatic HCP (AHCP) to predict the influence of this plan on habitat for owls and other terrestrial species. The AHCP provides protection of geologically unstable areas and protection of riparian management zones with only a single light selection harvest (variable 0-30% canopy removal) allowed during the life of the AHCP (2007-2057). Modeling of future landscapes using forest inventory data and GIS as well as implementation of the AHCP demonstrated that approximately 20% of the landscape will be retained in Riparian Management Zones (RMZs) and other geological instabilities (landslides, headwall swales, steep streamside slopes). The largest retention zones occur along Class I watercourses that are fish-bearing, but the greatest quantity of retention across the landscape occurs adjacent to Class II watercourses that typically originate as headwater streams. These watercourses provide habitat for aquatic vertebrates such as torrent salamanders and tailed frogs but are not fish bearing. The density of these headwater streams is quite high within the north coastal zone, and these stream retention areas often extend to near the ridge tops. Some Class II zones are associated with seeps or springs that do not form well-defined channels and therefore are not considered watercourses; however, these areas warrant the same level of canopy retention and protection zones that further contribute to retained forest habitat across the landscape. There is additional scattered tree retention along ephemeral class III watercourses under the AHCP that will function as dispersed vertical structure within the managed landscape. The amount of tree retention will be evaluated at three spatial scales: The ownership (landscape); the watershed; and the THP harvest unit. Evaluation of terrestrial habitat retention at each level is described below.

- **Ownership** – The baseline for determining whether an individual THP unit warrants retention is guided by the amount of forest habitat that is essentially set aside in a no harvest or in a partial harvest scenario by agreements entered into by the company and other parties. The ownership level of retention is based upon two landscape level planning documents: The AHCP and the FHCP. Under the AHCP, the amount of forest retention within riparian zones and other mitigated areas is estimated to be approximately 20%. This estimate will likely increase over time because additional watercourses (primarily Class IIs with substantial protection zones and canopy cover) are discovered each time a THP is developed in the field. This prediction is relative to what is known from the best available hydrological information. Also, retention of forest habitat around newly discovered geological zones will change over time. At the end of the AHCP term in 2057, an estimated ≥20% of the landscape will be in forest stands 65-140 years of age. Projections of spotted owl habitat under the FHCP are expected to increase and then plateau as the forests on Green Diamond reach a regulated state under the CA Forest Practice Rules.
- **Watershed** – This is an appropriate scale for addressing tree retention because it generally coincides with cumulative effects analyses conducted for THPs, and it allows for consideration of unique habitat areas. The goal is to retain at least 1 tree per clearcut acre harvested in areas (3rd-4th order watersheds of typically 10,000-20,000 acres) that currently have existing structure available for potential green wildlife tree value. In areas that have special wildlife value or in areas where past harvesting has already eliminated most of the snags and potential green wildlife trees the goal is to retain at least 2 trees

per clearcut acre harvested. Areas that have special wildlife value are regions that are known to support high densities of owls or have other sensitive wildlife species dependent on residual structure and dead wood. The specific areas that meet this criterion should be determined in consultation with the company's biological staff. Although the Little River Watershed contains significant stands of healthy well-formed trees, the thinning history of most of the stands has resulted in a general lack of snags, or trees with deformities, cavities, or forked/ platformed tops and hardwoods.

- **THP Unit** – After initial reconnaissance and during the course of layout, each RPF will determine the amount of RMZ or other partial harvest system occurring within each THP unit. Based upon these field assessments, the RPF will designate tree retention for each unit guided by the landscape and watershed factors discussed above. When a THP unit includes any acreage of RMZ or other partial harvest system, additional green tree retention in the form of scattered trees, tree clumps or an HRA will not be required (excluding hardwood areas and trees scoring ≥7 – see below). However, individual trees are always retained when they possess higher wildlife value (≥7) as determined from the Live Tree Retention Scorecard regardless of the acreage in RMZ or other partial harvest. In addition, existing evergreen hardwoods that do not meet the minimum score ("7") should also be retained at the watershed level of 1 or 2 trees per clearcut acre. Preference is given to the largest diameter trees and species such as tanoak and madrone, Also, any low economic value conifers "standing slash" should be retained.
- When a THP unit does not include RMZ or other partial harvest system, additional tree retention will be required at 1 or 2 trees per clearcut acre. In these circumstances, incorporate some form of green tree retention (HRA's, tree clumps or scattered trees).Trees included in the retention tally should be representative of the stand being harvested, but smaller diameter hardwoods with well-formed crowns should also be considered for retention. Any existing scorecard trees (≥7) should be the first candidates for retention followed by lower scoring hardwood and conifer trees.

E.1.3.2 Types of green tree retention

- Habitat retention areas (HRAs) are groups of trees ½ acre or more in size that are within a THP unit. Trees that are within the normal boundaries of a RMZ or special treatment area are not included as an HRA. However, areas extending beyond the required boundaries for a RMZ or special treatment area can be used as HRAs. Ideally, HRAs will include a portion of the harvest unit that tends to have trees with greater wildlife value, but lower economic value. HRAs are not considered no-cut areas, but the target for post-harvest overstory canopy cover is 70%. Harvesting in HRAs should be done with the objective of retaining the trees with the greatest future wildlife value. When possible, HRA's should encompass a critical habitat element or unique habitat feature (e.g. large snags, decadent hardwoods) within the THP unit. These "biological anchors" are often unique elements that can be rare within the managed landscape and contribute substantially to overall stand diversity. In addition, placement of HRA's should take into consideration use by wildlife (i.e., placement away from roads) as well as operational constraints.
- Individual or clumped retention (groups of 10-20 trees). Smaller groups of trees outside of RMZs including individual trees or tree clumps (10-20 trees) may also be retained in harvest units to achieve wildlife green tree retention standards. Also, hardwoods in SSS zones are counted towards the desired retention level for these species. Individual trees should be selected due to their high wildlife value, while tree clumps should be small groups of trees associated with one or more trees of high potential wildlife value. Retention of individual trees or tree clumps should be considered to promote dispersed

vertical structure and snag recruitment. Particular attention is given for additional retention in stands predominately composed of hardwoods where the greatest wildlife benefit can be achieved.

E.1.3.3 Placement of green tree retention

- Preference is always given to HRAs in cable units because of operational constraints, burning and wind throw. For the same reasons, HRAs are best placed low within the unit, or added on to the top or side of a Class III watercourse. The latter case is particularly well suited for situations where there already may be some concerns related to instability associated with the upper portion of a geological area. Even if an HRA has been designated, individual wind-firm trees with high wildlife value should always be considered for retention except when precluded by safety or operational constraints.
- Well-dispersed individual trees or tree clumps should be given preference in tractor ground-based units. However, concerns related to wind throw or the location of suitable trees with high wildlife potential may necessitate delineating an HRA instead of dispersed individual trees or tree clumps.

E.1.4 Guidelines for Snag Retention

Green Diamond's goal is to make a concerted effort to retain all snags (defined as a standing dead or mostly dead tree) throughout its ownership unless it constitutes a clear safety or fire hazard. When situations arise where snags must be felled because they represent a fire or safety hazard, a discussion of options will occur between the responsible parties (Operations, Forestry, IFM and Wildlife) prior to the felling of the snag. When the snag must be felled, it will be left on site as CWD. Also, anything classified as a snag is not counted in the tree retention tally

E.1.4.1 Snag Recruitment

The active recruitment of snags into a forest system where they are currently lacking typically involves intentional introduction of decay pathogens into trees or the mechanical disfigurement of living trees. The former is often costly and limited in scope due to the time, effort and potential controversy involved with such activities. The introduction of pathogens (inoculation) into trees will result in the "natural" development of heart rot and the subsequent use by woodpeckers, invertebrates, and secondary cavity users, Equipment can be used to create cavities or trees with snag-like qualities, but the use of chainsaws or larger equipment (log loaders) is also costly and is limited to confined areas or areas with suitable access. In addition, artificial cavities and snags will not develop into hollow trees and logs over the long-term in the absence of natural decay mechanisms. Creation of snags and cavities by mechanical means is difficult to replicate over large areas and the usefulness of these techniques requires further investigation. Another consideration for creation of snags or structures on trees is to allow some intentional burning within tree clumps, HRAs or RMZs. The one-time burning of trees or habitat areas may result in the creation of snags, but repeated low intensity burning is necessary to create hollows, cavities and other structural deformities. Basal hollows on redwoods and some hardwood species provide the best example from repeated low intensity fires that create and maintain this type of structure. The extensive RMZ networks and other upland tree retention areas such as HRAs would be suitable for exploring the efficacy of these techniques on Green Diamond's managed landscape because these retained trees will not be harvested within the life of the permit and will be available for voluntary efforts to actively accelerate the formation of wildlife structure. In the absence of proactive snag creation Green Diamond will be contributing to the accelerated process of potential snag development by retaining 2 trees per clearcut acre harvested in harvest units lacking partial harvest systems, through application of the tree retention score card and in areas dominated by hardwoods. This retention standard does not include trees retained within the RMZ's or existing retained snags.

E.1.5 Guidelines for Coarse Woody Debris Retention

Certain wildlife species have been shown to have a strong connection with downed CWD. In certain cases, (e.g. Oregon slender salamander) a species may have an obligate association with CWD. Studies to date on Green Diamond's ownership have shown little direct association between any wildlife species and CWD. The only exception is that Pacific fishers show a weak association with areas having a higher density of fir logs. There are no amphibian species in this area that are closely tied to CWD and unlike studies in other parts of its range, spotted owls within Green Diamond's ownership do not show an association with CWD. In spite of this, we believe that CWD plays an important role in the overall structural diversity of stands and may have important indirect benefits to a variety of species.

Our general policy is to retain all non-merchantable CWD within stands. Future recruitment of CWD will result directly from the natural tree mortality (stem exclusion, disease, animal damage and etc.) within developing stands as well as the retention of existing snags and green wildlife trees. Merchantable redwood logs without internal rot may be removed outside of watercourses, because we do not believe these logs provide critical wildlife habitat. Broadcast burning occasionally results in the loss of CWD, but Green Diamond always strives to have light intensity burns that only consume the smaller (<2 inches) material. For the same reasons that trees and snags with large hollows are considered critical conservation elements on the managed landscape, in general, large woody debris with hollows or large cavities have relatively greater value to wildlife compared to pieces without cavities or with small cavities. In areas where biomass harvesting is planned, the same guidelines will apply for retention of CWD. The definition of merchantability is different for biomass harvesting and large logs that would not be suitable for lumber or lumber products could be suitable for biomass harvesting.

E.1.6 Hardwood Areas

On broad ridges such as Wiregrass and Bald Mountain Ridge in the Korbel Operating Area, or Williams Ridge in the Klamath Operating Area, there are stands with few or no watercourses. When these stands are harvested, the only structure left behind tends to be what is designated as HRAs or individual tree clumps. In some instances, mechanical feller-bunchers are being used to harvest the smaller hardwood and conifer component on gentle ground. Hardwoods >28 inches at the base are typically not taken by the feller-buncher and have to be manually felled. Our regular guidelines call for leaving two trees per acre that are equal to the average stem diameter in the stand. In predominantly hardwood stands, the average stem diameter is often quite small so that many of the trees retained will be small and have little wildlife value. Given their high wildlife value, the maximum benefit for wildlife can be achieved through the retention of the larger residual hardwood trees that often occur throughout these stands.

To provide for beneficial future habitat structural elements in hardwood dominated stands (areas understocked with conifers), two of the largest hardwood trees (especially if they have structural deformities that provide high wildlife value) will be retained per clearcut or rehabilitation acre harvested regardless of the amount of RMZ or partial harvest present in the unit. If possible, these larger residuals should be well distributed throughout each harvest unit. If the area to be harvested is lacking in large residual hardwoods, then the largest hardwoods present in the stand should be selected for retention at a rate of 2 trees per clearcut acre. The RPF should choose the hardwoods with the best crown characteristics and those that are most likely to remain standing post-harvest. To make the retention successful over the long term, small group retention can be considered over individual tree retention. In addition to the scattered or clumped retention, an HRA will be designated in these areas. Where possible, HRAs should be located around a residual large hardwood or decadent conifer. Often, hardwood rehabilitation plans have large scattered fir trees with significant internal decay and structural deformities. All of these conifers with marginal merchantable value (e.g. broken top, long basal fire scar, evidence of internal rot and “grouse ladders”) should be marked for retention. The scattered hardwood retention is focused at providing dispersed den and rest tree opportunities for ambulatory species such as the fisher. The scattered retention could provide future nesting opportunities for spotted owls, but this species is more capable of accessing clumped retention within the managed landscape. The combination of clumped and scattered retention is likely to have the greatest benefit to a variety of species

E.1.7 Pre-Commercial Thinning

In areas scheduled for pre-commercial thinning (PCT) and lacking any previous hardwood retention under the 1992 NSO HCP or TREE (previously the Terrestrial Dead Wood Management Plan, TDWMP), the general prescription is to retain at least two unthinned evergreen hardwood sprout clumps per acre. These unthinned clumps will serve as future candidates for retention and habitat elements within the stand. If other existing larger evergreen hardwoods are present those shall be retained as first priority. Any hardwoods retained under either the HCP or TDWMP shall not be cut down during the PCT treatment.

E.1.8 Commercial Thinning

To date, Green Diamond has conducted commercial thinning on relatively few acres. As second and third growth stands mature, commercial thinning harvests may increase over time. In general, commercial thinning and selection have the potential to remove decadent trees and hardwoods that could function as nest trees or roost sites for owls as the stand matures. In addition, heavy thinning reduces the overall canopy closure in the short term, which may inhibit owls from using the area for nesting and roosting. In commercial thinning harvests, the age class typically targeted is the 30-45 year old forest. The timing of commercial thinning coincides with the stage of forest development at which Green Diamond biologists hypothesized that owls would begin colonizing young forests. If thinning is conducted on a large scale (ownership or watershed) it may inhibit owls from colonizing and reproducing due to the short time period between thinning harvests, stand recovery (crown closure) and clearcut rotation. Given the target rotation age for forests on Green Diamond ownership, it is likely that commercial thinning and clearcut harvesting will occur within a time frame of 10-15 years. Our own studies indicate that owls are less likely to reproduce in forests that were commercially thinned and where decadent/deformed trees and hardwoods were removed (Little River area). The resultant stands of clean, straight conifers offers few nesting opportunities for spotted owls and roosting opportunities are diminished due to the delimbing effect on retention trees. In this area, thinning within the limits of the California Forest Practice Rules does not significantly increase abundance of the owls’ primary prey species, the dusky-footed woodrat and may further inhibit use by spotted owls. Thinning is generally conducted over larger areas and has the ability to disrupt larger areas of the home ranges of species such as owls and fishers. Removal of a large percentage of the hardwoods in a stand may negatively affect fishers, a species which Green Diamond biologists found to be positively associated with hardwoods. Alternatively, many young stands in the 30-45 year age class have a high stem count and are currently marginally suitable for owls due to the lack of flight space under or within the tree canopy. In this instance, thinning may increase the suitability of the forest for spotted owls. By reducing the stem density and increasing canopy lift, thinning may promote the development of owl habitat.

The general assumption is that thinning will be conducted in stands with a relatively high conifer to hardwood ratio. In these stands it will be important to maintain the evergreen hardwood component where it exists (species such as tanoak, madrone, chinquapin). In general, the harvest of these species should be limited or avoided in order to promote species diversity and structural diversity within the forest. All decadent and residual conifers with deformities or structures likely to be used by wildlife should be retained during the thinning harvest so that they are present for use by wildlife before the clearcut harvest. In addition, these decadent conifers and hardwoods should be retained so that foresters have the option of designating these trees for retention at the time of clearcut harvest to meet requirements under the TREE. Removal of hardwoods and decadent/deformed conifers during the thinning will limit the opportunities available to future foresters and wildlife biologists. In addition, commercial thinning should be designed so that the basal area removed is not uniform throughout the unit. This practice will create areas with varying stand density and vertical diversity, and it will also create options for establishment of future HRAs and/or tree clumps. No-harvest HRA areas can be designated during the commercial thinning harvest so that these areas are available during the clearcut rotation. The rationale behind this uneven application of thinning is to create a stand more typical of a forest developing under a natural disturbance pattern. The general goal is that thinning be conducted in a manner to promote forest development and suitability for wildlife species such as spotted owls and fishers.

E.1.9 Directions for Use of Live Tree Retention Scorecard

To provide foresters and wildlife biologists with more specific guidance, the Live Tree Retention Scorecard (Section E.1.9.1) provides a system for ranking of the relative value of habitat elements that should be preferentially retained. The rankings are not absolutes, because the forester needs to also consider the ability to protect the structure during operations and site preparation, the likelihood that it will be destroyed by natural processes (e.g. wind throw) and safety.

A mix of conifers and hardwoods is normally preferred, but preference should be given to evergreen hardwoods if the stand is predominately composed of conifers.

During the course of normal THP layout, foresters will traverse a large percentage of the ground in each THP unit. As large trees are encountered, they will be evaluated per the scorecard. Each tree meeting the diameter criteria will be evaluated for the presence of other tree elements and assigned values when elements present meet the definitions and descriptions provided. Trees with a score ≥7 should be noted on a field map and marked for retention per the criteria on the scorecard. Trees not meeting the diameter threshold but exhibiting the described habitat elements should be considered as prime candidates for meeting the green tree retention guidelines if large trees are not available.

E.1.9.1 Live Tree Retention Scorecard and Definitions

	Tree elements					Unit Scarcity Factor[a]	Planning Watershed Factor[b]	
	DBH[d]	Bole features[c]			Crown features[c]	Post-harvest LSE density: =<1 ac, add 2 pts >1/ac, <2/ac, add 1 pt =>2/ac, add no pts	Impaired or special wildlife value, add 1 point. All others, add no points	
	conifer >30” hardwood >18”	internal hollow or large cavity	small cavity, internal rot or mistletoe broom	crevice cover (loose or deeply furrowed bark)	complex crown, lateral large limbs, epicormic branching			Total score
Wildlife score	3	4	2	1	1			

[a] Unit scarcity factor is determined at the THP level based on the number of residuals post-harvest (conifers and hardwoods are to be evaluated separately) and is added to the total score. Estimate is based on entire unit acres (including RMZs).

[b] Planning watershed factor is determined programmatically and is added to the total score.

[c] See Definitions and descriptions.

[d] Trees not meeting the diameter threshold but exhibiting the described habitat elements should be considered as prime candidates for meeting the green tree retention guidelines if large trees are not available.

Trees with a score equal to or >7 will be retained except under very rare circumstances where operational constraints prohibit retention as justified by Forestry and Wildlife. Trees with scores <7 can be harvested. Maximum obtainable score for combined tree elements is 11. The maximum score for each tree element column is depicted in the gray shaded box. For example, a tree with a complex crown and large lateral limbs would receive only 1 point for Crown Features.

Note: Trees not meeting the minimum retention score but exhibiting high potential defect (standing slash) or high harvesting costs so as to negate their value should also be considered as prime candidates for meeting green tree retention guidelines if high-scoring trees are not available.

The following information is intended to provide guidance for foresters and biologists assessing the relative value of wildlife trees in harvest units. The terms listed here should provide a common language for describing the various late seral habitat structures encountered in California north coast forests. These definitions and descriptions are not perfect, and if interpreted too narrowly may exclude some trees of obvious wildlife value or if interpreted too broadly may include some trees of little wildlife value. These descriptions should be used to obtain a general impression of the types of structures that may be visible in the field during THP development and review.

I. Trees and Snags

A. Residual tree (Legacy tree): A tree that existed in a stand prior to the most recent harvest entry.

Description: Structure and appearance varies substantially depending on residual tree age, species, and harvest history of the stand. For conifers, including redwood, the residual tree will almost always exhibit a greater diameter than the regenerated trees in the stand. If the residual has a live top it will likely project well above the surrounding canopy.

Two types of residual tree may be recognized:

1. Old-growth residual (Legacy tree): A residual tree at least two centuries old; minimum age varies by species

Description: Usually has a much greater diameter than the second-growth trees in the stand (for redwood, dbh is typically well over 4 feet for site class I, II, or III conditions) and often relatively tall (at "true" site potential height for site class). In addition to large size, old-growth residual trees usually exhibit one to several readily observable features of "old-growth" including broken top, large reiterations and large-diameter limbs, thick bark that may have deep furrows, fire scars or basal cavity, other cavities, possibly well-developed duff layers, moss, or lichen accumulations on horizontal limbs or platforms. Crown architecture visible from the air may include emergent crown (where the surrounding stand is relatively young), irregular or flat-topped shape (as opposed to conical top), obvious dead or spike top (note these may also occur in large second-growth trees), multiple leaders due to large reiterations (which may give the crown the appearance of a cluster of tall young trees).

2. "Mature" residual ("Bastard-growth"; Legacy tree): A residual that was probably <100 years old at the time of the initial harvest. The age at present is around 100 to 200 years old.

Description: Usually at or above the maximum dbh of the second-growth trees in the stand. Other characteristics (height and defect) vary depending on age, age relative to other trees in the stand, fire history, and whether damage to the residual occurred during the initial entry. Typically, "mature" residuals show a much smaller dbh than an old-growth residual for the site class and exhibit fewer of the structural features listed above for old-growth residuals. From the air, the crown of a "mature" residual tree may emerge above the surrounding canopy (where the surrounding stand is relatively young) or may not be particularly evident if the surrounding stand is mature second-growth. If the “mature” residual grew for an extended period above a regenerating stand, it may exhibit a relatively broad crown and high degree of taper, but otherwise be relatively free of physically induced defect.

B. Snag: A standing dead tree.

Description: Snags vary tremendously in appearance and function for wildlife depending on species, size, and decay class.

C. Green Wildlife Tree: A standing live tree with important, existing wildlife structure.

Description: A conifer or hardwood tree with existing habitat elements (II. and III. described below) that result in a score ≥7 based on evaluation from the score card.

D. Green Tree: A standing live tree

Description: A conifer or hardwood tree lacking existing habitat structure and possessing few elements that contribute to a score of ≤7 based upon evaluation from the score card. It is common for trees with low economic value but some wildlife value to be retained (e.g. hardwoods, hemlock, and cedar). These trees with low economic value but some existing wildlife structure should always be considered as prime candidates for retention even where there is no requirement for retention.

II. Bole Features

A. Large cavity: A cavity (or void within a tree bole or large limb) with a relatively small entrance suitable for use by a variety of wildlife species, such as spotted owl, wood rats, Pacific fisher, or American marten, or colonies of Vaux’s swift, purple martin, or bats. The small entrance precludes the entry of larger predators into the cavity. Cavities with larger entrances (classified as hollows, see below) may also be used by these species.

Description: A large cavity is generally several feet deep and at least 8 to 12 inches in diameter with an entrance size ranging from about 2.5 to 6 inches diameter. Entrance height is often at least 15 feet above the ground, but lower entrances may also be used. In practice, interior dimensions will usually just be a guess based on entrance size and appearance, as well as the characteristics of the tree, plus any observations of wildlife use of the cavity.

B. Hollow: A large cavity with an entrance or opening >6 inches diameter.

Description: Hollows have similar interior dimensions as large cavities and may be used by the same suite of species for cover; however, the larger entrance size of a hollow may not prevent larger predators from entering the hollow.

C. Basal hollow (Goose pen): A large hollow at ground level typically created by fire that destroys the cambium on a portion of the bole’s circumference. Repeated fires play an important role in maintaining and enlarging basal hollows.

Description: A basal hollow is a hollow that extends at least a third of the tree’s diameter into the bole and is generally several feet in height. It should be capable of providing shelter to small or medium-sized wildlife.

D. Small cavity: A cavity suitable for use by a variety of small to medium-sized wildlife species, such as small to large woodpeckers, secondary cavity-nesting birds, wood ducks, individual or small numbers of bats, northern flying squirrel, Douglas squirrel, and small owls.

Description: A small cavity is generally between about 7 inches and a few feet deep and between about 4 and 8 inches in diameter with an entrance size ranging from about 1.5 to 3 inches in diameter. Entrance height is often at least 10 feet above the ground, but lower entrances may also be used. Interior dimensions will usually be a guess based on entrance size and appearance, characteristics of the tree, plus observations of wildlife.

E. Internal decay (Heart rot): Widespread or localized heart rot fungus infection within the bole of a tree. Decayed, softened wood encompasses at least enough volume to allow excavation of a small cavity.

Description: Decayed wood in old scars may be visible at ground level or with binoculars well above the ground. Good indicators of internal decay include fungal fruiting bodies, such as conk, cavity entrances, and sloughing wood and bark. In practice, it may be difficult to discern the extent of internal decay in some cases.

F. Crack (Fissure): A longitudinal gap in the bole of a tree caused either by physical damage (including wind, lighting, or fire) or by growth of two trees or leaders into each other where the gap provides cover for wildlife.

Description: Cracks must be sufficiently deep relative to their width to provide partial cover for foraging birds or complete cover for nesting birds, roosting bats, or small- to medium sized mammals. Longitudinal indentations in which the deepest portions are visible from outside the tree are not considered cracks unless they are capable of providing cover for foraging or roosting small vertebrates.

G. Furrowed bark: A relatively deep linear indentation in the bark of a tree capable of providing cover for roosting bats or foraging bole-gleaners.

Description: Furrowed bark occurs where an underlying defect (crack, old lightning or fire scar, narrow strip of removed cambium) or the line of contact between two trees growing into each other has been covered by bark. The furrow is sufficiently deep and narrow to be capable of providing cover for small vertebrates. Furrowed bark should not be used to describe the bark of a large or fast-growing redwood tree on which the bark has developed a ropey or braided look, but does not provide cover for foraging or roosting small vertebrates.

H. Loose bark: A discrete, large piece of bark that has separated from the underlying tree bole but remains attached to the tree.

Description: “Loose bark” refers to a portion of a tree’s bark that provides cover for roosting bats, nesting birds, or possibly foraging bole gleaners. Typically, such bark pieces provide relatively tight, stable cover for small animals. The distance of separation from the underlying tree should be 2 inches or less and should not be so loose that the bark piece flaps in the wind. As a general rule, loose bark is attached along at least one edge at least 1 foot long. Although some bear-stripped trees may meet the definition of “loose bark”, most bear-stripped trees have bark that has been pulled away from the bole along most of the strip's edges, flaps against the underlying wood in the wind, and only provides a small amount of cover at one end of the strip. Such bear-stripped bark should not be scored as "loose bark".

I. Ledge (Platform): A relatively horizontal portion of a tree limb, exposed old cavity, or cluster of epicormic branches on the bole of a tree.

Description: A ledge or platform must be of sufficient size and have adequate cover to provide a nesting or resting opportunity for a moderately large wildlife species, such as Pacific fisher or peregrine falcon.

III. Crown Features (features contributing to a "complex crown")

A. Dead top (Spike): A dead tree leader.

Description: "Dead top" refers to dead leaders that are evidenced by leaf die-back along at least the top one-fifth of the tree height or with a minimum diameter at the lowest extent of leaf die-back of about 12 inches.

B. Broken top: A tree with the original leader broken off.

Description: "Broken top" refers to broken-topped trees with a minimum diameter at the original break of about 12 inches.

C. Reiteration (Reiterated top, Bayonet, "Schoolmarm", Candelabra): A sprouted leader or limb that exhibits apical dominance.

Description: Reiterations vary greatly depending on relative age and position on tree. All reiterations include some vertical growth that gives them the appearance of a "tree-on-a-tree". Old reiterations may exhibit a high degree of decadence and may themselves have additional reiterations. A tree should be scored for reiteration only if the reiteration provides opportunities for resting, denning, or nesting, or includes a substrate or epiphytes providing foraging opportunities for vertebrate wildlife.

D. Forked top: A split in a tree's leader.

Description: A tree should only be scored for a forked top if the structure provides an opportunity for resting or nesting for vertebrate wildlife, or if defect associated with the fork suggests that other structures may be present (such as internal rot or cavity).

E. Mistletoe broom (Witch's broom): A compact spray of branches infected with mistletoe.

Description: A tree should be scored for mistletoe broom if the structure is large and solid enough to provide an opportunity for resting or nesting of vertebrate wildlife, or if smaller brooms occur in multiple locations within the tree.

F. Large limb (Platform limb): A relatively horizontal limb of sufficient girth for vertebrate wildlife to use the structure for resting or nesting (but not including bird perches).

Description: A tree should be scored for large limbs if the limbs are distinctly larger than typical for similar size trees with good growth form. Generally, such trees in a stand of merchantable age will have at least two branches at least 12 inches in diameter.

A. Candidate Tree Selection:

- Retain large defective residual trees using the TREE's tree retention scorecard
- Retain defective or poorly formed trees, e.g., animal damaged, forked top, broken top, mistletoe broom, etc.
- Retain a mix of conifers and hardwoods (approximately 50/50 mix where possible
- Conifer species preference: Douglas-fir, hemlock, white fir, cedar, spruce, redwood
- Hardwood species preference: tanoak, Pacific madrone, California laurel, chinquapin
- Consider protection from windthrow and site preparation burning when designating HRA and tree clump locations
- Retain trees with the average diameter equal to or greater than the average diameter of trees in the THP unit

B. Retention Guidelines – Evaluate the method and level of tree retention needed within each THP unit as follows:

- Conifer Dominated Harvest Areas[1] with RMZ Retention:
  - Retain all scorecard trees ≥7
  - Retain other evergreen hardwoods at a rate of two trees per clearcut acre where they exist
- Conifer Dominated Harvest Areas without RMZ Retention:
  - Retain all scorecard trees ≥7
  - Retain other conifer at a minimum rate of one tree per clearcut acre.
  - Retain other qualifying evergreen hardwoods at a rate of two trees per clearcut acre where they exist. If the unit is lacking in hardwoods to meet minimum retention standards, additional conifer must be retained up to two trees per acre if harvest unit is located in a one or two tree per clearcut acre retention area
  - Retention should be a combination of approaches (HRA, tree clumps or scattered trees). HRAs are typically prescribed in cable yarding areas since this type of clumped retention is more practical in these areas. Trees retained in Streamside Management Zones (SMZ) and Class III Tier B areas can be counted toward overall tree retention
- Hardwood Dominated Harvest Areas[2] with RMZ Retention:
  - Require retention of all hardwood dominated areas at a level of at least two trees per clearcut acre regardless of the watershed
  - Retain all scorecard trees ≥7
  - Retain scattered or clumped evergreen hardwood trees at a rate of two trees per clearcut acre and also retain conifer trees scoring ≥7

[1]Forest stands with >15,000 board feet of conifer per acre.

[2]Forest stands with <15,000 board feet conifer per acre and dominated by hardwood stems.

- Hardwood Dominated Harvest Areas without RMZ Retention:
    - Retain all scorecard trees ≥7
    - Retain ½ acre HRA or clumps totaling 0.5 acres and scattered evergreen hardwood trees at a rate of two trees per clearcut acre

C. Relationship with Snag and RMZ Retention – Live tree retention is in addition to snag and RMZ retention. Green trees retained as described in these retention guidelines will augment structure provided by snag retention and within AHCP areas, i.e., Green Diamond will not include retained snags and trees left within RMZs as part of the count for Wildlife Tree Retention.

D. Live Tree Retention Scoring Criteria Used for Identification of Existing Wildlife Habitat Elements:

- Dbh – Conifers ≥30 inches and Hardwoods ≥18 inches (3 points)
- Bole features:
    - Trees with an internal hollow or large cavity (4 points)
    - Trees with a small cavity, internal rot or mistletoe broom (2 points)
    - Trees with crevice cover, i.e., loose or deeply furrowed bark (1 point)
- Crown features – Trees with complex crown, lateral large limbs, epicormic branching (1 point)
- Vole nest factor – Tree containing an active or remnant tree vole nest having canopy connectivity with existing RMZ/Geological retention (2 points) and all others (1 point)
- Unit scarcity factor (i.e., post-harvest density of late seral habitat elements) <1 acre (2 points), >1/acre but <2/acre (1 point), >2/acre (0 points)
- Watershed scarcity factor (planning watershed factor is determined programmatically and is added to the total score), impaired or special wildlife value (1 point), all others (0 points)

E.1.10 Training

Green Diamond Resource Company biologists provide annual training to company Forestry and Operations departments regarding the requirements and proper implementation of the Northern Spotted Owl Habitat Conservation Plan and company guidelines such as the TREE. This training is also provided to contractual foresters, operators and timber fallers, although complete attendance cannot be guaranteed for contractual workers. The training consists of a “classroom” review to insure consistent application of the plans.

Appendix F. Protocol

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F.1 INTRODUCTION

Appendix F is a compilation of the field survey and monitoring protocols that are necessary to support the objectives in the Effectiveness Monitoring Program for all the covered species described in Section 5.3.5. Effectiveness monitoring refers to field surveys and studies that will be used to verify and quantify the extent to which the overall biological goals and objectives of this FHCP are achieved. If data gathered as part of the effectiveness monitoring do not support the conclusion that all of the biological objectives are being achieved, these data will be used to trigger adaptive management as described in Section 5.3.6. For each of the monitoring protocols, there is a description of the field protocol including the rationale and intent to prevent "protocol drift" during a 50-year plan when progressive subtle changes in the protocol may result in substantial changes to objectives of the monitoring. Following this more detailed description, there is a condensed version of the protocol outline the required details of the monitoring.

A variety of survey and monitoring protocols have been developed for the Covered Species. The U.S. Fish and Wildlife Service (USFWS, or Service) has recommended a protocol for surveying and monitoring the northern spotted owl (NSO) since shortly after the listing of the species under ESA (i.e., 1992). The agency has provided more recent revisions to that protocol, and released the most recent version in 2011 (USFWS, 2011b). It is our goal to select the most efficient and effective methodologies for the site specific conditions found in the Plan Area of this FHCP. Green Diamond incorporated two decades of experience studying and monitoring these species within the Plan Area into the protocols described in this appendix. In addition, Green Diamond is an active participant in the Northern Spotted Owl meta-analysis and the Coastal Martes Working Group, which has provided the knowledge and experience for Green Diamond to consider the approaches that are best suited to achieve the goals and objectives of this FHCP.

As noted above, the Effectiveness Monitoring Protocols are the key to measuring the success of the conservation program in achieving the Plan's biological goals and objectives. The survey and monitoring protocols for NSOs will insure that individual NSOs are not being negatively impacted by harvesting activities and it will monitor the NSO population's response in the amount and distribution of high quality habitat. If the NSO population responds favorably as predicted to increasing habitat and removal of the barred owl threat, the monitoring results will allow implementation of a new habitat-based landscape plan that will have a reduced monitoring requirement.

In a similar manner, fishers (Appendix F.3) and tree voles (Appendix F.4) will be monitored to determine if our habitat models are accurately projecting current and future relationships between specific habitat elements and the long-term persistence of these species.

Each species' FHCP Effectiveness Monitoring Protocol is based on current monitoring technology and methodologies and on current understanding of the habitat conditions required by the Covered Species. We expect that monitoring techniques and related technology will change significantly through the fifty-year life of this Plan, and that our understanding of habitat associations of the Covered Species will also change. To facilitate these anticipated future changes, we built flexibility into the monitoring program. Some monitoring programs may be retired or replaced by more efficient and/or accurate techniques to address the same issues, and entirely new monitoring programs may be implemented to address currently unforeseen issues. Any changes to the monitoring program considered will be evaluated to insure that they do not reduce the ability of the program to achieve its objectives: to evaluate the effectiveness of the conservation measures and provide feedback for adaptive management. All changes to the monitoring program will be subject to the concurrence of the Service.

F.2 NORTHERN SPOTTED OWL SURVEYS AND MONITORING

This section describes the survey and monitoring protocol Green Diamond developed for use in this FHCP, to meet the conservation program commitments described in Section 5. We have modeled this protocol substantially on the protocol recommended for use by the Service. However, we deviate from that protocol when local data, collected substantially on Green Diamond lands over the 20 years of implementing the NSO HCP, supports a different standard while meeting the overall intent of the Service protocol. Hence, the reader should be aware that differences exist that are supported by locally applicable data and scientific rigor.

F.2.1 Surveys of Timber Harvest Plans to Protect NSOs

As described in Section 5.3.3.1 of this FHCP, all stands scheduled for timber harvest must be surveyed during the NSO breeding season. The objectives of these surveys are to avoid harassing individual NSOs in a manner that might negatively impact their ability to successfully reproduce, to avoid any direct harm to adult birds, their eggs, nestlings or dependent fledged young, and to avoid habitat modification that would result in an unscheduled direct or indirect take. This section (F.2.1) includes a description of the field protocol including the rationale and intent of the surveys and it is followed by condensed version of the protocol outline the required details of the monitoring.

The FHCP NSO survey protocol proposed herein is based substantially on the USFWS 2011 NSO survey protocol (USFWS, 2011b), but it also considers site-specific data and information acquired by Green Diamond during more than 20 years of surveys and research across the company's ownership. Similar to the Service's recommended protocol, our strategy is intended to achieve the same overall 95% probability of detecting a territorial NSO if currently occupying a site. The methods used to calculate detection probabilities followed the statistical analyses for NSO used by the Service when developing the 2011 NSO survey protocol (USFWS, 2011b) and in other recent publications (Bailey et al., 2009; Dugger et al., 2009; Wiens et al., 2011). All differences that occur between this FHCP and USFWS protocol standards are due to site-specific data from the Plan Area that yielded estimates of detection probabilities that differed from those calculated for the federal protocol guidelines.

In addition to using site-specific data to achieve overall detection probabilities, the managed landscape in which the NSO protocol will be implemented requires greater care to avoid unintended negative consequences associated with conducting surveys. The small clearcut size and dispersed harvest associated with adjacency rules leads to the necessity for 100's of surveys in selected watersheds on Green Diamond's managed landscape. Clearly surveys are important to protect NSOs and their habitat, but there are also negative impacts to NSOs associated with the surveys. NSO surveys are based on the NSO's territorial behavior in which a resident NSO will vocalize, and if within its defended space, potentially fly in to confront a perceived conspecific intruder. Every time this occurs, and even when the resident NSO does not vocalize, the NSO's normal activities are disrupted potentially resulting in increased energy expenditures, elevated corticosteroid levels, lost time to forage or care for young and increased risk of predation or harassment from competing barred owls. Green Diamond's biological staff has observed surveys that triggered barred owl attacks on NSO and daytime surveys that resulted in ravens attacking the nest or fledglings. The reduced detection probabilities associated with the barred owl influence has resulted in even more surveys being required and we are using more sophisticated calling techniques to insure that the resident NSOs are sufficiently agitated to respond. Although numerous studies have been conducted on the impact of noise disturbance to NSOs, we are not aware of any studies that have attempted to quantify the impacts of surveys on NSO. However, we believe this has the potential to have unintended consequences and our survey protocol for the NSO emphasizes the importance of avoiding undue survey impacts.

F.2.1.1 Identifying the Project Area, Survey Area and Habitat to Survey

The project area includes the polygon or multiple polygons that form the timber harvest unit boundaries and associated road construction rights-of-way that require timber falling or any other area in which any of the Covered Activities could result in harm or take of a NSO. This area includes all lands delineated for the proposed project that may be subject to activities potentially impacting NSOs through habitat modification, direct injury, noise disturbance, or any other means. The survey area is defined in the FWS protocol as the area that extends one provincial median annual home range radius from the perimeter of the project area. Data from 17 NSOs in this FHCP Plan Area indicated that one median home range radius is 0.62 mile. However, we assess potential take within a 0.5 mile radius circle, so there would be no management implications associated with locating an NSO that is more than 0.5 miles from the project area. Therefore, to reduce the potential for negative impacts associated with surveying, the survey area is a minimum of 0.5 miles from the boundary of the project area. Within the survey area, the calling points will be laid out to insure that any potential nesting, roosting, or foraging habitat is covered.

F.2.1.2 Survey Period

The survey period is the time during which surveys will be counted toward meeting criteria for complete surveys (Appendix F.2.1.8). The general survey period throughout the range of the NSO is specified as 15 March through 31 August. However, local information collected for the NSO HCP suggested that NSOs were defending established nesting territories or activity centers as early as 1 March. Therefore, in the Plan Area, the survey period may be initiated on 1 March, and surveys conducted at that time will be counted toward a complete survey. There will be cases where positive responses of NSO will occur outside the above survey periods associated with barred owl surveys. These responses may provide important information relative to future activity centers, but they will not count as part of the “official survey” for the previous or following survey periods.

F.2.1.3 Survey Design

NSO surveys are based on the NSO’s territorial behavior in which a resident NSO will vocalize, and if within its defended space, potentially fly in to confront a perceived conspecific intruder. Since the intent of the surveys is to obtain complete coverage of NSO habitat within the survey area, the calling points need to be laid out to insure the surveyor is heard and perceived as a potential intruder to any resident NSO whose territory might overlap the survey area. In addition, the calling points need to be laid out to insure that the surveyor will be able to hear the responding NSO vocalizations (i.e., avoid stream noise or acoustic barriers).

Calling stations and survey routes will be established to achieve complete coverage of all habitat within the survey area. The specific spacing of calling stations will be determined by the topography and acoustical characteristics (e.g., background noise such as creeks) of the area, but the stations typically will be spaced approximately 0.25 miles apart. Surveyors will take advantage of prominent points with good acoustical characteristics within the survey area when establishing calling stations.

F.2.1.4 Known NSO Sites

Where known NSO sites exist within the survey area, surveys will be initiated at all the known activity centers (Appendix F.2.1.9.2) within 0.5 miles of the project area boundary. If a known site is occupied, NSO habitat within close proximity of the site center (up to 0.5 mile) will be excluded from further surveying for the remainder of the season to avoid unnecessary harassment of the resident NSOs. However, the placement of the calling points around known occupied NSO sites will be variable depending on the acoustics of the calling point relative to the known NSO site and the potential for an additional NSO site to exist near the occupied site. If the calling point has no acoustic impedance relative to the known site (e.g., directly across a drainage), calling stations will be at least 0.5 from the known sites. Adjustments beyond the 0.5 mile area will be made (i.e., calling point will be dropped) if subsequent surveys elicit responses from the known resident NSOs. However, if there is an acoustical barrier (i.e., topographic break), and sufficient habitat exists to support an additional NSO site, calling points may be placed closer than 0.5 miles of the known site. This is necessary because adjacent occupied territories in the Plan Area have been documented to be within 0.33 miles when intervening ridges act to isolate the two sites. The intent of surveys around known NSO sites is to insure that a neighboring site is not missed while minimizing disturbance to the known NSOs.

F.2.1.5 Survey Procedures

Surveys of known NSO sites will include both daytime and nighttime surveys. Initial surveys will be conducted using daytime surveys because many long-time resident NSOs habituate to human presence and will fly in to be moused. This minimizes the potential for harassment of the NSOs and is the most effective method to locate some individual NSOs. However, daytime surveys increase the risk of attracting nest predators. Calling will be terminated if ravens or other potential predators are heard in the vicinity of a potential active NSO nest site. If it can be determined that the potential predator has left the area, calling can be resumed, but the decision should favor caution to minimize increased predation risk to the NSO nest. The same caution applies to nighttime calling when harm to the NSOs or their nest could occur from attracting the attention of barred or great horned owls.

If daytime surveys do not detect NSO, then nighttime surveys will be conducted. Nighttime surveys will include a different suite of recorded calls being played near the perimeter of the NSO’s territory (generally about 0.5 miles). Based on survey results under the NSO HCP, this seems to be most effective for resident NSOs that have become habituated to both human presence and the standard recorded calls. Furthermore, historical NSO sites within the influence of barred owls (Section 6.2.4.8, Appendix F.2.1.12) will receive one stand search on or after 1 June to increase the probability of locating evidence of roost sites or elicit the begging calls of juvenile NSOs.

Project (THP) surveys will be nighttime surveys with calling commencing no earlier than 0.5 hours before official sunset. Surveys generally consist of a series of fixed calling points approximately 0.25 mile apart or as needed to account for local acoustical conditions, along roads or trails. Whatever the topographic situation, the survey stations will be arranged to insure sufficient overlap in calling coverage from point-to-point, whereby the entire survey area is adequately covered and all responding NSOs will be heard.

F.2.1.6 Surveyor Qualifications

FHCP protocol surveys will be conducted by Green Diamond wildlife biologists, and, in some cases, by other employees meeting the following qualifications recommended for NSO surveyors

Normal hearing abilities are requisite. An NSO surveyor must be able to hear the NSO(s) if they were calling and:

- Have training in NSO and barred owl survey techniques, and during their first field season, work under the oversight of a fully qualified Green Diamond wildlife biologist.
- Following 1 year/season of satisfactory NSO survey experience, surveyors can work independently with occasional protocol refreshers and evaluation by their field supervisor.

Due to the prevalence and impact of barred owls on NSO surveys, surveyors will also be trained to be able to identify and interpret barred owl vocalizations and behaviors.

F.2.1.7 Calling Methods

Surveyors will use high quality digital callers with digital recordings of high fidelity. Human mimicking of NSO calls will be initially used when visiting known NSO sites since many habituated NSOs will fly up to be moused without becoming agitated and hooting, which draws the attention of potential nest predators such as ravens. Lacking a response during that survey visit, calling will revert to the digital caller.

The amplified sound should be at least as loud as a NSO, and as noted below, somewhat louder during the final stages of the calling sequence. Calling sequences will incorporate calls from both sexes and include the standard 4-note hoot, series calls, and contact calls. Since the objective is to locate while minimizing disturbance or potential harassment of the resident NSOs, the calling sequence will begin with standard 4-note hoots and soft contact calls. The calling will progressively incorporate louder calls and the more aggressive series hoots,.

For project surveys, calling at each station will continue for at least 10 minutes at each station. Calling will be terminated if a NSO responds, but the surveyor will listen for additional NSOs that may be responding. An estimate will be made of the distance and azimuth to the responding NSO or barred owl. Once a response is obtained from one calling station, the remainder of the survey calling points will be dropped or modified to insure that the NSO is not unnecessarily harassed.

If several visits to the area have used the same set of NSO calls without eliciting a response by a NSO, the surveyor will switch to a different set of calls/recordings of a different individual that had not been used previously at the site or survey area. This ‘new’ NSO may elicit a stronger reaction (e.g., because it is considered a ‘stranger’ rather than a known ‘neighbor’) from a resident but relatively non-vocal NSO. Surveys are conducted for each timber harvest unit until an NSO is located or a 95% detection probability has been achieved (Appendix F.2.1.8).

Surveys will not be conducted under inclement weather conditions, such as high wind, rain, or heavy fog, or when high ambient or human-generated noise levels would prevent hearing of responses (e.g., stream noise, continuous tree drip after a rain event, machine noise, etc.). Surveys can be conducted under conditions with moderate wind speeds (approximately < 12 mph) when flags may extend, and leaves move, but small branches are not moving. However, as sustained wind levels reach >12 mph (small branches move, dust begins to blow) conditions are not acceptable as background sound level substantially reduces ability of the NSO to hear the caller, and vice versa. If weather conditions or noise levels are in doubt, we will be conservative and not survey.

F.2.1.8 Complete Visits

Complete visits include a thorough survey of all the calling stations for the entire project area in one field outing, which reduces the chance of NSOs moving between portions of the Survey Area and not being detected. Complete surveys minimize the potential harassment of NSOs by reducing the number of visits when vocalizations are being broadcast in a particular area. The habitat distribution, topography and road networks will be considered when laying out the survey area to achieve complete visits whenever feasible. However, in some cases this may not be possible due to inclement weather or untenable logistical constraints. Reasonable effort will be made to cover the survey area in one outing. If this is not feasible, then the remaining unsurveyed area will be surveyed as soon as possible within one week (7 days) to be considered a complete visit. If a surveyor detects a NSO or unidentified *Strix* species (including owls that fly-in without calling) at night and conducts a daytime follow-up, the combination of the night outing and the daytime follow-up will be counted toward one complete visit (Appendix F.2.1.9).

F.2.1.9 Number of Complete Visits

F.2.1.9.1 THP Surveys

To determine the appropriate number of complete visits to achieve a 95% detection probability for THP (project) surveys, we analyzed past surveys of THPs from 1994-2011 (Appendix H). This analysis excluded surveys of known NSO sites, which due to knowing the NSO's activity center have a different detection probability than THP surveys in which potential habitat is being surveyed without any prior knowledge of where NSOs may be located. The analysis indicated there was a seasonal trend, which starts with a low single visit detection probability of 0.34 on 1 March and progresses to a high of 0.62 on 31 August. From this logarithmic trend, we developed a THP survey calculator of the number of visits necessary to achieve an overall detection probability of 95% (Appendix H). For example, if the first survey visit is on 1 March, with a subsequent survey visit every 7^{th} day, it would take until 5 April with seven survey visits to achieve an overall detection probability >95%. However, the necessary overall detection probability could be achieved with four surveys, if the first survey were on 10 August with subsequent surveys spaced 7 days apart. It is important to note that just like in the past, future THP detection probabilities are likely to change due to changes in barred owl densities or refinements in survey techniques. Although barred owl influences were included in the analysis of NSO detection probabilities, to address potential changes, detection probabilities will be re-estimated at least once every five years and the THP survey calculator will be updated as necessary.

Although the number of surveys will be determined by the survey calculator as described above, each survey for an individual timber harvest unit will be spaced at least one week apart (a minimum of five days between visits and visits occur in different calendar weeks). The intent of this provision is to insure calling is distributed over enough time to capture changes in individual seasonal detection probabilities that may not be accounted for with the average seasonal detection probabilities used in the survey calculator. In areas without project surveys in the previous year or area-wide surveys as part of the NSO HCP, at least one survey will be conducted after 1 May. In areas with project surveys in the previous year, at least one survey will be conducted after 1 April.

The FWS protocol (USFWS, 2011b) requires two years of surveys to determine the presence or absence of NSO. The two-year protocol is to address the annual fluctuation in detection probabilities associated with nesting attempts If an NSO site may be unoccupied in any given year, two years of surveys increases the probability that the site will be occupied and detected in at least one of the survey years. Most of the Plan Area falls within Green Diamond's demographic study area that has been completely surveyed every year since 1990. As a result, with potential very minor exceptions, all of the NSO sites in the Plan Area are known and have a long history of surveys to estimate annual occupancy and nesting status. Therefore, THP surveys are designed to locate potentially new NSO sites that have become established in the year in which timber harvesting is planned. The intent of a two-year protocol has been met for most of the Plan Area with 20+ years of survey history and a single year survey during the year of harvest is deemed sufficient if other survey data are available indicating non-occupancy the previous three years. However, a two-year protocol will be required for any area if no survey data are available for two of the previous three years and for any isolated tracts without prior surveys or new acquisitions that are not in the demographic study area and do not have a prior history of NSO surveys.

F.2.1.9.2 Known or Historical NSO Sites

To determine the appropriate number of visits to achieve a 95% detection probability for known or historical NSO sites, we analyzed past surveys of NSOs sites from 1990-2011 (Appendix H). This analysis excluded surveys of THPs, which due to not knowing the NSO's activity center have a different detection probability than surveys of known NSO sites. The analysis indicated both annual and seasonal trends, and that barred owls negatively influenced detection probabilities. The seasonal trend was a quadratic relationship with detection probabilities highest in mid-summer and lower in early and late season. From this quadratic seasonal trend and annual variation, we developed a site visit survey calculator of the number of visits necessary to achieve an overall detection probability of 95% with or without barred owls present (Appendix H). Determinations for barred owl presence (NSO site influenced by a barred owl) is described in 6.2.4.8. The calculator determines the number of survey visits required to meet 95% annual detection probability based on the number of already completed surveys over an area, and the starting date of the completed surveys. For example, in the absence of barred owls, it would require 4 surveys if the starting date were 1 March and 6 surveys with barred owls present. If the first survey were on 15 May, it would require 3 or 5 surveys without and with barred owls, respectively. In the late season, the pattern is the same as the early season. This indicates that for efficiency and reduced disturbance of the birds, the surveys should be conducted in mid-season. However, the primary objective of site visits is to potentially locate nest sites or activity centers, which can only be accomplished with confidence in the spring months. As noted above, future site visit detection probabilities are likely to change due to changes in barred owl densities or refinements in survey techniques. To address this, detection probabilities will be re-estimated at least once every five years and the site visit survey calculator will be updated as necessary.

F.2.1.10 Additional Visits

If a NSO responds, and after completing the necessary follow-up visits (Appendix F.2.1.11) resident status has not been determined, then up to 3 additional visits may be necessary in that year. There must be at least three additional visits following a response, so if the response occurs in the next to last visit, two additional visits will be required, but if the response is obtained in the last visit, three additional visits would be required. These additional visits will only be conducted in the general area of the response (approximately 0.5-mile radius around the detection location). If three follow-up visits cannot be completed by the end of August (late season response), then the area will not be cleared for timber harvest until after surveys are conducted in the subsequent breeding season. If the required number of night surveys and follow-up visits are conducted before the end of the breeding season and the results are negative, the area will be cleared for harvest.

F.2.1.11 Follow-up Visits

The objective of the daytime follow-up visit is to locate NSOs by conducting an intensive daytime search of NSO habitat within the general vicinity (approximately a 0.5-mile radius) of the response location that prompted the follow-up. Daytime locations are very important in determining key nesting and roosting sites, which in turn provides more precise information for management and issues of take. Each survey response is followed-up as soon as possible with a daytime visit by Green Diamond biologists to locate the NSO and determine its pair status, activity center, or nest site. If the first follow-up visit is negative, at least two more visits ideally one week apart will be conducted before it is concluded that the initial response was from an NSO that did not have an activity center in the survey area. If a follow-up visit is successful in locating a NSO in early spring (March to early April), at least one follow-up visit will be conducted after 1 May to insure accurate assessment of the nesting status of the NSOs.

Prior to going into the field, the biologist will review aerial photos or GIS data to identify the available habitat and determine the best approach to surveying the area. The daytime visit will occur under favorable weather conditions towards evening so that visibility is still good, but NSOs are more inclined to respond. A stand search in suitable habitat in the vicinity of the response will be conducted along with low hooting, contact whistles and squeaking. The surveyor will watch for NSOs approaching without responding and other evidence of occupancy, such as pellets, whitewash, and molted feathers. Mobbing jays and other birds may alert the observer to the presence of a NSO or barred owl. Excessive hooting will be minimized, because it may modify NSO behavior, stimulate them to move around more than is typical and increase risk of predation of the NSO or its nest. In particular, high stress calls (i.e., barking or agitated contact calls) will not be used around potential nest sites since this will stress nesting NSOs and potentially bring the female off the nest, which makes the nest vulnerable to predation by ravens.

If NSOs are located in or within 0.25-miles of a THP early in the nesting season (March to early April), and a nest site is not located, the THP will not be activated until after 1 May. If a minimum of three visits including one after 1 May indicate there is no nest, the whole plan becomes available for timber falling within the constraints of Green Diamond's Incidental Take Permit (ITP).

If a nest is found, the nest tree will be marked and retained and the THP will be immediately available for harvest within the constraints of the ITP providing that no timber falling or yarding is allowed within a 0.25-mile radius of the nest tree until it is determined that the owlets have fledged or that the nest has failed. After the owlets have fledged, the radius of protection will be 500 feet from the owlets and connectivity to continuous habitat, which maintains the 500 foot radius of protection, will be maintained. When the owlets have apparently dispersed because they can no longer be located, or based on stage of development are sufficiently matured to disperse (i.e., lost all down feathers and show interest in mousing), or it is determined that the nest has failed, falling and yarding will be allowed within the 500-foot radius.

F.2.1.12 Barred Owls

The barred owl management program proposed by this FHCP (Section 5.3.4) should keep the barred owl presence within the Plan Area at a low level. However, dispersing barred owls that are attempting to colonize a site and barred owls along the borders of the Plan Area will continue to have a presence in the Plan Area and a potential impact on NSOs. All surveyors in the Plan Area will be trained to recognize all *Strix* calls and behaviors to be able to properly ascertain the species of *Strix* owls detected, either visually or auditory, during surveys. If a barred owl is heard or seen during a survey, calling will continue for the entire survey period or until a NSO responds. If a NSO responds and the barred owl is in close proximity and/or acting aggressively toward the responding NSO, discontinue calling at that station immediately, but listen at that station for at least the entire 10-minute period so that any NSO or additional barred owl responses will be heard and recorded. The rest of the survey calling route will be continued beyond the distance defended by resident NSOs (generally at least 0.5 mi.). Similar procedures will apply to other owls and raptors that may be acting aggressively toward (or represent a capable predator of) NSOs.

If an unknown species of *Strix* is detected, the surveyor will continue to call using NSO calls for the entire 10-minute duration, or until the NSO or barred owl identification is confirmed. If the identification has not been made following the 10-minute survey period, the surveyor will wait silently and listen for at least an additional 5 minutes. If the *Strix* remains unidentified, a follow-up will be conducted to increase the probability of identifying which species is present. If all parameters of the protocol are met and the *Strix* species remains uncertain, the response will be recorded as “*Strix* unknown.”

F.2.1.13 Activity Center Searches

Given the high site fidelity of NSO, the objective is to search habitat and locate NSO in known core areas used in previous years for nesting and roosting with minimal calling and disturbance to the resident NSOs. These daytime searches of known NSO sites will be conducted as part of the initial visit to the survey area , prior to the initiation of nighttime routes as described above under “Known NSO Sites.” As noted above for “Follow-up Visits”, these daytime searches will occur under favorable weather conditions towards evening (i.e., generally 2-3 hours prior to sunset) so that visibility is still good, but NSOs are more inclined to respond. A stand search of historical roost and nest sites and suitable habitat in the near vicinity (i.e., 100-200m) will be conducted along with low hooting, contact whistles and squeaking. The surveyor will watch for NSOs approaching without responding and other evidence of occupancy, such as pellets, whitewash, and molted feathers. Nighttime calling will also be conducted at sites where NSO are not detected.

F.2.1.14 Surveys for Disturbance-only Projects

Activities that do not modify NSO habitat but have the potential to result in disturbance to NSOs usually represent short-term effects compared to the long-term effects of habitat modification. The frequent location of NSO nest sites adjacent to roads suggests that NSOs are habituated to typical administrative and maintenance activities on Green Diamond’s managed landscape with relatively high road densities and frequent traffic. Furthermore, most of the potential disturbance such as road building, timber falling and yarding will be surveyed because it also includes habitat modification. Smoke associated with control burns and blasting rock at quarries are the only activities that are potentially disturbance-only projects.

The potential disturbance of smoke from control burns to non-nesting NSOs is very minimal, because these burns are highly regulated so that the potential effects of smoke are localized and of short duration. The disturbance associated with surveying would likely exceed the potential impacts of smoke to non-nesting NSOs. Although still highly unlikely, nesting NSOs are at greater risk since they cannot simply fly away if conditions should become unfavorable. To protect nesting NSOs from potential impacts of spring slash burns, Green Diamond biologists will review a list of THP units to be burned after 1 March. If it is determined that the fire or smoke generated from a burn could disturb a historical nest site, then at least 3 site visits will be conducted to determine the status of the NSOs. If the NSOs are determined to be nesting, appropriate measures will be taken to prevent the disturbance including canceling or postponing the burn if the nesting effort fails.

There is only one historical NSO site that is in close proximity (<0.5 miles) of an existing rock quarry. The NSOs were observed by Green Diamond's biologist during one blasting event in the past and the NSOs flew up in anticipation of getting a mouse, but showed no response to the blast that sounded like distant thunder. However, should a future NSO site become established in close proximity (<0.5 miles) to a rock quarry, at least 3 site visits will be conducted to determine the status of the NSOs and blasting will be scheduled to avoid the period when females are incubating eggs or brooding young.

F.2.1.15 Additional Spot Calling and Second Year Surveys

THP surveys conducted from 1 March – 31 August that clear an area in one year will be considered valid until 1 March of the following year assuming the area has a history of surveys and does not require a two-year survey. However, any timber harvesting or other Covered Activities that could result in take beginning after 1 March of the following year will receive another protocol survey even though it may have been surveyed in the previous year. However, timber harvesting associated with some THPs may on rare occasions span two or more NSO breeding seasons. Although the likelihood of NSOs establishing a territory in such THP units is considered low, if more than 10 acres of contiguous timber remain in the unit, and falling is not continuous, then the area will receive a second-year protocol survey. This second-year protocol consists of a minimum of four nighttime surveys spaced at least seven days apart (or five days apart in different work weeks) with at least one survey on or after April 1. If less than 10 acres of contiguous timber remain in the unit, and the harvesting has not been continuous preceding the beginning of the NSO nesting season, the remaining habitat in the unit will be spot called by a biologist at least two times with at least one week between calls before felling is re-initiated. Spot calling will focus calling on the remaining timber in the plan from one or several locations to ensure adequate coverage of the area.

Continuous harvest refers to timber falling and operations that are initiated on or before February 21 and continue without a substantial break (generally a week or less). Under these circumstances a full survey is not required, but starting on February 21, a biologist will conduct nighttime spot calls of the entire THP area (unit with continuous operations) concurrently with continuous harvest operations. Surveys should be conducted starting at dusk to maximize the probability of detecting a resident NSO. Surveys will be conducted once each week for four weeks or until less than 10 acres of contiguous timber remain. A fifth night survey will be conducted on or after April 1, at which time the unit will be free of further operational restrictions if no NSOs have been detected. If an NSO is detected during one of the surveys, operations must stop until Green Diamond biologists determine if an NSO activity center exists.

F.2.1.16 Mousing

The purpose of mousing is to determine if NSOs are nesting and reproducing. By offering one or more mice to NSOs, their nesting status can be determined based on the behavior of the adult. Mousing will also be used to locate nests (and brooding females) by inducing the male to lead the surveyor to the nest tree and, later in the nesting season, can be used to locate and count young recently out of the nest. Mousing consists of the following steps.

1. Locate one or both members of a pair during the day and offer at least one member of the pair a minimum of four mice (or other similar prey items)
2. Once the NSO(s) take prey, or are found with natural prey, record the 'fate' of each prey item (e.g., eaten, cached, given to female or young) along with the sex of the NSO that captured the prey. The fate of the prey is used to classify nesting status
3. If the NSO eats the prey item, continue to offer additional prey items until the NSO caches the prey, sits on it for an extended period of time (30-60 minutes), refuses to take additional prey, or carries the prey away. If the bird flies with the prey, follow and try to determine the final disposition of the prey
4. Field personnel should make a concerted effort to get the NSO(s) to take mice. Be creative in placing a mouse where the NSO can easily see and capture it and offer mice to the mate of an NSO that has refused mice on that visit. A long pole or stick can be used to place mice higher in a tree where an NSO may more likely take it

F.2.1.17 Determining New Activity Centers

In areas where a NSO site has not been previously designated, a new activity center will be designated based on the follow-up visits for a NSO response if, during the breeding season (21 February[1] to 31 August) any of the following applies:

- A pair is detected at least two times in the same core area over at least 1 month (30 days)
- A single NSO is detected in the same core area over at least 2 months (60 days)
- An NSO response obtained during a THP survey is not followed-up adequately using the protocols described previously in Section 6.2.1. (Note: this designation of site status only applies relative to take assessment; for demographic purposes, the site status would be “unknown”)

The NSO responses will not lead to the designation of an activity center, if three adequate protocol site visits at least five days apart all result in no NSO being found within 30 (pair) or 60 (single) days of the initial response. If the initial response occurs in March, then at least one of the three site visits will be done in April.

First responses of NSOs late in the survey season will not be used to determine an NSO site when the required number of surveys and/or follow-ups visits cannot be completed. However, without assuming the location of the response constitutes a new activity center, the area will not

[1] The 21 February start to the NSO breeding season provides a 3-week buffer period prior to the earliest known nest initiation date of 12 March on the Plan Area.

be cleared for timber harvest until after surveys are conducted in the subsequent breeding season. If the required number of night surveys and follow-up visits are conducted before the end of the breeding season and the results are negative, the area can be cleared for harvest.

F.2.1.18 Determining Site (Activity Center) Status

Determining the occupancy, pair and reproductive status of NSO sites is necessary for take determinations and assessing demographic parameters relative to FHCP NSO objectives. Some determinations vary for THP and take determinations relative to definitions outlined in the density and demography survey guidelines.

F.2.1.18.1 Territorial pair status

Any of the following criteria establishes that a site is occupied by a territorial pair:

1. A male and female are heard and/or observed (either initially or through their movement) in close proximity (< ¼ mile apart) to each other on the same visit including banded birds seen together previously that are seen singly at the same site; or
2. A male takes a mouse to a female; or
3. A female is detected (seen or heard) on a nest; or
4. One or both adults are observed with young; or
5. Young identifiable based on plumage characteristics observed late in the season by knowledgeable surveyors or young identifiable based on molecular data

F.2.1.18.2 Resident Single Status

Any of the following criteria establishes that a site is occupied by a resident single NSO:

1. The presence or response of a single NSO within the same general area on 2 or more occasions within the breeding season, with no response by an NSO of the opposite sex after a complete survey

F.2.1.18.3 Status Unknown

"Status unknown" is the appropriate determination, following a complete survey, if a male and/or female are seen or heard, but do not meet any of the above site status definitions.

F.2.1.18.4 Site Occupancy

Site occupancy can be defined in several ways depending on the site status as described above. "Occupied pair" and "occupied single" refer to sites meeting the respective definitions while simple "occupancy" refers to a site with any detection of an NSO regardless of its status including "status unknown." If a site receives a complete survey and no NSO is detected, the site visit receives a '0.' Using the site visit calculator (Appendix F.2.1.9; Appendix H), if the necessary number of complete visits have been completed to achieve a 95% overall detection probability and all the visits have been negative, the site will be designated as unoccupied for that year.

Being unoccupied in any given year does not mean the site is abandoned. For further information on site abandonment and the application of 'take' see Section 6.2.4.6. For a perennial NSO site (occupied in multiple years) to be considered vacant (unoccupied for three consecutive years), which means timber harvest or other forms of potential take can occur in or around the historical NSO site without triggering a take assessment, it has to meet the definition for being unoccupied without evidence of being influenced by a barred owl (Section 6.2.4.8) in at least three consecutive breeding seasons. If the site is influenced by a barred owl that for some reason cannot be removed, or barred owls recolonize the site so rapidly that NSO have a limited opportunity to colonize the site, the NSO site has to be unoccupied for five consecutive breeding seasons before it is considered vacant. A newly colonized site occupied by a single NSO or a non-nesting pair that is unoccupied after the year of colonization will not be considered an NSO site so the vacancy criteria do not apply.

F.2.1.19 Determining Nesting and Reproductive Status

Reproduction surveys include two stages: nesting status and reproductive success. Nesting status including the location of the nest tree is critical for implementing measures to protect nesting NSOs and for take assessments. Reproductive success or fecundity is important to assess demographic parameters relative to FHCP NSO objectives.

F.2.1.19.1 Nesting Status Surveys:

Initiation of nesting has been confirmed in the Plan Area from 12 March to approximately 15 April excluding several very rare re-nesting attempts. A standard mousing procedure as described above will be used to determine nesting status. However, care will be taken to not mouse birds any more than is necessary to determine nesting status. Stimulating the NSO to move around excessively during the day may increase their risk of predation. Similarly, excessive calling near a nest site may cause harassment and endanger eggs or young by bringing the female off the nest. A minimum of four mice should be offered to one or both birds during each visit unless nesting is already confirmed through the criteria listed below.

F.2.1.19.2 Determining Nesting Status

Nesting is confirmed if, on 1 visit between 1 April and 31 May any of the following conditions are observed:

1. The female is observed on the nest
2. Either member of a pair carries natural or observer-provided prey to the nest; or
3. Young are heard or seen in the nest with adult present; or
4. A female possesses a brood patch when examined in hand during mid-April to mid-June (only one observation is required). Care needs to be taken to not confuse the normal small area of bare skin (i.e., apteria) on the abdomen and breast with the much larger brood patch. A fully developed brood patch covers most of the lower abdomen, extending to the base of the wings. or
5. Young identifiable as NSO or young detected in the presence of one or both adults.

F.2.1.19.3 Determining Non-Nesting or Non-Reproductive Status

Because nesting attempts may fail before surveys are conducted, the non-nesting status includes NSOs that did not attempt to nest as well as those with failed nesting attempts. To determine non-nesting status there must be two site visits between April 1st and May 31st. To determine non-reproductive status there must be two site visits between April 1st and August 31st. At least one visit to determine non-nesting should occur after May 1st.

Non-nesting is inferred if any of the following conditions are met between April 1st and May 31st and non-reproductive is inferred if any of the following conditions are met between April 1st and August 31st:

1. The female is observed roosting greater than 40 minutes during both visits conducted three weeks apart (at least one visit after May 1st)
2. The female does not possess a brood patch when examined in-hand between mid-April and mid-June; or
3. Four prey items are offered to 1 or both members of the pair and at least one member of the pair takes at least two mice but makes no deliveries on two or more visits conducted three weeks apart.

F.2.1.19.4 Nesting Status Unknown

If nesting status is not determined before 1 June, it is not possible to classify the NSOs as non-nesting using the criteria listed above. If NSOs are found after 1 June, without young, nesting status is unknown, and if no NSOs are found after 1 June (at those sites where NSOs were present prior to 1 June), nesting status is unknown.

F.2.1.19.5 Reproductive Success (Fecundity) Surveys

Once a pair is classified as nesting, surveys will be conducted to determine reproductive success (fecundity) after the time the young leave the nest (fledge), usually from late May to early June depending on initiation of nesting.

1. At least 2 visits will be scheduled to the site to locate and count fledged young, timing the visits so that the fledged young are observed as soon after leaving the nest as possible to avoid missing young that may be lost to predation later in the season.
2. Visual searches will be initially attempted to locate fledged young without subjecting them to increased risk of predation. If this is unsuccessful, adults will be moused. If young are present, the adults should take at least some of the prey to the young. The sight of an adult with prey will usually stimulate the young to beg, revealing their number and location.
3. If the adults take at least 2 prey items and eventually cache, eat, sit with, or refuse further prey without ever taking prey to fledged young; on at least 2 occasions, separated by at least 7 days, 0 young are recorded.

To determine the true number of fledged young:

1. On the first reproductive success visit, the number of fledged young seen or heard will be counted.
2. A minimum of 1 additional visit will be conducted 3 to 10 days after the first fledged young is seen to insure other fledged young were not missed.
3. If fledgling(s) are counted on the first visit but a second visit is not conducted, or no NSOs are found on the second visit, the number of fledged will be based on the results of the initial visit.
4. Opportunistic mousing late in the season (after July 30) may be used to provide supplemental information about the site’s reproductive success.

F.3 FISHER SURVEYS AND MONITORING

F.3.1 Survey Design

Green Diamond has conducted non-invasive surveys for detecting *Martes spp*. since 1994. The initial approach followed Fowler and Golightly (1993) using a linear array of sooted track plates along forest roads. A variety of non-invasive survey techniques are currently available to detect forest carnivores (Long et al., 2007; Long et al., 2010; Long and MacKay, 2012), and refinement of these techniques and development of new techniques will continue in the future. The technique Green Diamond has recently applied is using remote infra-red cameras deployed in an array that is suitable for both marten and fisher on Green Diamond lands (Hamm et al., 2012).

This initial focus of Green Diamond surveys from years one to five of this FHCP will be to validate or refine the existing occupancy model developed from four different time periods of track plate surveys (Section 5.3.5.2). It is likely that use of a different detection method (i.e., cameras) will initially result in refinement of the fisher occupancy model that predicts the occurrence of fisher within the plan area. However, if validation is achieved within the initial five-year period, the remaining surveys will consist of monitoring to establish high occupancy within the Plan Area. After refinement of the occupancy model, complete surveys of the Plan Area will occur at ten year intervals with at least one-half of the Plan Area surveyed at five year intervals. For example, let's assume that 600 sample stations occur across the Plan Area following the methods in Hamm et al., 2012. Green Diamond would stratify the sample stations so that at least one-half (300) of the total stations were sampled within the initial five year period and that these stations were distributed nearly equally across the Plan Area. For logistical purposes, Green Diamond may further stratify these 300 stations into logical sampling areas to survey over the course of a given year. One scenario could be to survey 25% (150) of sampling units in year two and the remaining 25% are sampled in year three to complete 50% of the survey within year 5. The remaining 300 units could be sampled in years 6 and 7 for completion of the entire survey by year 10. Green Diamond would have flexibility in determining the percent of sample units to survey and the years to conduct the surveys while maintaining the goal of complete occupancy surveys of the Plan Area within the 10-year time frame.

F.3.2 Survey Period and Procedures

Unlike NSO pairs that defend a nesting core during the breeding season from March through August, fishers and martens are solitary, and the female is solely responsible for rearing young. Their secretive and solitary behavior often results in heterogeneous detection rates that must be considered when designing surveys.

F.4 TREE VOLE SURVEYS AND MONITORING

F.4.1 Surveys

Given the lack of any direct survey method for tree voles, the primary approach to monitoring property-wide trends in tree vole populations will be through evaluating presence of tree voles in NSO pellets collected during demographic monitoring. Pellets will be collected at NSO sites during daytime demographic stand searches, and pellets will only be collected from sites that receive demographic surveys for NSOs during a given breeding season. In other words, for any given year surveyors will not collect pellets outside of the NSO breeding season or at sites where NSO demographic surveys were not conducted. All pellets will be dissected in order to identify tree vole bones.

F.4.2 Monitoring

To estimate tree vole occupancy, Green Diamond will continue to collect pellets from all NSO sites being monitored with an expected minimum sample size of 200 total prey items (average annual number of prey items in the NSO pellets collected from 1989-2009) . In addition, an analysis of past tree vole occupancy at NSO sites will be done on pellets collected from 1989-2012. This analysis will be completed within a year of Plan approval and it will be used to establish adaptive management thresholds.

Tree vole occupancy and distribution using NSO pellets will remain the default commitment unless a more effective and cost efficient protocol is developed that is mutually acceptable to the FWS and Green Diamond, Such a potential protocol has emerged due to recent advances in genetic technology that have created opportunities to monitor populations that may be more sensitive to detecting changes in the population with relatively less effort and cost. Green Diamond will investigate the feasibility and cost of using a landscape genetic approach to monitoring vole populations. Measures of genetic diversity and genetic structure within and among vole populations may provide insight into trends in population size and identify the level of migration among sites. Based on studies with other species (Luikart et al., 1998; Garza and Williamson, 2001; Storfer et al., 2009) genetic data can be used to assess either increases or reductions in population size that are not immediately obvious demographically. In these instances, losses of genetic diversity can be detected as changes in genetically effective population size (Ne), which estimates the number of breeding individuals (Luikart et al., 1998).

In addition to benefits of using genetic analyses to estimate population sizes, maintaining genetic diversity within and among vole populations may be important to ensure long term survival in an actively managed landscape. Genetic diversity is maintained in relatively large population sizes, as well as via connectivity (i.e., gene flow) among populations. Immigrants can bring new genetic diversity into populations, thereby increasing overall diversity (Wright, 1931; Slatkin, 1985). For these reasons, genetic diversity and connectivity assessments have become an increasingly common tool for guiding management of amphibian populations (Storfer et al., 2009).

Typically, landscape genetic studies involve capturing and removing small tissue samples to obtain high quality genetic material. Since there is no effective technique to trap tree voles, obtaining tissue samples would involve climbing a potential nest tree, flushing the occupant from the nest and then capturing by hand on the ground. Although Green Diamond has done this previously to support several phylogenetic studies (Murray, 1995; Bellinger et al., 2005; Blois and Arbogast, 2006), it does involve substantial effort and has the potential to injure the tree vole. As a result, we will also investigate the feasibility of using tree vole bones from NSO pellets to obtain genetic material. If this is feasible, it will also allow Green Diamond to take a retrospective look at the genetics of tree vole populations from NSO pellets that were collected beginning in 1989.

Following NSO model validation, Green Diamond will no longer be monitoring all NSO sites throughout the Plan Area (see Section 5.3.2), which will reduce the number of pellets that will be collected to assess relative frequency of tree voles. However, Green Diamond will continue to monitor a minimum of 44 DCAs along with 12 supplemental sites to estimate annual fecundity rates (see Section 5.3.2) and 20% of the take sites. Therefore, pellets will continue to be collected at a minimum of 56 sites scattered across the Plan Area, which will provide an adequate sample for assessment of tree vole population dynamics. Ultimately, a landscape genetic approach may supplement, replace or be rejected as a tool for monitoring tree vole populations.

Tree Vole Monitoring Commitment (Objective 1E, 5C): Within three years following FHCP approval, Green Diamond will develop an occupancy model to detect changes in tree voles in NSO pellets. Green Diamond will also investigate the feasibility and cost effectiveness of using tree vole bones from pellets to obtain genetic material that potentially can be used in a landscape genetic approach to monitoring tree voles. If the landscape genetic approach is found to be effective and efficient, it may with the concurrence of the FWS and Green Diamond, supplement or replace the approach based on collection of NSO pellets. An initial list of possible adaptive management measures is included in Section 5.3.6. Green Diamond may consider and propose other adaptive management options, should other responses to vole declines be more appropriate and effective.

Appendix G. Northern Spotted Owl Sites Not Proposed as Dynamic Core Areas

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G.1 INTRODUCTION

The primary mitigation strategy for NSO under this FHCP is the establishment of DCAs that are intended to be dynamic within the managed landscape of the Plan Area. Green Diamond concludes the best strategy for maintaining NSO sites is letting NSOs choose the core areas and demonstrate the potential of the site through established targets for occupancy and fecundity. This allows NSO pairs, not biologists, to choose the sites. These sites are dynamic through time because they will move in response to changes in the landscape and the NSOs' selection of suitable core areas.

Upon issuance of the ITP, Green Diamond will immediately designate and protect 44 DCAs. Green Diamond selected the initial DCAs by first evaluating all sites within the Plan Area during the course of study (1990-2015). The criteria included selecting the most functional sites in terms of high occupancy and fecundity while considering extenuating factors related to maintaining a good spatial distribution and considering recent barred owl impacts (Section 5.3.1.4.1). As a consequence, some sites not occupied in recent years, but demonstrated high occupancy and fecundity during the early years of the NSO HCP warranted inclusion, because these sites have clearly been impacted by barred owls in recent years. Green Diamond believes they should return to high productivity as soon as this negative impact has been eliminated. Some other sites with more moderate productivity were selected over more productive sites, because they fulfilled spatial objectives where no other potential DCAs were available.

The NSO sites not initially designated as DCAs are listed below in Table G.1 along with fecundity and occupancy characteristics associated with those sites.

Table G-1. Characteristics of 196 Spotted Owl Sites within the Initial Plan Area not Proposed as DCAs

Site #	Site Name	Last 10 Years (2006-2015)			All Years (1992-2015)			Year Last Occupied
		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
1	4107	0.33	4	6	0.33	6	9	2015
2	4128	0.10	1	7	0.10	1	7	2015
3	4230 #2	0.00	0	5	0.00	0	5	2015
4	4300	0.00	0	5	0.00	0	7	2015
5	4800	0.00	0	3	0.00	0	3	2011
6	4850	ENA[a]	---	0	0.41	9	11	2002
7	4910	ENA	---	5	ENA	---	5	2015
8	5700	0.15	3	10	0.13	6	24	2015
9	6000 CF	0.00	0	5	0.00	0	5	2014
10	6400	ENA	---	0	0.38	9	13	2004
11	6610	0.13	1	6	0.10	1	7	2015
12	7000	0.14	2	10	0.24	8	21	2015
13	A400	ENA	---	0	ENA	---	5	1998
14	Aldo Dusi	0.28	5	10	0.38	9	15	2015
15	Arrow Mills	ENA	---	1	0.12	3	15	2006
16	B.C. Powerline	ENA	---	1	ENA	---	2	2014
17	B1200	ENA	---	0	ENA	---	4	1995
18	Bald Mt. Creek	ENA	---	0	0.19	5	14	2005
19	Bear Creek	0.35	7	10	0.33	16	24	2015
20	Bear Gulch	ENA	---	0	ENA	---	1	1999
21	Beaver Creek	ENA	---	1	0.14	2	14	2006
22	Beaver West	ENA	---	1	ENA	---	6	2008
23	Big Lagoon Mill	ENA	---	0	0.00	0	6	2004
24	Blue Blossom	0.50	6	6	0.50	6	6	2015

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Site #	Site Name	Last 10 Years (2006-2015)			All Years (1992-2015)			Year Last Occupied
		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
25	Boulder Creek #1	0.00	0	4	0.21	3	8	2015
26	Boulder Creek #4	0.00	0	2	0.00	0	4	2013
27	Boundary Creek	0.17	3	9	0.12	4	18	2015
28	Bradshaw	ENA	---	0	0.23	5	12	2004
29	C2300	0.00	0	8	0.08	2	16	2015
30	Cal Barrel	0.00	0	4	0.17	4	16	2009
31	Camp Gate	0.00	0	5	0.00	0	5	2015
32	Canyon North	0.00	0	6	0.14	2	16	2015
33	Clear Creek	0.00	0	1	ENA	---	1	2015
34	Coyote North	0.00	0	10	0.14	5	22	2015
35	Crowsfoot	ENA	---	0	0.00	0	2	2002
36	Cuddeback South	ENA	---	0	0.00	0	3	2001
37	D100	ENA	---	0	0.00	0	2	1996
38	Dandy Creek	ENA	---	0	0.17	2	8	2002
39	Delilah Creek	0.00	0	2	0.00	0	2	2015
40	Denman Creek	0.00	0	1	0.25	1	3	2006
41	Dick Bird	0.00	0	7	0.29	10	21	2012
42	Dolf Creek	ENA	---	0	0.00	0	4	1995
43	East Goodman	ENA	---	4	0.00	0	6	2013
44	Eighteen Creek	ENA	---	0	0.50	1	1	1998
45	Fern Prairie	ENA	---	1	ENA	---	1	2015
46	Fielder Creek	ENA	---	0	0.14	2	8	1999
47	Freeman	0.25	5	10	0.33	15	24	2015
48	GAP	ENA	---	0	ENA	---	2	2002

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
49	Garrett South	ENA	---	5	0.14	2	16	2013
50	Graham West	ENA	---	0	ENA	---	1	1994
51	Guptil Gulch	0.50	2	3	0.50	2	3	2012
52	H131	ENA	---	7	0.00	0	18	2013
53	H132	ENA	---	0	ENA	---	1	1992
54	Hancorne Prairie	ENA	---	0	0.00	0	5	1996
55	Hulla Crup Turwar	0.00	0	2	0.00	0	2	2015
56	Humbug South	ENA	---	0	ENA	---	1	1994
57	Hunter 100	0.20	2	7	0.29	4	9	2014
58	Hunter 110	ENA	---	0	0.33	2	5	1996
59	Hunter 300	ENA	---	3	0.20	2	11	2012
60	Hunter 410	ENA	---	0	ENA	---	1	1993
61	Hunter 510	0.50	2	2	0.33	2	4	2015
62	Hunter CF	0.00	0	3	0.00	0	3	2015
63	HWY 101	0.00	0	3	0.14	3	16	2010
64	J1600	0.50	2	8	0.20	2	13	2013
65	Jackson Hill	0.00	0	6	0.07	2	19	2015
66	Jiggs Creek	ENA	---	1	0.21	5	13	2006
67	Johnson Creek	0.00	0	7	0.21	3	20	2015
68	K&K 1400	ENA	---	0	ENA	---	3	1997
69	K&K 400	ENA	---	0	0.10	1	6	1998
70	K&K 600	ENA	---	0	0.00	0	5	1998
71	Klamath Bar	ENA	---	0	0.25	1	5	1996
72	Klamath Mill	0.00	0	3	0.29	10	17	2008

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
73	L2000	ENA	---	0	0.00	0	2	1993
74	Lindsay Creek	ENA	---	0	ENA	---	2	1995
75	Liscom Hill	ENA	---	1	0.50	6	8	2015
76	Little Boulder Creek	0.00	0	3	0.00	0	3	2015
77	Little River #1	ENA	---	1	0.25	1	6	2006
78	Little River #2	0.17	2	7	0.08	2	15	2012
79	Little Surpur	ENA	---	0	0.00	0	6	1998
80	Lord Ellis Creek	0.00	0	7	0.28	10	21	2015
81	Lower Beach Creek	0.00	0	5	0.00	0	11	2015
82	Lower Dry Creek	0.31	5	10	0.19	6	20	2015
83	Lower McCloud Creek	0.42	5	10	0.31	8	17	2015
84	Lower SF Winchuck	ENA	---	2	ENA	---	2	2014
85	Lower Simpson	0.00	0	3	0.00	0	3	2011
86	Lower South Fork #1	ENA	---	0	ENA	---	3	2001
87	Lower South Fork #2	0.00	0	5	0.00	0	11	2011
88	Lower Tulley Creek	ENA	---	2	ENA	---	10	2012
89	Lupton Creek #2	ENA	---	3	0.25	2	10	2009
90	Lupton Creek #3	ENA	---	2	0.00	0	13	2014
91	M1150	0.00	0	8	0.08	1	17	2015
92	Mad River Overlook	1.00	2	1	1.00	2	1	2015
93	Mad River STS	0.50	4	4	0.50	4	4	2015
94	Madrone Creek	ENA	---	0	0.00	0	7	2004
95	Madrone South	ENA	---	2	0.50	1	11	2015
96	Maple B.L. #1	ENA	---	0	ENA	---	2	1999

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
97	Maple Creek #1	ENA	---	6	0.31	5	19	2015
98	Maple Creek #2	0.25	2	10	0.23	5	22	2015
99	Mather #2	0.00	0	6	0.00	0	10	2012
100	McCloud Creek	0.20	4	10	0.21	8	23	2015
101	McDonald Creek	ENA	---	0	ENA	---	1	1998
102	McGarvey Creek	ENA	---	0	ENA	---	1	1994
103	Mettah Creek #2	ENA	---	0	0.00	0	4	1996
104	Middle Ribar	ENA	---	1	0.15	3	15	2015
105	Middle Salmon Creek	0.21	3	9	0.44	15	19	2015
106	Middle Stevens Creek	0.00	0	8	0.00	0	8	2015
107	Middle Tulley Creek	ENA	---	0	ENA	---	2	1993
108	Mill West	ENA	---	1	0.40	4	6	2015
109	Miller Ridge	ENA	---	3	ENA	---	3	2015
110	M-Line Creek	ENA	---	1	0.00	0	9	2006
111	Mule Creek	0.25	1	6	0.11	2	20	2015
112	Mynot School	0.00	0	5	0.17	1	6	2011
113	NF1300	0.00	0	5	0.14	4	18	2015
114	Noname North	0.00	0	3	0.00	0	3	2015
115	North Fork Maple Creek	ENA	---	0	ENA	---	3	2001
116	Nursery	0.63	5	6	0.63	5	6	2015
117	Old 299 #2	ENA	---	0	0.27	6	12	2003
118	Old 299 Pine Creek	0.21	3	8	0.38	15	22	2015
119	Omagar Creek	ENA	---	0	0.00	0	5	2000
120	Panther Creek	0.15	3	10	0.28	10	20	2015

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
121	Panther East	ENA	---	0	0.00	0	3	2002
122	Pecwan Creek	ENA	---	1	ENA	---	1	2012
123	Pollock Creek #1	ENA	---	0	1.00	2	1	1992
124	Pollock Creek #2	0.06	1	10	0.22	10	24	2015
125	Poverty Creek	0.14	2	9	0.18	7	22	2015
126	Powerline East	0.67	4	5	0.75	6	6	2012
127	Powerline North	0.50	2	7	0.33	8	20	2015
128	Puter Creek	0.00	0	7	0.00	0	8	2015
129	Quarry Creek	0.20	2	6	0.22	7	20	2015
130	Quiet Lane	0.38	3	5	0.38	3	5	2015
131	R13	0.33	4	7	0.29	4	9	2015
132	R1400	ENA	---	0	0.17	3	10	2005
133	R15	ENA	---	0	1.00	2	1	2005
134	R200	0.06	1	10	0.14	4	24	2015
135	R-8-1	0.50	2	5	0.30	3	8	2015
136	Redwood House	0.30	3	6	0.30	3	7	2015
137	Roach LP	ENA	---	0	ENA	---	4	1995
138	Rock Ranch	ENA	---	0	1.00	2	1	2001
139	Rocky Gulch	ENA	---	0	ENA	---	2	1995
140	Roddiscraft Powerline	0.00	0	7	0.04	1	18	2015
141	Rohner Creek	0.25	2	5	0.25	2	5	2015
142	Ryan Creek	0.25	3	10	0.28	5	17	2015
143	R-Line	0.00	0	2	0.00	0	2	2015
144	S12	ENA	---	0	0.30	3	5	1996

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
145	Salmon Creek #2	0.44	8	10	0.24	10	24	2015
146	Salmon Creek #4	0.33	4	7	0.33	4	9	2015
147	Salmon Creek #5	0.17	1	4	0.17	1	4	2015
148	Salmon Creek East	0.33	2	10	0.25	5	19	2015
149	SF Ah Pah Creek	ENA	---	0	ENA	---	1	2000
150	Simpson Creek	0.00	0	10	0.13	5	24	2015
151	Snow Camp Creek	ENA	---	1	0.61	11	12	2006
152	Spring Prairie	0.00	0	2	0.00	0	2	2015
153	Stevens Creek East	0.22	4	10	0.25	6	16	2015
154	Stone Lagoon	ENA	---	0	ENA	---	3	2000
155	Sullivan Gulch	0.25	2	6	0.25	2	6	2015
156	Summit West	ENA	---	0	ENA	---	3	1994
157	Sunny Slope	0.00	0	5	0.00	0	5	2015
158	Surpur Creek	ENA	---	0	0.25	1	4	1995
159	Surpur Mouth	ENA	---	0	ENA	---	1	1993
160	T300	0.50	3	6	0.25	3	15	2015
161	Tectah Mouth	ENA	---	0	0.10	1	7	1998
162	Terwer 200	ENA	---	0	0.50	2	2	1998
163	Three Cabins	0.00	0	4	0.21	3	17	2011
164	Tom Creek	ENA	---	0	ENA	---	1	1999
165	Trouble Creek Turwar	ENA	---	1	ENA	---	1	2015
166	U10	ENA	---	0	0.25	1	4	1997
167	U700	ENA	---	0	ENA	---	2	1994
168	Upper Beach Creek	0.00	0	7	0.13	2	12	2013

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		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
169	Upper Bear Gulch	ENA	---	2	ENA	---	2	2014
170	Upper Black Dog Creek	0.25	2	4	0.25	2	4	2015
171	Upper Devil's Creek	ENA	---	0	0.50	2	3	2012
172	Upper Little River	0.00	0	2	0.11	2	10	2015
173	Upper Low Gap	0.00	0	1	0.00	0	1	2011
174	Upper Maple BL	0.00	0	2	0.00	0	9	2008
175	Upper Maple Creek	0.50	2	7	0.50	2	8	2015
176	Upper Morgan Creek	ENA	---	0	ENA	---	3	1997
177	Upper Mynot Creek	ENA	---	2	ENA	---	2	2013
178	Upper Noname Creek	0.00	0	6	0.14	2	17	2015
179	Upper Pardee	ENA	---	0	0.00	0	2	1994
180	Upper Ribar	ENA	---	0	0.00	0	6	1999
181	Upper Roach Creek	0.00	0	4	0.20	2	8	2015
182	Upper South Fork #1	0.00	0	3	0.17	3	11	2009
183	Upper South Fork #2	ENA	---	0	1.00	2	2	1999
184	Upper Stevens Creek	0.29	4	8	0.44	14	21	2015
185	Upper Tulley Creek	ENA	---	0	0.50	2	4	1996
186	W400	0.00	0	6	0.08	1	10	2015
187	Walsh	0.25	5	10	0.29	14	24	2015
188	Waukell Creek	ENA	---	0	ENA	---	2	1993
189	West Fork Stevens	ENA	---	1	ENA	---	3	2014
190	Weyerhauser Shop	ENA	---	0	0.00	0	3	1997
191	Wiggins Pond	ENA	---	0	ENA	---	1	2002
192	Williams Ridge	ENA	---	3	0.00	0	7	2014

Table G-1. Characteristics of 196 Spotted Owl Sites within the Initial Plan Area not Proposed as DCAs

Site #	Site Name	Last 10 Years (2006-2015)			All Years (1992-2015)			Year Last Occupied
		Mean Fecundity	Number of Fledglings	Years Occupied	Mean Fecundity	Number of Fledglings	Years Occupied	
193	Winchuck River	0.50	3	5	0.50	3	5	2015
194	Windy Point	0.33	4	6	0.29	4	10	2015
195	Wiregrass 200	ENA	---	1	ENA	---	1	2015
196	WM1600	ENA	---	0	ENA	---	1	1993
Total		**0.17**	**157**		**0.21**	**491**		

[a]ENA – Estimate Not Available because reproductive status was unknown or site was unoccupied.

Appendix H. Northern Spotted Owl Detection Probabilities and Number of Surveys

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H.1 NORTHERN SPOTTED OWL DETECTION PROBABILITIES AND NUMBER OF SURVEYS

H.1.1. Background

Green Diamond Resource Company has been operating under an approved NSO Habitat Conservation Plan (HCP) since 1992 (Green Diamond, 1992), which requires project surveys for forest management activities (mostly timber harvest plan – THP surveys), demographic monitoring and property-wide population density estimates. Project surveys covered under this FHCP are critical to avoid unintended direct or indirect impacts to NSO and to properly account for the amount of take. Demographic and population monitoring is equally dependent on effective surveys to provide good estimates of NSO site occupancy, survival and fecundity.

The NSO HCP project surveys have generally followed protocols put out by the US Fish and Wildlife Service (Service) that are designed to achieve a minimum 95% within season detection probability (USFWS, 2011b). The Service protocol was designed to be applied throughout the range of NSO, and although it contains regionally-specific survey buffers reflecting regional differences in home range size, the Service protocol is not specific to regional or temporal differences that may exist in NSO detection probabilities. However, the Service does encourage the use of site specific data where it exists to refine the survey protocol (USFWS, 2011b).

Demographic monitoring conducted by Green Diamond involves mark-recapture surveys of all resident NSO territories to estimate site occupancy, survival and fecundity. Green Diamond's demographic study has been conducted continuously since 1990, and one of primary objectives was to locate NSO at known sites or activity centers (primary roosting and nesting areas) and to relocate NSO if their activity centers shifted substantially (i.e., >1 kilometers). THP surveys, on the other hand, occurred in and around THPs and were designed to detect individual NSO in locations with no prior history of occupancy to insure that timber harvesting activities did not harm individual NSO or their habitat. In short, demographic surveys were designed to locate NSO typically associated with known sites, while THP surveys were designed to detect unknown NSO that might have colonized areas not previously known to be occupied. From these data, Green Diamond has site specific data that allows estimation of detection probabilities at sites with and without prior history of NSO occupancy.

The Service's protocol (USFWS, 2011b) was developed largely with data derived from annual surveys and visits to known or historical NSO sites in selected demographic study areas. Consequently, detection probabilities achieved by the Service's protocol in areas without prior knowledge of NSO occupancy was largely unknown. Despite this, the demographic survey protocol was commonly applied to areas where management activities were planned (e.g., THPs).

On a mixture of private and public timberlands, Farber and Kroll (2012) estimated detection probabilities for "night station surveys," which were equivalent to Green Diamond's THP surveys. They compared night station surveys to "informed day searches," which were similar to Green Diamond's demographic surveys except that the surveys of Farber and Kroll (2012) were not associated with a demographic study area and did not involve a mixture of day and night surveys as Green Diamond's do. Direct comparison of the Farber and Kroll (2012) surveys and Green Diamond's surveys is also complicated by the fact that their study area contained very few barred owls.

The primary objective of this analysis is to provide site specific estimates of the number and seasonal timing of surveys necessary to achieve a minimum 95% seasonal detection probability for both THP and demographic surveys in the Plan Area. In addition, we identify factors that influence detection of NSO and determine their seasonal pattern of influence. Finally, we assess the efficacy of the demographic surveys for detecting NSO in proposed project areas, as recommended in the Service's protocol (USFWS, 2011b). These objectives are achieved by estimating a patch occupancy model (MacKenzie et al., 2002, 2003) from data collected by both types of surveys and studying the external covariates with the greatest predictive abilities.

H.1.2. Methods

H.1.2.1 Field Methods

THP and demographic surveys have been conducted throughout the Plan Area since 1990. However, due to incomplete records in the early years, survey-specific occupancy information required by this analysis was compiled only from 1994 through the present for THP surveys, and from 2004 through the present for demographic surveys because only data from 2004 and later was available in electronic form. Both the THP and demographic field protocols were initially adapted from Forsman (1983) to support Green Diamond's NSO HCP (Green Diamond, 1992). Later, both protocols were further modified to be compatible with other range-wide NSO demographic study protocols so that Green Diamond’s data could be incorporated into the periodic meta-analysis of range-wide trends in NSO demographic parameters (Franklin et al., 1999; Anthony et al., 2006; Forsman et al., 2011; Dugger et al., 2016). In general, both survey protocols were consistent with the Service’s NSO protocol (USFWS, 2011b), but included minor differences to account for localized timing of breeding events and differences in home range sizes.

The annual survey period for both THP and demographic purposes was 1 March to 31 August on the Plan Area. THP surveys were done at a series of calling stations surrounding the intended project area during nighttime hours starting no earlier than 0.5 hours before official sunset, and most were completed by midnight. Prior to 2009, a night survey consisted of imitating NSO vocalizations by voice or with recordings projected by a variety of amplifiers for 10 minutes at each survey station. Beginning in 2009, high quality recordings of vocalizations were projected using digital wildlife callers (Wildlife Technologies, Manchester, NH, KAS-2030ML and MA 15).

Daytime surveys were used to locate activity centers or nest sites and to determine the status (paired, nesting, etc.) of NSO at sites where NSO had been previously located or where nighttime responses had previously been heard. Demographic study area surveys were conducted similarly, but during daytime hours in the vicinity of known or historical NSO roosting and nesting sites that were also inside Green Diamond's demographic study area.

Once an NSO was located during daytime surveys, it was typically offered live mice to determine whether it had been previously captured, and if so, to determine its identity. When NSO captured the live mice, an attempt was made to determine whether the individual was paired, and if so, the pair's reproductive status (Forsman, 1983). Pairing and reproductive status were determined by following males, if possible, back to the nest where they commonly attempted to deliver the mouse to the female. When a nest was located, it was revisited one or more times after the typical fledging period (late May through early June) to determine the status of the nesting attempt.

During daytime surveys, an attempt was made to capture all previously unknown NSO, primarily juveniles. When captured, two tags were attached. A locking USFWS leg band was attached to one tarsus. This USFWS band displayed a unique number issued by the Fish and Wildlife Service. A plastic color band was attached to the other tarsus by means of a pop-rivet. The color band consisted of the same color/pattern for all juvenile NSO banded in a given year (i.e., cohort color band). However, when a territorial NSO wearing a juvenile color band was captured, the juvenile band was replaced with a plastic band containing a unique color pattern associated with the individual as an adult. Individual color patterns were not repeated on other owls within approximately 12-15 miles. The adult color band allowed individuals to be identified without recapture. On rare occasions, a territorial NSO moved to a new location and this required us to recapture the NSO to identify it by the unique number on its Fish and Wildlife Service band.

H.1.2.2 Analytical Methods

The analytical methodology used here estimated detection probabilities, occupancy, site extinction, and site colonization using established NSO occupancy models (Olson et al., 2005; Dugger et al., 2009). Data recorded during both THP and demographic surveys included date, location, method of calling, duration of calling at individual calling stations, whether a NSO or barred owl was detected, and, from 2009-2011, whether the sites were in an experimental barred owl removal area. Location information consisted of the site identifier, which was either the name of the historical site, or the name of the associated THP. For analysis, separate patch occupancy models were estimated for both the THP and demography surveys. The details of analysis for both survey types are described in separate subsections below. Identifiers for the various variables and co-variables used throughout the paper appear in Table H1.

Table H1. Notation and brief description of variables used to model NSO occupancy

Notation	Description
.	Intercept only or constant model
J	Julian day within year. Julian day was coded as the number of days between January 1 of each year and date of the survey. That is, surveys on January 1 were coded as 1, surveys on February 1 were coded as 32, surveys on March 1 were coded as 60, etc.
JJ	Julian day squared. When included with J, fits a quadratic trend in Julian day.
lnJ	Natural logarithm of Julian day. Fits a trend with increasing or decreasing slope within years.
t	Time (i.e., year) as a factor. Assuming *t* periods, this variable produces separate estimates for each period and generates *t* – 1 coefficients
T	Linear time (i.e., year). Linear time was coded as 0 for the first year contained in the data set (either 1990 or 2004) and incremented by 1 every year afterward. Fits a single linear slope parameter across years.
TT	Linear time squared. When included with T, fits a quadratic trend in time.
lnT	Natural logarithm of linear time. Fits a trend with increasing or decreasing slope among years.
Trt	Barred owl treatment. Trt equals 1 if a site was in a BAOW removal area during a particular year. Trt equals 0 otherwise.
BO	Barred owl detection. BO equals 1 if a BAOW was detected at least once at a site in a year. BO equals 0 if not.
R	Annual reproductive success. R equals the proportion of nests that produced 1 or more

	fledglings during a year.

H.1.2.2.1 Demographic (NSO site visit) surveys

Demographic surveys conducted from 2004 to 2012 were analyzed to estimate occupancy of historical sites using the occupancy (Psi, Ψ), extinction (epsilon, ε) and colonization (gamma, γ) parametrization of the Robust Occupancy design (Mackenzie 2003). Under this model, repeat surveys conducted at the same site within a single year were considered secondary occasions. Years were considered to be the primary occasions. In this way, secondary occasions were nested within primary occasions in a fashion similar to that of robust design capture-recapture models (Pollock, 1982). The Robust Occupancy model is “open” to changes in occupancy status between primary occasions, but not between secondary occasions (Mackenzie, 2003; Olsen, 2005). Consequently, information on probability of detection is contained in the sequence of detections within primary occasions (across secondary periods), and occupancy information is obtained by essentially amalgamating secondary surveys into primary surveys using the detection histories (i.e., whether or not an NSO is detected on each occasion). The parameters inherent in the Robust Occupancy model consisted of the probability of detecting a NSO at site i during visit k of year j given that it is present (pijk), the initial proportion of occupied sites (Ψ1), local probability of extinction at site i between year j and j +1 (εij), and local probability of colonization at site i between year j and j +1 (γij).

Given that survey-specific occupancy information was only available for demography surveys from 2004 through 2012, four primary occasions were observed (one per year). The maximum number of demographic revisits to a single site within a year was 16; consequently, the number of secondary occasions was set to 16 even though the actual number of revisits to a site was typically fewer, and varied within and among years. Records for sites visited fewer than 16 times in a year were filled with missing values (i.e., “.”) in appropriate places to compete the site’s visit record.

MacKenzie et al., (2003) used a series of probabilistic arguments to derive the likelihood of observing a series of independent detection histories. MacKenzie et al., (2003) also related external covariates, such as those in Table H1, to the parameters of the likelihood (i.e., Ψ_1, ε_{ij}, γ_{ij}, and p_{ijk}) using a logistic link function. That is, colonization, extinction, and detection were modeled using logistic equations of the form,

$$log(\frac{\epsilon_{ij}}{1-\epsilon_{ij}}) = \alpha_o + \alpha_1 x_{1ij} + . . . + \alpha_A x_{Aij}$$

$$log(\frac{\gamma_{ij}}{1-\gamma_{ij}}) = \beta_o + \beta_1 y_{1ij} + . . . + \beta_B y_{Bij}$$

$$log(\frac{p_{ijk}}{1-p_{ijk}}) = \delta_o + \delta_1 z_{1ijk} + . . . + \delta_C x_{Cijk,}$$

where the Greek symbols on the right-hand side are unknown coefficients, and the x's, y's and z's are covariate values. Covariates in the ε_{ij} and γ_{ij} models were site-specific values that changed annually. Covariates in the p_{ijk} model were site and survey-specific values that changed during each survey to site *i*.

The process of selecting a set of covariates for inclusion in the above models was completed in a three-step process (Table H2). First, within year models for probability of detection were fitted while assuming general models for detection among years, colonization, and extinction. That is, covariates for p_{ijk} that varied over the visit index *k* were fitted while allowing other parameters (among year detections, annual colonization, and annual extinction) to vary annually (Models 1 to 4 of Table H2). The top within year model, as measured by the AICc statistic (Burnham and Anderson, 2002), was then used in step 2 to identify reasonable models for among year detection probabilities while allowing colonization and extinction models to vary annually (Models 5 to 33 of Table H2). Finally, the best within year and among year detection probability models were used in step 3 to fit a series of models for colonization and extinction (Models 34 to 133 of Table H2). The best fitting model at the end of step 3 was deemed the top model. Final estimates of within and among year detection probabilities, as well as annual occupancy, were computed from the top model.

Table H2. The *a priori* variable selection steps used to estimate a robust-design occupancy model for demographic site surveys.

			Detection	
Model	**Extinction**	**Colonization**	**Among Year**	**Within Year**
1	t	t	T	.
2	t	t	T	J
3	t	t	T	J+JJ
4	t	t	T	ln(J)
End Step 1: Choose best *within yr* model from above and label it Mw				
5	t	t	.	Mw
6	t	t	T	Mw
7	t	t	T+TT	Mw
8	t	t	ln(T)	Mw
9	t	t	T	Mw
10	t	t	R	Mw
11	t	t	R+T	Mw
12	t	t	R+T+TT	Mw
13	t	t	R+ln(T)	Mw
14	t	t	Trt	Mw
15	t	t	Trt+T	Mw
16	t	t	Trt+T+TT	Mw
17	t	t	Trt+ln(T)	Mw
18	t	t	Trt+t	Mw
19	t	t	Trt+R	Mw

Table H2. The *a priori* variable selection steps used to estimate a robust-design occupancy model for demographic site surveys.

Model	Extinction	Colonization	Detection	
			Among Year	Within Year
20	t	t	Trt+R+T	Mw
21	t	t	Trt+R+T+TT	Mw
22	t	t	Trt+R+ln(T)	Mw
23	t	t	BO	Mw
24	t	t	BO+T	Mw
25	t	t	BO+T+TT	Mw
26	t	t	BO+ln(T)	Mw
27	t	t	BO+t	Mw
28	t	t	BO+R	Mw
29	t	t	BO+R+T	Mw
30	t	t	BP+R+T+TT	Mw
31	t	t	BO+R+ln(T)	Mw
32	t	t	Trt*t	Mw
33	t	t	BO*t	Mw
End Step 2: Choose best *among yr* model from above and label it Ma				
34	·	·	Ma	Mw
35	·	T	Ma	Mw
36	·	T+TT	Ma	Mw
37	·	ln(T)	Ma	Mw
38	·	t	Ma	Mw
39	·	BO	Ma	Mw
40	·	BO+T	Ma	Mw
41	·	BO+T+TT	Ma	Mw
42	·	BO+ln(T)	Ma	Mw
43	·	BO+t	Ma	Mw
44	T	·	Ma	Mw
45	T	T	Ma	Mw
46	T	T+TT	Ma	Mw
47	T	ln(T)	Ma	Mw
48	T	t	Ma	Mw
49	T	BO	Ma	Mw
50	T	BO+T	Ma	Mw
51	T	BO+T+TT	Ma	Mw
52	T	BO+ln(T)	Ma	Mw
53	T	BO+t	Ma	Mw
54	T+TT	·	Ma	Mw

Table H2. The *a priori* variable selection steps used to estimate a robust-design occupancy model for demographic site surveys.

Model	Extinction	Colonization	Detection	
			Among Year	Within Year
55	T+TT	T	Ma	Mw
56	T+TT	T+TT	Ma	Mw
57	T+TT	ln(T)	Ma	Mw
58	T+TT	t	Ma	Mw
59	T+TT	BO	Ma	Mw
60	T+TT	BO+T	Ma	Mw
61	T+TT	BO+T+TT	Ma	Mw
62	T+TT	BO+ln(T)	Ma	Mw
63	T+TT	BO+t	Ma	Mw
64	ln(T)	.	Ma	Mw
65	ln(T)	T	Ma	Mw
66	ln(T)	T+TT	Ma	Mw
67	ln(T)	ln(T)	Ma	Mw
68	ln(T)	t	Ma	Mw
69	ln(T)	BO	Ma	Mw
70	ln(T)	BO+T	Ma	Mw
71	ln(T)	BO+T+TT	Ma	Mw
72	ln(T)	BO+ln(T)	Ma	Mw
73	ln(T)	BO+t	Ma	Mw
74	t	.	Ma	Mw
75	t	T	Ma	Mw
76	t	T+TT	Ma	Mw
77	t	ln(T)	Ma	Mw
78	t	t	Ma	Mw
79	t	BO	Ma	Mw
80	t	BO+T	Ma	Mw
81	t	BO+T+TT	Ma	Mw
82	t	BO+ln(T)	Ma	Mw
83	t	BO+t	Ma	Mw
84	BO	.	Ma	Mw
85	BO	T	Ma	Mw
86	BO	T+TT	Ma	Mw
87	BO	ln(T)	Ma	Mw
88	BO	t	Ma	Mw
89	BO	BO	Ma	Mw
90	BO	BO+T	Ma	Mw

Table H2. The *a priori* variable selection steps used to estimate a robust-design occupancy model for demographic site surveys.

Model	Extinction	Colonization	Detection	
			Among Year	Within Year
91	BO	BO+T+TT	Ma	Mw
92	BO	BO+ln(T)	Ma	Mw
93	BO	BO+t	Ma	Mw
94	BO+T	·	Ma	Mw
95	BO+T	T	Ma	Mw
96	BO+T	T+TT	Ma	Mw
97	BO+T	ln(T)	Ma	Mw
98	BO+T	t	Ma	Mw
99	BO+T	BO	Ma	Mw
100	BO+T	BO+T	Ma	Mw
101	BO+T	BO+T+TT	Ma	Mw
102	BO+T	BO+ln(T)	Ma	Mw
103	BO+T	BO+t	Ma	Mw
104	BO+T+TT	·	Ma	Mw
105	BO+T+TT	T	Ma	Mw
106	BO+T+TT	T+TT	Ma	Mw
107	BO+T+TT	ln(T)	Ma	Mw
108	BO+T+TT	t	Ma	Mw
109	BO+T+TT	BO	Ma	Mw
110	BO+T+TT	BO+T	Ma	Mw
111	BO+T+TT	BO+T+TT	Ma	Mw
112	BO+T+TT	BO+ln(T)	Ma	Mw
113	BO+T+TT	BO+t	Ma	Mw
114	BO+ln(T)	·	Ma	Mw
115	BO+ln(T)	T	Ma	Mw
116	BO+ln(T)	T+TT	Ma	Mw
117	BO+ln(T)	ln(T)	Ma	Mw
118	BO+ln(T)	t	Ma	Mw
119	BO+ln(T)	BO	Ma	Mw
120	BO+ln(T)	BO+T	Ma	Mw
121	BO+ln(T)	BO+T+TT	Ma	Mw
122	BO+ln(T)	BO+ln(T)	Ma	Mw
123	BO+ln(T)	BO+t	Ma	Mw
124	BO+t	·	Ma	Mw
125	BO+t	T	Ma	Mw
126	BO+t	T+TT	Ma	Mw

Table H2. The *a priori* variable selection steps used to estimate a robust-design occupancy model for demographic site surveys.

Model	Extinction	Colonization	Detection	
			Among Year	Within Year
127	BO+t	ln(T)	Ma	Mw
128	BO+t	t	Ma	Mw
129	BO+t	BO	Ma	Mw
130	BO+t	BO+T	Ma	Mw
131	BO+t	BO+T+TT	Ma	Mw
132	BO+t	BO+ln(T)	Ma	Mw
133	BO+t	BO+t	Ma	Mw

Following model estimation, the probability that a site remains unoccupied for *k* or more years was computed for planning purposes. Given a site was unoccupied, constant colonization probabilities, and that occupancy in a particular year is independent of the occupancy status in all previous years, the number of years until re-colonization follows a geometric distribution (Freund, 1961). That is,

$$P(X = k) = \gamma(1-\gamma)^{k-1}$$

where *X* is the (random) number of years until re-colonization and γ is the recolonization rate. From the cumulative geometric distribution, it is possible to compute the probability of an unoccupied site remaining unoccupied for at least k years as,

$$P(X \geq k) = \sum_{i=k}^{\infty} P(X = i) = (1-\gamma)^{k-1}.$$

All robust occupancy models were estimated using program MARK (http://warnercnr.colostate.edu/ $\sim$gwhite/mark/mark.htm and R http://www.r-project.org). Other estimation tasks were performed in R using the RMark package (http://cran.r-project.org/web/packages/RMark/index.html).

H.1.2.2.2 Timber Harvest Plan (THP) Surveys

We analyzed THP surveys from 1994 to 2011 to estimate detection probabilities when prior knowledge of NSO presence did not exist. The THP surveys analyzed here excluded those near known NSO sites, which may have different detection probabilities. The overall data included 598 THP surveys, of which 121 were excluded because they had at least one survey point within 0.5 miles of a known NSO site. A total of 477 (= 598 - 121) surveys remained for analysis. Data recorded during each survey included the date, associated THP, method of calling, duration at the individual calling station, whether a NSO or barred owl was detected, and since 2009, whether the THPs were in a barred owl removal area (Table H1).

Eighteen primary THP sampling occasions (1994 to 2011) were observed. The maximum number of resurveys from a given point within a year was 8. Records for sites with fewer than 8 resurveys were augmented with missing values (i.e., ".") to complete the record.

Similar to demographic surveys, the detection probability of THP surveys was analyzed using the Ψ1, ε, γ) parametrization of a Robust Occupancy design (MacKenzie et al., 2003). A primary difference between these models and those estimated for demographic surveys was the lack of interest in estimates of initial occupancy (Ψ_1), local colonization (γ_{ij}), and extinction (ε_{ij}). These parameters were not of interest because the surveys were designed to confirm that no previously undetected NSO sites existed and the objective of this analysis was to determine how many surveys were necessary to achieve this with a >95% probability.

The process used to select a set of covariates for inclusion in models of p_{ijk} was to fit the sequence of models appearing in Table H3 and rank them according to the AICc criterion. These models were fit with initial occupancy (Ψ_1), local colonization (γ_{ij}), and extinction (ε_{ij}) parameters set as constants. Final estimates of within-season estimates of detection probabilities were derived from the lowest AICc model. If the lowest AICc model contained annual variation in detection, within-season detection probabilities were averaged over the last two years of the study (2010 and 2011). Only the last two years were used because there were adjustments to the equipment and survey protocol in those years designed to increase NSO detection probabilities with barred owls on the landscape. Finally, estimates of annual average detection probability for 1994 through 2011 were computed by model averaging over the 12 models that appear in Table H3.

Table H3. A priori variable model selection for detection probabilities estimated from Green Diamond's northern spotted owl THP visit data

	Detection Model	
Number	**Among Yr**	**Within Yr**
1	.	.
2	.	T
3	.	TT
4	.	ln(T)
5	t	.
6	t	T
7	t	TT
8	t	ln(T)
9	CT	.
10	CT	T
11	CT	TT
12	CT	ln(T)

H.1.3. Results

H.1.3.1 Demographic (NSO site visit) surveys

The best fitting *within year* model for the demographic surveys included a quadratic term for day within the year (Table H4). The quadratic *within year* model achieved a 22.6 AICc difference over the next best fitting model (Table H4), indicating strong support for a quadratic seasonal effect. This model advanced to the second and third steps of model selection. Estimates of within year detection probabilities will be presented later with results from the final model.

The best fitting among year detection probability model contained an interaction between the *BO* (barred owl) and *t* (annual time) effects (Table H5). The top model from step 2 received high support, as measured by AICc (Delta AICc = 6.24), and implied that the effect of barred owls on detection varied by year. This model advanced to the third step in model construction.

The best fitting occupancy model at the end of step 3 contained a linear time trend (*T*) in the colonization model and no trend (.) in the extinction model (Table H6). Estimates of probability of detection in the middle of the survey period (approximately 15 May) computed using this model ranged from 0.2294 in 2008 to 0.68197 in 2011 *with* barred owls in the vicinity (Figure H1). The detection probabilities during the same time period ranged from 0.5475 in 2008 to 0.7546 in 2005 *without* barred owls in the vicinity (Figure H1). At annual average barred owl occurrence rates, the average annual NSO occupancy rate on the surveyed area declined from approximately 0.90 in 2004 to a low of approximately 0.65 in 2007 and 2008. After 2008, estimated occupancy increased to approximately 0.70 (95% confidence interval 0.65 to 0.75) in 2011 (Figure H2).

Using the best fitting model, probability of colonization was $\gamma = 0.275$ ($=e^{-0.9680} / (1+e^{-0.9680})$, Table H7). Using this estimate of γ, the probability of a site remaining unoccupied for at least 1, 2, …, 7 more years is contained in Table H8. Assuming the estimated colonization rate is true, the probability of an unoccupied site remaining unoccupied for another 2 years (i.e., 3 years unoccupied) is approximately 50% (Table H8).

Table H4. Model fitting results for step 1 of robust-design occupancy model estimation for demographic survey data collected from 2004 through 2011

ε	γ	P(among)	P(within)	AICc
t	t	t	J+JJ	7814.93
t	t	t	J	7837.54
t	t	t	ln(J)	7841.74
t	t	t	.	7843.94

Table H5. Top 20 models from step 2 of robust-design occupancy model construction for demographic survey data collected from 2004 through 2011

ε	γ	P(among)	P(within)	AICc
t	t	BO+t+BO:t	J+JJ	7783.55
t	t	BO+t	J+JJ	7789.79
t	t	Trt+t	J+JJ	7811.55
t	t	t	J+JJ	7814.93
t	t	Trt+t+Trt:t	J+JJ	7815.08
t	t	BO+R+lnT	J+JJ	7855.25
t	t	BO+R+T+TT	J+JJ	7859.75
t	t	Trt+R+lnT	J+JJ	7862.71
t	t	Trt+R+T+TT	J+JJ	7866.81
t	t	R+lnT	J+JJ	7871.28
t	t	BO+R+T	J+JJ	7872.87
t	t	Trt+R+T	J+JJ	7875.33
t	t	R+T+TT	J+JJ	7875.7
t	t	BO+lnT	J+JJ	7884.09
t	t	Trt+R	J+JJ	7884.78
t	t	R+T	J+JJ	7886.53
t	t	Trt+lnT	J+JJ	7887.00
t	t	BO+R	J+JJ	7887.13
t	t	BO+T+TT	J+JJ	7892.64
t	t	Trt+T+TT	J+JJ	7894.52

Table H6. The top 30 at the end of step 3 of robust-design occupancy model construction for demographic survey data collected from 2004 through 2011

Rank	ε	γ	P(among)	P(within)	Npar	AICc	AICc
1	T	1	BO+t+BO:t	J+JJ	22	7776.360	0.00
2	T+TT	1	BO+t+BO:t	J+JJ	23	7776.600	0.24
3	BO+T	1	BO+t+BO:t	J+JJ	23	7777.530	1.17
4	BO+T+TT	1	BO+t+BO:t	J+JJ	24	7778.090	1.73
5	T	BO	BO+t+BO:t	J+JJ	23	7778.250	1.88
6	T+TT	BO	BO+t+BO:t	J+JJ	24	7778.400	2.04
7	T	T	BO+t+BO:t	J+JJ	23	7778.420	2.05
8	T	lnT	BO+t+BO:t	J+JJ	23	7778.420	2.06
9	t	1	BO+t+BO:t	J+JJ	27	7778.450	2.09
10	T+TT	T	BO+t+BO:t	J+JJ	24	7778.660	2.30
11	T+TT	lnT	BO+t+BO:t	J+JJ	24	7778.670	2.30
12	lnT	1	BO+t+BO:t	J+JJ	22	7778.880	2.52
13	BO+T	BO	BO+t+BO:t	J+JJ	24	7779.390	3.03
14	BO+T	T	BO+t+BO:t	J+JJ	24	7779.590	3.23
15	BO+T	lnT	BO+t+BO:t	J+JJ	24	7779.600	3.23
16	BO+lnT	1	BO+t+BO:t	J+JJ	23	7779.760	3.40
17	BO+t	1	BO+t+BO:t	J+JJ	28	7779.910	3.54
18	BO+T+TT	BO	BO+t+BO:t	J+JJ	25	7780.140	3.78
19	BO+T+TT	T	BO+t+BO:t	J+JJ	25	7780.160	3.79
20	BO+T+TT	lnT	BO+t+BO:t	J+JJ	25	7780.160	3.80
21	t	BO	BO+t+BO:t	J+JJ	28	7780.240	3.88
22	T	BO+T	BO+t+BO:t	J+JJ	24	7780.300	3.94
23	T	BO+lnT	BO+t+BO:t	J+JJ	24	7780.300	3.94
24	T	T+TT	BO+t+BO:t	J+JJ	24	7780.440	4.08
25	T+TT	BO+T	BO+t+BO:t	J+JJ	25	7780.470	4.10
26	T+TT	BO+lnT	BO+t+BO:t	J+JJ	25	7780.470	4.11
27	t	T	BO+t+BO:t	J+JJ	28	7780.520	4.16
28	t	lnT	BO+t+BO:t	J+JJ	28	7780.530	4.16
29	T+TT	T+TT	BO+t+BO:t	J+JJ	25	7780.610	4.25
30	lnT	BO	BO+t+BO:t	J+JJ	23	7780.790	4.43

Table H7. Coefficients in the top occupancy model fitted to the demographic survey data.

Coefficient	Estimate	95% Confidence Interval	
		Lower	Upper
ψ:(Intercept)	2.1724	2.0109	2.3339
ε:(Intercept)	-1.3063	-1.45	-1.1627
ε:Time	-0.1634	-0.2223	-0.1044
γ:(Intercept)	-0.9680	-1.1574	-0.7787
p:BO	-0.1198	-0.3054	0.0659
p:session2004	0.8727	0.7196	1.0258
p:session2005	1.1229	0.9456	1.3002
p:session2006	0.7696	0.6001	0.9391
p:session2007	0.3113	0.1564	0.4662
p:session2008	0.1901	0.0426	0.3375
p:session2009	0.6620	0.482	0.8420
p:session2010	0.8341	0.6451	1.0231
p:session2011	0.7155	0.5521	0.8789
p:Jul	-0.0014	-0.0025	-0.0002
p:Jsq	-0.0001	-0.0001	0.0000
p:BO:session2005	-0.5742	-1.1967	0.0484
p:BO:session2006	-1.0228	-1.6284	-0.4173
p:BO:session2007	0.1054	-0.9183	1.1291
p:BO:session2008	-1.2824	-2.2524	-0.3123
p:BO:session2009	-0.6588	-1.1914	-0.1262
p:BO:session2010	-0.6585	-1.2433	-0.0737
p:BO:session2011	0.1666	-0.2962	0.6295

Table H8. Probability of an unoccupied NSO site remaining unoccupied for k additional years, given various values of colonization (γ). Colonization, estimated from the demographic survey data, was γ = 0.275. Values in the table are $(1 - \gamma)^{k-1}$

	k						
γ	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0.1	0.9	0.81	0.73	0.66	0.59	0.53	0.48
0.2	0.8	0.64	0.51	0.41	0.33	0.26	0.21
0.275	0.73	0.53	0.38	0.28	0.2	0.15	0.11
0.3	0.7	0.49	0.34	0.24	0.17	0.12	0.08
0.4	0.6	0.36	0.22	0.13	0.08	0.05	0.03

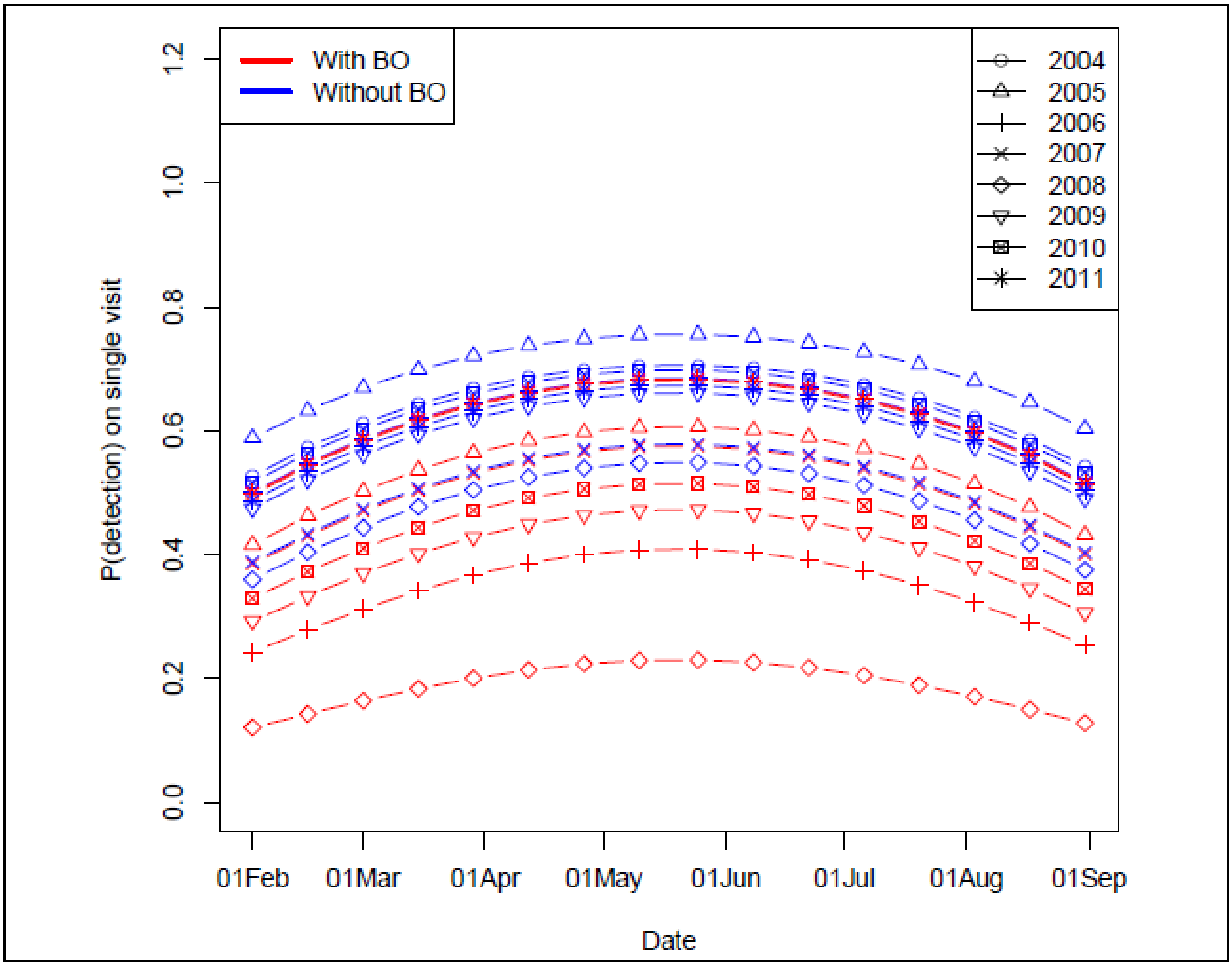

Figure H1. Estimates of within year probability of detection of an NSO on a single visit to a site. Estimates produced by the final robust-design occupancy model for the reduced data set (2004 through 2011).

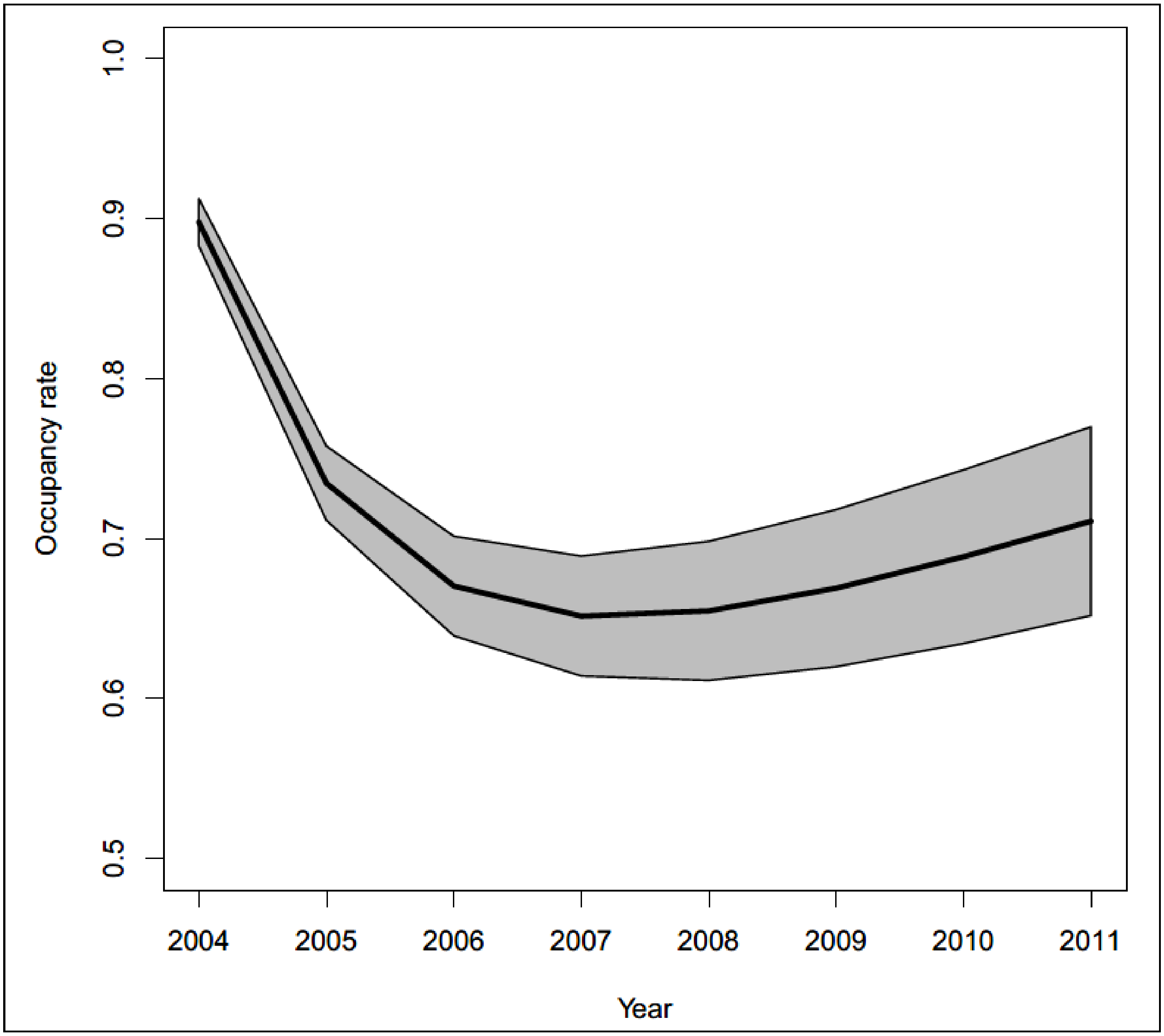

Figure H2. Annual NSO occupancy rates from 2004 through 2011 estimated from demographic survey data. Estimates were obtained from top robust-design occupancy model after setting all covariates to their annual average. The gray region is a 95% point-wise confidence region for the true occupancy rate.

H.1.3.2 Timber Harvest Plan (THP) Surveys

The top THP detection probability model contained ln(T) (Table H9) and produced within-season estimates of detection probabilities that increased through time (Figure H3), but by smaller amounts later in the season. Among seasons, the vast majority of AICc weight (92%) was contained in the three models that allowed separate estimates of annual detection probabilities (Table H9). This implies strong support for the hypothesis that detection probabilities varied annually (see Discussion). Annual estimates of single-visit detection probabilities computed by model averaging estimates from the middle of each field season (May 7) showed a general downward trend until 2010 and 2011 (Figure H4).

Table H9. Rankings by AICc for NSO detection probability models derived from Green Diamond's THP data.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Number of Parameters	Deviance
p(t,ln(T))	813.2648	0	0.51139	1	20	768.4648
p(t,T)	814.4851	1.2203	0.27782	0.5433	19	772.1669
p(t,TT)	816.0337	2.7689	0.12808	0.2505	20	771.2337
p(CT,ln(T))	819.6643	6.3995	0.02085	0.0408	4	811.4549
p(CT,T)	820.0261	6.7613	0.0174	0.034	4	811.8167
p(.,ln(T))	820.1981	6.9333	0.01597	0.0312	3	814.0731
p(.,T)	820.3751	7.1103	0.01461	0.0286	3	814.2501
p(CT,TT)	821.759	8.4942	0.00732	0.0143	5	811.4432
p(.,TT)	822.2915	9.0267	0.00561	0.011	4	814.0821
p(t,.)	826.8643	13.5995	0.00057	0.0011	18	786.9999
p(.,.)	828.5632	15.2984	0.00024	5.00E-04	2	824.5011
p(CT,.)	829.7862	16.5214	0.00013	3.00E-04	3	823.6612

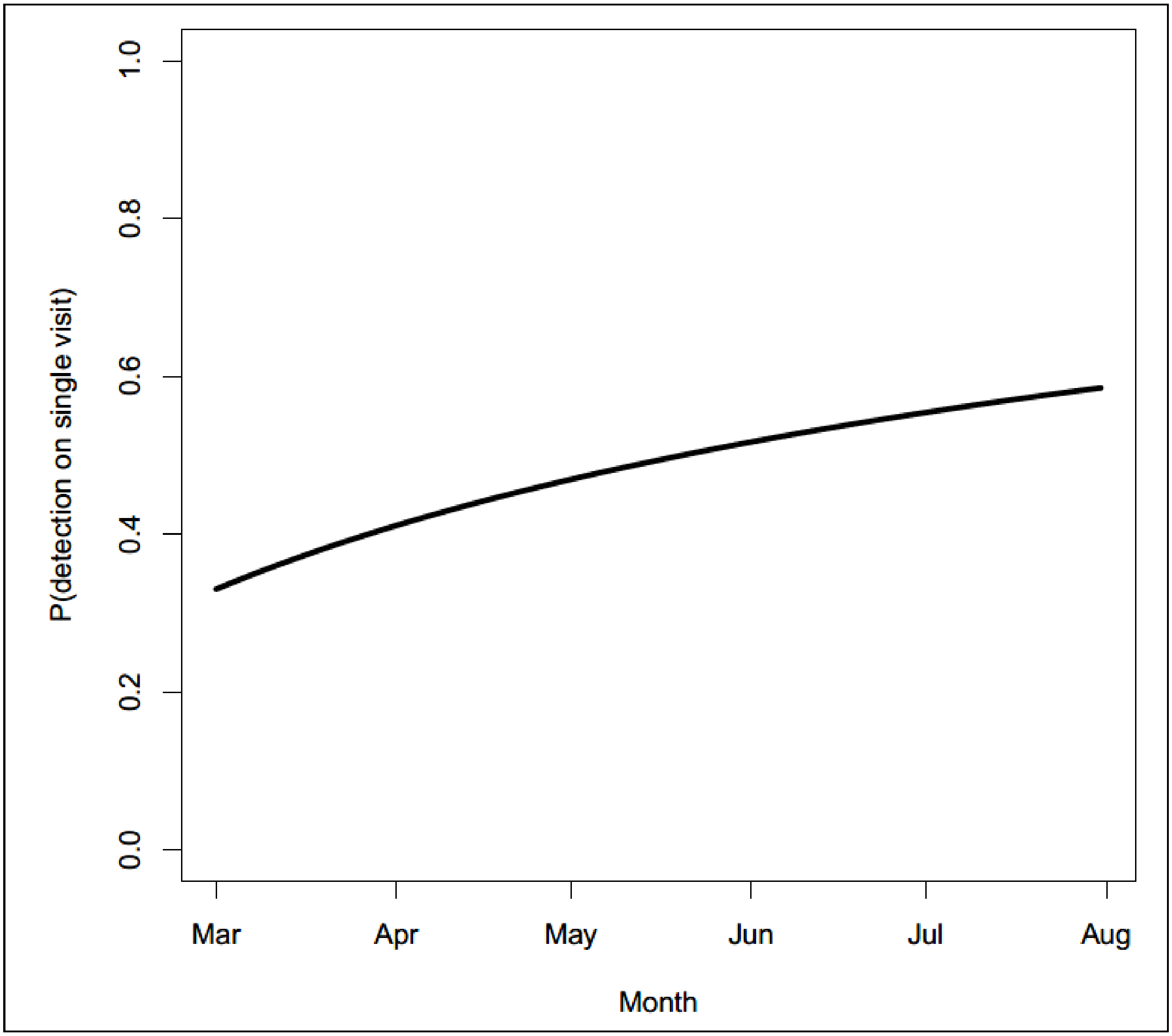

Figure H3. Within-season estimates of NSO detection probabilities, averaged over 2010 and 2011. Estimates were derived from the best fitting THP detection model containing a logarithmic trend through the season.

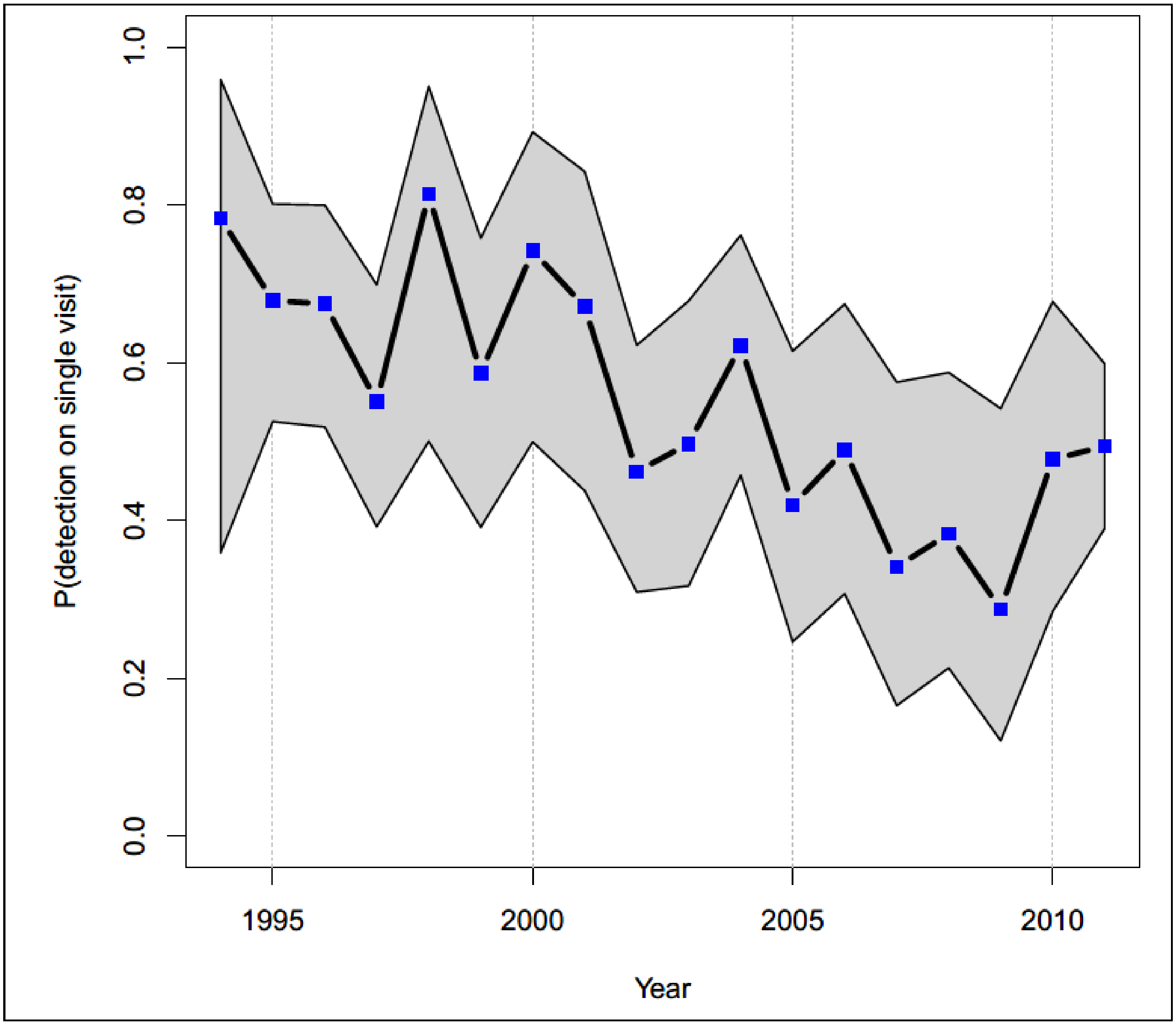

Figure H4. Model averaged estimates of detection probabilities with 95% confidence limits derived from THP survey data. Estimates were generated for May 7 of each year.

H.1.4. Discussion

H.1.4.1 Demographic (NSO site visit) surveys

The presence of barred owls had a strong negative effect on detection probabilities of NSO in 5 of 8 years. A negative effect of barred owls on NSO detection rates has been recorded for every study that has been done on detection rates of NSO where barred owls were present (Dugger et al., 2009; Olson et al., 2005; Crozier et al., 2006; and Wiens et al., 2011). The specific mechanism for this suppression of calling is not fully understood, but it is known that both species are highly territorial and interspecific aggressive interactions occur near their respective nest sites or activity centers (Van Lanen et al., 2011). Anecdotal observations of aggressive interactions between the species have been observed on the Green Diamond and other demographic study areas (P. Carlson, pers. comm., Willow Creek Demographic Study Area) and the outcomes were that larger barred owls were successful in physically attacking and driving off the smaller NSO. There is one recorded case of a NSO potentially being killed by a barred owl (Leskiw and Gutierrez, 1998), and although the potential exists, we think this is a very rare outcome of a physical encounter between the species. However, following one of these physical encounters, it seems likely that a NSO would become more reticent to call to avoid another negative interaction with a barred owl.

Annual variation in detection rates for NSO with and without barred owls was also reported by Dugger et al. (2009). It is likely that this annual variation results from a combination of factors including stochastic events associated with selection of calling points and NSO occupancy, weather, proportion of birds nesting and experience or ability of the surveyors. For the Green Diamond study, 2008 had the lowest p (detection probability) for both with and without BO, which corresponded with the lowest year of occupied NSO sites before BO removal was initiated in 2009. Beyond this one observation, there were no apparent trends between detection rates and occupancy or mean annual fecundity.

There was a fairly strong quadratic effect of Julian date on detection probabilities with highest detection rates in mid-season. This is likely the result of a combination of factors, including less than ideal early spring survey conditions and greater potential for rain, wind and stream noise. While the survey protocol requires that certain minimum conditions be met before surveys are conducted, the reality is that spring weather conditions in many years result in some surveys being conducted near the limits of suitable calling conditions. We also have anecdotal evidence that NSO pairs may more reluctant to respond during the early nesting season and the female will generally not call from the nest unless seriously agitated by an intruder.

The drop-off in detection rates in the late season was presumably influenced by NSO moving away from their primary roost/nest areas either because they did not nest, nested and failed or the fledglings had flight skills sufficient to move away from the nest area. In these situations, calling done at the traditional nest sites or activity centers would likely yield negative results because the resident birds had moved out of the area.

The trend in occupancy was consistent with the impact of barred owls on the NSO population causing a decline, followed by an increasing trend after a portion of the study area was incorporated into an experimental barred owl removal area.

For demographic surveys, a total of 4 weekly surveys would be required to achieve a 95% seasonal detection probability if surveys were initiated on 1 March without barred owls, but 6 weekly surveys would be required if barred owls were present (Table H10). Only 3 surveys would be required to achieve 95% detection if surveys were initiated on 15 May, and 5 surveys if initiated on the same date with barred owls present (Table H10). If surveys were initiated on 10 August, 4 and 6 surveys would be necessary to achieve the 95% seasonal detection probability for sites without and with barred owls (Table H10). This indicates that time of year had little effect on detection probabilities at demographic sites, but presence of barred owls had a major impact. However, if it is important to find nest sites at demographic sites, this can only be accomplished during the spring months prior to fledging.

Table H10. The probability of detecting a NSO during demographic site visits with and without barred owls on subsequent weeks as a function of the number of visits and time of year.

	Date of First Survey					
	1-Mar		**15-May**		**10-Aug**	
Visit #	**w/o BO**	**w/ BO**	**w/o BO**	**w/ BO**	**w/o BO**	**w/BO**
1	0.53	0.357	0.655	0.47	0.573	0.379
2	0.8	0.628	0.887	0.746	0.818	0.645
3	0.92	0.802	**0.963**	0.883	0.919	0.792
4	**0.97**	0.895	0.988	0.944	**0.969**	0.88
5	0.989	0.947	0.996	**0.975**	0.982	0.923
6	0.996	**0.947**	0.999	0.988	0.991	**0.967**

H.1.4.2 Timber Harvest Plan (THP) Surveys

As noted above, barred owls have been shown to reduce the probability of detecting NSO (Dugger et al., 2009; Olson et al., 2005; Crozier et al., 2006; Wiens et al., 2011) The overall downward trend in annual detection probabilities observed here (Figure H4) was most likely associated with increased numbers of barred owls and decreased effectiveness of voice imitation of NSO calls. After 2009, when use of digital callers and a barred owl removal experiment were initiated, an increase in detection probabilities was anticipated. We assume the digital callers and decreased presence of barred owls in some areas was responsible for the increase in detection probabilities observed in 2010 and 2011 (Figure H4).

To estimate within-seasonal trends in detection probabilities, we used estimates averaged over 2010 and 2011 because these years best reflect the protocol that will be used in the future when barred owls have minimal influence in most parts of the study area. The observed within-season trend starts with a low single visit detection probability of 0.34 on 1 March and progresses to a high of 0.62 on 31 August (Figure H3). From this logarithmic trend, it is relatively easy to calculate seasonal (multi-visit) detection probabilities given a plan for the number and timing of surveys. To facilitate these calculations, we developed a THP survey calculator (Excel spreadsheet, available from the authors) which computes the number of visits necessary to achieve an overall detection probability of 95%.

As an example of how this calculator works, we computed detection probability assuming surveys on consecutive weeks (7-day interval between all surveys) and an early, mid and late season starting point, even though other constraints might prevent such weekly surveys.

Achieving a 95% probability of detection starting early in the season (1 March) would require 7 visits (Table H11). If surveys started on 15 May, 5 surveys would achieve 95% probability of detection (Table H11). In an extreme case, 95% detection probability could be achieved in 4 weeks between 10 August and 10 September (Table H11). This indicates that for efficiency and reduced disturbance to NSO, the surveys could be conducted later in the survey season. However, the primary objective of many surveys is to locate nest sites or activity centers for protection from harm or to collect reproductive information, which can only be accomplished in the spring months.

Table H11. The probability of detecting an NSO during a sequence of night surveys as a function of the start date.

	Date of first survey		
Visit #	**1-Mar**	**15-May**	**10-Aug**
1	0.34	0.50	0.60
2	0.58	0.76	0.85
3	0.74	0.88	0.94
4	0.84	0.95	**0.98**
5	0.91	**0.98**	
6	0.95	0.99	
7	**0.97**	1.00	

Appendix I. Model Validation Process

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I.1 HABITAT FITNESS MODEL

The NSO HCP (Green Diamond, 1992) was based on approximately two years of site specific data collection and now its successor, the FHCP, is based on approximately two decades of research and monitoring resulting in one of the largest datasets on NSOs in existence. The data collected were incorporated into extensive sophisticated analyses as part of a mandated Ten-Year Review (see Appendix C.2), which led to the development a model of habitat fitness that could be projected into future landscapes for NSOs. The future projections of habitat fitness indicate an overall increasing trend in the best habitat (i.e. greatest fitness values), which suggests that if the non-habitat covariates (e.g., weather and barred owls) are within the median values under which the habitat fitness model projections were made, the NSO population is capable of increasing in the Plan Area. However, this habitat fitness model suffers from the same limitations of all mathematical models of ecological processes in that it cannot ever completely capture all the complexity and nuances inherent in any ecological system. In addition, it is a deterministic model when both future habitat and non-habitat variables are in fact highly stochastic; particularly as those projections are made further into the future. So while this habitat fitness model was based on extensive site-specific data and state-of-the-art statistical models, all statistical models require verification or validation and initially should be viewed as testable hypotheses. The term “model validation” can have a variety of meanings, but as we are using the term, the habitat fitness model will be considered validated when we can verify that the conclusions and predictions from the models are both reliable and useful.

One of the primary objectives of the effectiveness monitoring program for NSOs is to validate the habitat fitness model through independent verification of the model predictions. It is problematic to measure habitat fitness directly, because while mean fecundity can be estimated for an area, estimates of mean survival would be complicated by movements of resident NSOs during their lifetime. So rather than attempting to directly validate the predictions of the model for a particular area in terms of fecundity and survival, the closest approximation will be to correlate the predictions of the model relative to NSO abundance within some designated area. For example, if the habitat fitness model predicts that an area in the future will have increasingly high habitat fitness (λ_H >1.0), the NSO in the area should have sufficiently high survival and fecundity such that the resident NSO population in this area will increase assuming non-habitat variables are within median past values (see Appendix C, Chapter 4, pp. C-168 to C-172).

Using future survey results gathered throughout the Plan Area, the estimated number of occupied NSO sites in the three NSO regions (spatially grouped OMUs which represent different physiographic regions in the Plan Area) will be compared to the estimated number of NSO sites at the initiation of the Phase II (Plan Area-wide) barred owl removal experiment. Green Diamond will validate the overall predictions of the habitat fitness model by a comparison of trends in estimated NSO abundance as indicated by the region-wide estimated number of paired and single occupied NSO sites and the predicted trend in property-wide habitat quality. In general, since the highest category of habitat fitness (λ_H >1.05) is projected to increase dramatically averaged across the three NSO regions (Appendix C, pp. C-210 to C-215), validation will be achieved when NSO abundance has a similar upward trend through time.

Specifically, how this is expected to function is illustrated with three OMU example areas in Figure I-1 below. On initiation of the Plan, the average habitat fitness values of the Korbel OMU predict a moderately increasing NSO population, which should increase at an accelerated rate until 2040. In contrast, the Northern Klamath OMU is predicted to have a declining population until 2020 and then have a moderately increasing population over the next two decades. Finally, the Wiggin's Ranch is predicted to start with a moderately increasing population, show a moderately increase rate followed by a declining rate. Model validation will be based on the extent to which the observed trends mirror (i.e., have parallel trajectories) relative to the predicted trends. However, given the many factors in addition to habitat quality (i.e. weather, competition from barred owls, fluctuations in prey base abundance and stochastic demographic factors) that can influence NSO populations, it is not expected that the trajectories between observed and predicted NSO numbers will be in precise concordance within some predetermined statistical limits for all OMUs. Following the necessary time interval described below (approximately 7 years), model validation with all the FHCP ramifications for monitoring and take will be achieved as long as the overall observed long term trends in estimated occupied NSO sites for each of the three NSO regions are statistically shown to be stable or increasing (*P* = 0.95) as predicted by the region-wide upward trend in habitat quality. If the projections of the habitat fitness model have not been met because of inconclusive population trends or depression of the NSO population due to a non-habitat covariate (e.g., weather, disease or off-property illegal rodenticide use), Green Diamond will continue to gather the extensive NSO survey and mark-recapture data until validation has been achieved or during periods when there is a lapse in permitting to conduct barred owl removal experiments.

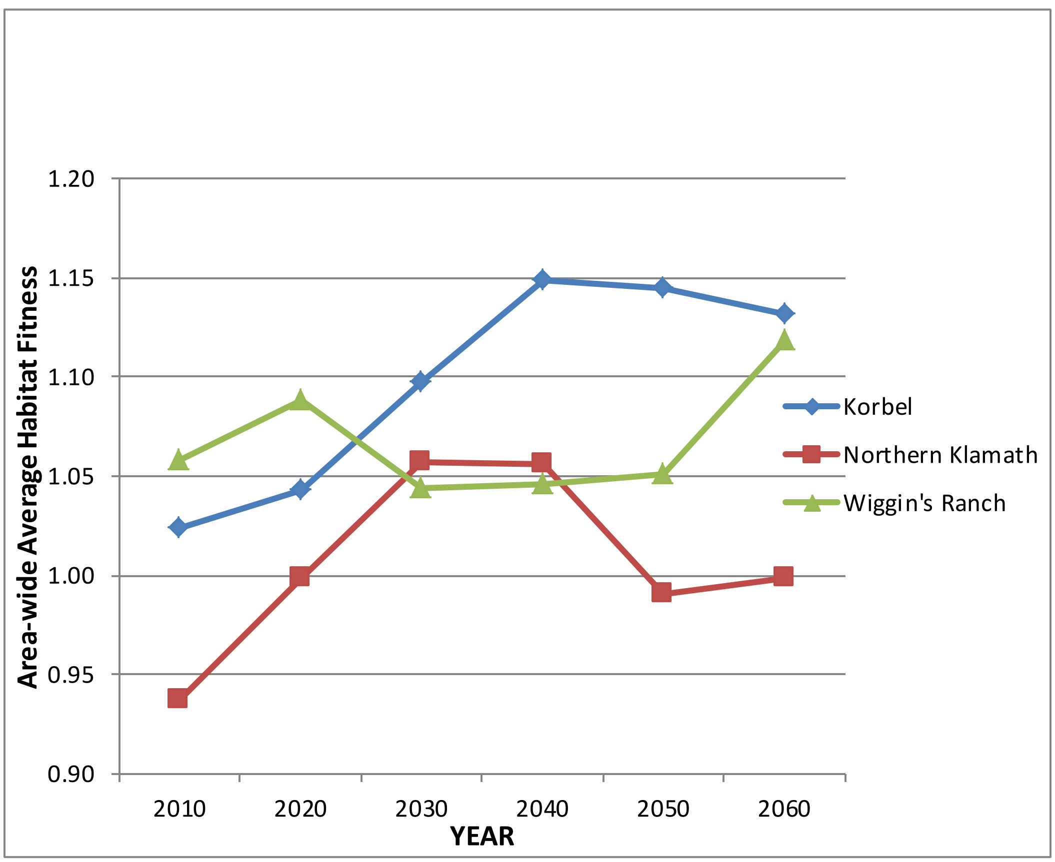

Figure I-1. Trends in average habitat fitness values for selected areas designated as owl management units (OMU).

It is impossible to predict exactly how much time will be necessary for the NSO population to respond favorably to improving habitat conditions following implementation of the Plan Area-wide barred owl removal experiment. Although strongly associated with habitat conditions, site occupancy, survival and fecundity are also influenced by stochastic variables dependent on the vagaries of weather, prey population levels, the effectiveness of barred owl removal and other unforeseen factors. Currently, NSO populations throughout the Northwest are in a declining phase, which at least partially, is due to competition with barred owls (Forsman et al., 2011, Dugger et al. 2016). However, there may be other future factors such as weather or declines in prey species suppressing the NSO population that cannot be predicted. However, the preliminary results of the barred owl removal experiment indicated that there was already compelling evidence indicating that barred owls were having a strong negative impact on NSO occupancy rates, and where barred owls were controlled, the number of occupied NSO sites increased dramatically (see Section 4.4.1). This indicates that there will be data that can be used to validate the habitat fitness model and the results from the Lower Mad River case study (see Section 4.4.1) suggest that an overall increasing NSO population is possible within a few years following approval of the FHCP and implementation of the Plan Area-wide barred owl removal experiment. However, to insure that it is not due to a temporary anomaly in the NSO population due to something like an unusually high population in one of the NSO's primary mammalian prey species, a minimum of 7 years will be required before FHCP model validation will be achieved. However, if the survey data do not support a long term increasing trend, the achievement of model validation will be extended until the trend is established or it is apparent that model validation is not going to be possible.

I.2 SITE OCCUPANCY MODEL

While validation of the habitat fitness model is based on the question: "Do trends in NSO abundance match model predictions in overall habitat fitness?" a second model will be developed to address the question: "Are NSOs found at the specific sites where the model predicts occupancy should be high?" The second type of model will be a site occupancy model (MacKenzie et al., 2006), which will not be used as a threshold or trigger for achieving FHCP habitat fitness model validation, but it will be a requirement to have successfully completed a NSO site occupancy model before the new FHCP conservation measures contingent on habitat fitness model validation will be implemented.

As part of the Ten-Year Review of the initial Green Diamond NSO HCP, an abandonment model was developed (see Appendix C, pp. C-25 to C-33), but we lacked the necessary data to construct a site occupancy model for NSOs. Green Diamond has begun to assimilate data that can be used for development of an occupancy model, and within three years of the signing of the FHCP, a first draft of a site occupancy model will be developed. Further developments of occupancy models have led to the development of multi-state occupancy models (Nichols et al., 2007, 2008). As implied by the name, instead of a single state (species detected/not detected), multiple states can be modeled. In the case of the NSO surveys for the Plan Area, the multiple states will likely include detection/non-detection of NSO and detection/non-detection of fledglings. A full suite of covariates both biologically meaningful and readily implemented by management will be included in this occupancy model. Along with providing estimates of site occupancy and reproduction, the habitat covariates associated with this multi-state occupancy model will potentially provide a new more management useful definition of NSO habitat and thresholds of take. For example, the habitat fitness model integrated model inputs from separate nesting, nighttime activity, survival and fecundity models (Appendix C, Chapter 4, pp. C-168 to C-172). Included in these models were a variety of spatially explicit covariates (e.g., edge density and mean patch density) produced by complex computer intensive GIS analyses using

FRAGSTATS. While very useful to understand how the various habitat elements function to meet the needs of NSO, and how overall forest management strategies influence Plan area-wide habitat quality, the complex habitat fitness model does not lend itself to predicting how site specific management actions (i.e., harvest units) may influence habitat quality for a specific NSO site. The goal of the multi-state occupancy model will be to include management covariates that are more easily calculated and interpreted, which potentially can then be used to provide a simpler definition of NSO habitat and the thresholds likely to result in take.

Following its development, the site occupancy model will be tested and refined so that future spatially explicit projections of NSO occupancy and reproduction can be made. Testing of the model will be done through comparisons of expected versus observed occupied NSO sites with successful nesting and the results will be used to continue to improve the predictability of the model. Maximizing predictability of the model will be important, because it will be used as one component for estimating take of NSO sites following model validation.

To support validation and development of both of these models, Green Diamond must do surveys for NSOs throughout the Plan Area and annually attempt to locate all individual territorial NSOs. However, unlike the surveys with an overall detection probability of 95% that were designed to avoid impacts to individual NSOs due to timber harvesting, these surveys will only be required to have a sufficiently high detection probability that the models can be validated within the prescribed statistical limits.

Appendix J. GLOSSARY OF TERMS AND ABBREVIATIONS

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J.1 ABBREVIATIONS

AHCP	Aquatic Habitat Conservation Plan
BACI	Before-After-Control-Impact
BOWG	Barred Owl Working Group
CAS	California Academy of Sciences
CBD	Center for Biological Diversity
CCAA	Candidate Conservation Agreement with Assurances
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CESA	California Endangered Species Act
CFGC	California Fish and Game Commission
CWD	Course Woody Debris
DCA	Dynamic Core Areas
DCA MA	Dynamic Core Area Management Areas
DPS	Distinct Population Segment
DSA	Density Study Area
EA	Environmental Assessment
EEZ	Equipment Exclusion Zones
EIS	Environmental Impact Statement
EPA	Eligible Plan Area
ESA	Endangered Species Act
FBRI	Forest Biometrics Research Institute
FHCP	Forest Habitat Conservation Plan
FPA	Forest Practice Act
FPR	Forest Practice Rules
FPS	Forest Projection and Planning System

GIS	Geographic Information Systems
GDRCo	Green Diamond Resource Company; also abbreviated 'Green Diamond'
HCP	Habitat Conservation Plan
HPA	Hydrographic Planning Area
HRA	Habitat Retention Area
IA	Implementing Agreement
IPA	Initial Plan Area
ITP	Incidental Take Permit
LWD	Large Woody Debris
MATO	Master Agreement for Timber Operations
MBTA	Migratory Bird Treaty Act
MSP	Maximum Sustained Production
NEPA	National Environmental Policy Act
NHPR	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NSO	Northern Spotted Owl
ODFW	Oregon Department of Fish and Wildlife
OMU	Owl Management Unit
PA	Plan Area
RMZ	Riparian Management Zone
RPF	Registered Professional Forester
TDWMP	Terrestrial Deadwood Management Plan
THP	Timber Harvest Plan
TREE	Terrestrial Retention of Ecosystem Elements
USFWS	United States Fish and Wildlife Service, also abbreviated 'the Service'
WDR	Waste Discharge Requirement

J.2 DEFINITIONS

Abandoned owl site: As defined in the 1992 NSO HCP, a perennial owl site that is unoccupied for three consecutive years is defined as abandoned. Since this does not imply that the site no longer has suitable habitat for spotted owls or that it may not be recolonized in the future, this term will be replaced with 'vacant' in this FHCP. If a vacant site is reoccupied during a subsequent breeding season, it becomes an active owl site.

Active owl site: An occupied or unoccupied perennial owl site; not an abandoned owl site.

Activity center (owl): The location (point in space) of a nest site, the primary daytime roost site, or the geometric center of several roosts where owls or owl sign have been detected. Nighttime responses may constitute an activity center if the owls are consistently heard in the same area.

Adaptive management: As defined by the Services for purposes of their HCP program, a method for examining alternative strategies for meeting measurable biological goals and objectives, and then, if necessary, adjusting future conservation management actions according to what is learned (65 Federal Register 106, 36245)

Adjacency constraints: adjacent timber stands cannot be harvested for 3-5 years following the eve-aged harvest of the first unit.

Adjustment area: Commercial timberland acreage within the 11 HPAs that is not within Green Diamond's ownership on any given date during the term of the Plan. This includes lands that are eligible for addition to the Plan Area through acquisition or that may be removed from the Plan Area through sale, subject to the limitations imposed by the Plan and IA.

Aerial yarding: Movement of logs to a landing by use of helicopters, or balloons, often used where roads cannot be constructed to provide access to a harvesting unit.

Age class: One of the intervals into which the age range of trees is divided for classification or use in management.

Bankfull channel: Channel between the tops of the most pronounced bank on either side of a stream reach where water would just begin to flow out onto the floodplain.

Basal area: The cross sectional area of a single stem, including the bark, measured at breast height (4.5 feet above the ground).

Base sites: All spotted owl sites that occur throughout the Plan Area that may at some point be taken because they are not designated as dynamic core areas (DCA).

Before-After-Control-Impact (BACI): An experimental approach that utilizes a paired design with treatment and control sites. Data are collected from both experimental sites before and after the treatment and an analysis is done to determine if the relationship of the response variable(s) between the treatment and control sites differs following the treatment.

Broadcast burn: A prescribed fire allowed to burn over a designated area with well-defined boundaries to achieve some land management objective.

Bucking: Use of a saw to remove log lengths from a tree after it has been felled.

Buffer: A vegetation strip or management zone of varying size, shape, and character maintained along a stream, lake, road, or different vegetation zone to minimize the impacts of actions on sensitive resources.

Cable yarding: Taking logs from the stump area to a landing using an overhead system of winch-driven cables to which logs are attached with chokers.

California Forest Practice Rules (CFPRs): Rules promulgated by the California Board of Forestry and administered by the California Department of Forestry and Fire Protection governing the conduct of commercial timber operations on state and private land in California.

Candidate conservation agreement with assurances (CCAA): An agreement between a non-federal property owner and the Service(s), in which the property owner commits to implement conservation measures for a proposed or candidate species or a species likely to become a candidate or proposed in the near future. The property owner also receives assurances from the Service(s) that additional conservation measures will not be required and additional land, water, or resource use restrictions will not be imposed should the currently unlisted species become listed in the future (64 Federal Register 116, 32727). The agreement accompanying with an enhancement of survival permit issued under section 10(a)(1)(A) of the ESA.

Canopy closure: The ground area covered by the crowns of trees or woody vegetation as delimited by the vertical projection of crown perimeters and commonly expressed as a percent of total ground area.

Canopy cover: The proportion of ground or water covered by a vertical projection of the outermost perimeter of the natural spread of foliage or plants, including small openings within the canopy.

Changed circumstances: Changes in circumstances affecting a species or geographic area covered by a conservation plan that can reasonably be anticipated by plan developers and the Services and that can be planned for (e.g. the listing of a new species, or a fire or other natural catastrophic event in areas prone to such events.). 50 CFR §§ 17.3, 222.102. Changes that will constitute Changed Circumstances, and the responses to those circumstances, are described in Plan Section 5. Changed Circumstances are not Unforeseen Circumstances.

Channel: Natural or artificial waterway of perceptible extent that periodically or continuously contains moving water.

Channel migration zones (CMZs): Current boundaries of bankfull channel along the portion of the floodplain that is likely to become part of the active channel in the next 50 years. The area of the channel defined by a boundary that generally corresponds to the modern floodplain, but may also include terraces that are subject to significant bank erosion.

Class I watercourses: All current or historical fish-bearing watercourses and/or domestic water supplies that are on site and/or within 100 feet downstream of the intake.

Class II watercourses: As used in the Plan, watercourses containing no fish, but support or provides habitat for aquatic vertebrates. Seeps and springs that support or provide habitat for aquatic vertebrates are also considered Class II watercourses with respect to the conservation measures.

Class II-1 watercourse: A subset of Class II watercourses, as illustrated in Figure C-1 of the Plan.

Class II-2 watercourse: A subset of Class II watercourses, as illustrated in Figure C-1 of the Plan

Class III watercourses: Small seasonal channels which do not support aquatic species, but have the potential to transport sediment to Class I or II watercourses.

Clearcutting: Even-aged regeneration method where all the merchantable trees in the stand are removed in one harvest. Regeneration is accomplished by natural or artificial means.

Co-dominant tree: A tree whose crown helps to form the general level of the main canopy in even-aged stands or in uneven-aged stands, the main canopy of the tree's immediate neighbors, receiving full light from above and comparatively little from the sides.

Commercial harvest: Removal of merchantable trees from a stand.

Commercial thinning: removing selected trees that may contain commercial value, to create additional growing space for crop trees.

Covered activities: Certain activities carried out by Green Diamond in the Plan Area that may result in incidental take of Covered Species and all those activities necessary to carry out the commitments reflected in the Plan's Operating Conservation Program and IA.

Covered species: The species identified in Table 1-1 of this Plan, which the Plan addresses in a manner sufficient to meet all of the criteria for issuing an incidental take permit under ESA Section 10(a)(1)(B) and all of the criteria for issuing an enhancement of survival permit under ESA Section 10(a)(1)(A), as applicable.

Critical habitat: Specific areas, both occupied and unoccupied, that are essential to the conservation of a listed species and that may require special management considerations or protections.

Cumulative effect: As defined in the Services' HCP Handbook and Draft CCAA Handbook: Under NEPA regulations, the incremental environmental impact or effect of the action together with the impacts of past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions (40 CFR 1508.7). Under ESA section 7 regulations, the effects of future state or private activities not involving federal activities, that are reasonably certain to occur with the action area of the federal action subject to consultation (50 CFR 402.02).

Decadent structure: Tree structure in condition of decline or decay due to age.

Deep-seated landslide: Landslides that have a basal slip plane that is relatively deep and commonly extends into bedrock. These are typically vegetated with trees and/or grass and typically move incrementally.

Demographic Study Area: A portion of Green Diamond's ownership and selected adjacent areas in which all known northern spotted owl sites are monitored annually to estimate occupancy, fecundity and survival following accepted scientific protocols. The Green Diamond demographic study area is one of 11 long-term, ongoing studies that contribute to a periodic, region-wide meta-analysis of the status of the northern spotted owl.

Density Study Area: A defined subset of the demographic study area in which the entire area is surveyed each year in an attempt to locate all occupied northern spotted owl sites, which can be used to calculate an annual estimate of spotted owl density.

Diameter at breast height (DBH): The diameter of a tree 4.5 feet above the ground on the uphill side of the tree.

Direct displacement: Any timber harvesting or forest management activities that result in falling trees or killing dominant or co-dominant stand trees within a 500-foot radius of the most recent nest site or activity center for an occupied or active northern spotted owl site.

Displacement: Timber harvesting or any of the covered forest management activities that result in disruption of northern spotted owl essential behaviors such that the resident single or pair is no longer found to be occupying the site.

Distinct population segment (DPS): A vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species. The smallest division of a taxonomic species permitted to be protected under the Endangered Species Act.

Dominant tree: A tree whose crown extends above the general level of the main canopy of even-aged stands or, in uneven-aged stands, above the crowns of the tree's immediate neighbors and receiving full light from above and partly from the sides.

Dynamic core areas (DCA): A suite of spatially distributed highly functional northern spotted owl sites based on current long-term occupancy and high fecundity (reproduction), or potential for high occupancy and fecundity following release from barred owl influences. These northern spotted owl sites protected from take or other negative impacts of timber management include the core nesting and roosting areas of 89 acres, if it exists, and surrounding foraging habitat that with the core area totals 233 acres. These sites are referred to as dynamic because these highly functional sites are expected to change throughout the life of the Plan and will be replaced over time by new, equally or more functional, well distributed core areas established by NSO as habitat conditions evolve across the Plan Area.

Effective date: The date(s) upon which the ITP and ESP are issued by the Services.

Eligible plan area (EPA): All privately owned commercial timberlands that, over the life of the Plan, are either included within the Plan Area or are eligible for inclusion in the Plan Area. This is the entire commercial timberland acreage analyzed in the Plan to support the Plan's provisions allowing for additions and deletions of lands from the Plan Area of the term of the Plan and Permits.

Endangered: The classification given to an animal or plant in danger of extinction within the foreseeable future throughout all or a significant portion of its range.

Equipment exclusion zone (EEZ): An area where use of heavy equipment is not allowed.

Even-aged stand: A stand of trees composed of a single age class in which the range of tree ages is usually +/- 20 percent of rotation.

Even-aged management: The application of a combination of actions that results in the creation of even-aged stands. Clearcut, shelterwood, or seed tree cutting methods produce even-aged stands.

Environmental impact statement (EIS): A document prepared to describe the effects for proposed activities on the environment.

Feasible: Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, operational, and technological factors, and considering what is allowable under the law.

Fecundity: The potential level of reproductive performance of a population; calculated as the number of female young fledged per female spotted owl.

Fitness: Ability of an individual to survive and reproduce

Foraging habitat (NSO): From an ecological perspective, foraging habitat includes any habitat that supports prey species of NSO in which owls might actively pursue and capture their prey. However, relative to this FHCP, only stands greater than 30 years are considered foraging habitat even though the prey of NSO are known to occupy younger stands and the juxtaposition of young (6-30 years) adjacent to older stands (>45 years) increases the probability of foraging.

Forest management: The practical application of biological, physical, quantitative, managerial, economic, social, and policy principles to the regeneration, management, utilization, and conservation of forests to meet specified goals and objectives while maintaining the productivity of the forest.

Front-end loader: A machine with special forks, lifts, or grapples for loading logs onto trucks, pallets, or railcars.

Green Diamond's ownership: Commercial timberlands that Green Diamond owns in fee and lands owned by others subject to Green Diamond harvesting rights.

Ground-based yarding: Movement of logs to a landing by use of tractors, either tracked or rubber tired (rubber tired skidders) or shovels (hydraulic boom log loaders).

Habitat: The place, natural or otherwise, (including climate, food, cover, and water) where an animal, plant, or population naturally or normally lives and develops.

Habitat conservation plan (HCP). As defined in the Services' HCP Handbook, a planning document that is a mandatory component of an application for an incidental take permit under ESA Section 10(a)(1)(B); also known as a conservation plan. The document that, among other things, identifies the operating conservation program that will be implemented to minimize, mitigate, and monitor the effects of incidental take on the species covered by a Section 10(a)(1)(B) permit.

Habitat fitness: Effect of habitat quality on an individual's ability to survive and reproduce.

Harass: A form of take under the ESA. Defined in ESA implementing regulations promulgated by the Department of Interior as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3).

Harm: A form of take under the ESA. Defined in federal regulations as an act which actually kills or injures fish and wildlife. Such an act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering (50 CFR part 222.102; also see 50 CFR part 17.3).

Harvesting: All activities necessary to cut, remove, and transport timber products from the Plan Area.

Harvesting rights: The rights to conduct timber operations on lands owned in fee by another. Short-term harvesting rights generally expire upon the conclusion of timber operations, upon a date certain, or a combination of the two. Perpetual harvesting rights pertain to existing and subsequent crops of timber and continue without expiration.

Headwall swales: Areas of narrow, steep, convergent topography (swales or hollows) located at the heads of Class III watercourses that have been sculpted over geologic time by repeated debris slide and debris flow events.

Helicopter yarding: (Alternatively: aerial yarding). Movement of logs to a landing by use of helicopters, or balloons, often used where roads cannot be constructed to provide access to a harvesting unit.

Hydrographic planning area (HPA): The hydrographic areas and hydrologic units mapped in the AHCP/CCAA which encompass the Eligible Plan Area and surrounding lands in common watersheds

HPA group: HPAs that have been grouped together based on their geologic and geomorphic characteristics for purposes applying slope stability measures.

Implementation Agreement (IA): An agreement between the Service(s) and the incidental take permittee(s) that identifies the obligations of the parties, identifies remedies if parties fail to meet their obligations, provides assurances to the Service(s) that the conservation plan will be implemented, and provides assurances to the permittee(s) that implementation of the plan satisfies ESA requirements for the species and activities covered by the plan and permit.

Incidental take: The taking of a federally listed species, if such taking is incidental to, and not the purpose of, carrying out otherwise lawful activities.

Incidental take permit (ITP): A permit issued by the Services pursuant to ESA Section 10(a)(1)(B) authorizing incidental take of federally listed species named on the permit.

ITP species: The Covered Species for which Green Diamond is seeking an ITP; the species named on the ITP.

Indirect displacement: Any timber harvesting or covered forest management activities within a 0.5 mile radius of the most recent nest site or activity center of an occupied or active owl site that reduces the habitat below thresholds established in this FHCP. The thresholds include 89 acres of stands 46 years and older, and 233 acres of stands 31 years and older.

Initial plan area (IPA): The Plan Area that exists on this FHCP Implementation Agreement and Permit; based on Green Diamond ownership and harvesting rights at time of permit.

Intermittent stream: A stream that flows only at certain times of the year and/or when it receives water from springs or from a surface source. It ceases to flow above the streambed when losses from evaporation or seepage exceed the available streamflow.

Jeopardy: term under the Endangered Species Act that refers to an action that is reasonably expected to diminish a species' numbers, reproduction, or distribution so that the likelihood of survival and recovery in the wild is appreciably reduced.

Landings: The areas where harvested trees are gathered (through skidding or yarding) for subsequent transport out of the forest.

Large woody debris (LWD): Larger pieces of wood in stream channels or on the ground, including logs, root wads, and large chunks of wood that provide important biological and physical functions.

Listed species: A species, subspecies, or qualifying distinct population segment of a vertebrate species on the lists of threatened and endangered wildlife and plants in 50 CFR 17.11 and 17.12. Also, a species, subspecies, or variety of plant or animal on the lists of the endangered, threatened, and rare species maintained by the California Fish and Game Commission. **Nest Site (Owl):** A tree in which a pair of spotted owls has nested.

Maximum extent practicable. Term used in the ESA and federal regulations to describe the level of impact minimization and mitigation required for incidental take of a listed species to be authorized under ESA Section 10(a)(1)(B).

Maximum sustained production: Harvest levels planned under CFPRs to balance forest growth and timber harvest over a 100-year period and to achieve maximum sustained production of high quality timber products while protecting resource values such as water quality and wildlife.

Merchantable: Trees or stands having the size, quality, and condition suitable for marketing under a give economic condition, even if not immediately accessible for logging.

Migratory Bird Treaty Act (MBTA): The Migratory Bird Treaty Act implements various treaties and conventions between the U.S. and Canada, Japan, Mexico and the former Soviet Union for the protection of migratory birds. Under the Act, taking, killing or possessing migratory birds is unlawful.

Minor forest products: Secondary forest materials including tree burls, stump products, boughs and greenery for wreaths and floral arrangements or similar purposes.

National Environmental Policy Act (NEPA): The Act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals within the federal agencies.

National Marine Fisheries Service (NMFS): A division of the U.S. Department of Commerce that is responsible for the stewardship of the nation's marine resources, the protection and recovery of listed marine species, and the authorization of incidental take of listed marine species.

Nesting habitat (NSO): For the purposes of this FHCP, nesting habitat is defined as stands 46 years and older, although many NSO pairs have been documented to nest in younger stands.

NSO HCP residual area: Green Diamond ownership within California that is outside the Eligible Plan Area of this FHCP. This area is subject to the 1992 USFWS approved NSO HCP.

Occupied owl site: A perennial owl site occupied by a single owl or a pair of territorial owls during the breeding season.

Old growth: A forest stand with moderate-to-high canopy closure; a multi-layered canopy dominated by large overstory trees; a high incidence of large trees with large, broken tops, and other indications of decadence; numerous large snags; and heavy accumulations of logs and other woody debris on the ground.

Operating conservation program: As defined in 50 CFR §§ 17.3, 222.102, those conservation management activities which are expressly agreed upon and described in a conservation plan or its implementing agreement, if any, and which are to be undertaken for the affected species when implementing an approved conservation plan, including measures to respond to changed circumstances. In this Plan and the IA, the conservation management activities and specific measures (including provisions for changed circumstances, funding, monitoring, reporting, adaptive management, and dispute resolution) as set forth in Section 5.2.

Overstory: That portion of the trees, in a forest of more than one story, forming the upper or uppermost canopy layer.

Owl management units (OMU): Mapped polygons within the IPA of approximately 20,000 to 60,000 acres with similar physiographic and/or biological factors that are large enough to potentially support 10-15 NSO sites. OMU boundaries may be subject to modification in the future, with the concurrence of the Service, to account for future potential refinements in the habitat fitness model or modifications in how Green Diamond validates the habitat fitness model.

Owl site: The area within a five-hundred-foot radius of an owl activity center.

Perennial owl site: An active owl site that has been established for at least two consecutive field seasons. For example, if a site is established in year one as newly colonized, it is not perennial. If the site is again occupied in year two, it is designated as a perennial site.

Plan: The Forest Habitat Conservation Plan prepared by Green Diamond.

Plan area (PA): All commercial timberland acreage where Green Diamond owns fee lands and Harvesting Rights (Green Diamond's ownership), during the period of such ownership within the term of the Permits, subject to the limitations described in the IA, and roads on lands where Green Diamond owns and exercises Road Access Rights within its approved Timber Harvesting Plan (THP) areas in the Eligible Plan Area during the term of the Plan and Permits. This is the geographic area where incidental take will be authorized, the Covered Activities will occur, and the Operating Conservation Program will be implemented. Except where stated otherwise in the Plan, references to lands, commercial timberlands, and Green Diamond's ownership in the context of the Plan Area include lands owned in fee and lands subject to harvesting rights. (All commercial timberlands within the Eligible Plan Area during the term of this FHCP)

Precommercial thinning: Thinning or pruning dense young forest trees to achieve optimum diameter growth and increase the eventual product value of the tree.

Prescribed burning: Introduction of fire under controlled conditions to remove unwanted brush, logging slash, and/or woody debris or specified forest elements.

Project area: the polygon or multiple polygons that form the timber harvest unit boundaries and associated road construction rights-of-way that require timber falling or any other area in which any of the Covered Activities could result in harm or take of a spotted owl.

Red light threshold: A threshold triggered by multiple negative monitoring responses (a series of yellow light triggers) indicating a more serious condition than the yellow light threshold.

Regeneration: The renewal of tree cover by natural or artificial means. Also the young tree crop (seedlings and saplings).

Registered professional forester (RPF): A person who holds a valid license as a professional forester pursuant to Article 3, Section 2, Division 1 of the California Public Resources Code (as in effect on the date of issuance of the Permits).

Residual: A tree that remains standing after some event such as selection harvest.

Riparian management zone (RMZ): A riparian buffer zone on each side of a Class I or Class II watercourse that receives special treatments, to provide temperature control, nutrient inputs, channel stability, sediment control, and LWD recruitment.

Riparian Slope Stability Management Zone (RSMZ): A RMZ below an SMZ or where streamside slopes exceed the minimum Steep Streamside Slope gradients. This is the SSS inner zone.

RMZ inner zone: The first 30 to 70 feet of RMZ area (depending on stream class and side slopes), as measured from the first line of perennial vegetation.

RMZ outer zone: The remaining 45 to 100 feet of RMZ area (depending on stream class and side slopes) or the entire area extending to the edge of the floodplain from the RMZ inner zone edge.

Roosting habitat (NSO): For the purposes of this FHCP, roosting habitat is primarily associated with nesting habitat (stands >45 years), but roosting also occurs in stands 31 years and older.

Rotation: The planned number of years between the regeneration of an even-aged stands and its final cutting at a specified stage.

Rotation age: The age of a stand when it is harvested at the end of a rotation.

Salvage operations: The removal of dead trees or trees damaged or dying because of injurious agents other than competition, to recover economic value that would otherwise be lost.

Second growth: Timber stands established after natural or human-caused removal of the original stand or previous forest growth.

Selection harvest: The removal or trees, individually or in small groups, from the forest.

Set-Asides: Special conservation areas precluded from timber harvesting; established through the NSO HCP.

Shallow-rapid landslide: Rapid landslide event that is confined to the overlying mantle of colluvium and weathered bedrock (in some instances competent bedrock) that commonly leave a bare unvegetated scar after failure. These landslides may include debris slides, debris flows, channel bank failures, and rock falls.

Shovel loader: (Alternatively: heel-boom loader). A stationary piece of log loading equipment located on roads and landings, similar to a construction crane, that uses a crane-like grapple to deck, move, and load logs onto log trucks from one central pivot point.

Silviculture: The specific methods by which a forest stand or area is harvested and regenerated over time to achieve the desired management objectives.

Sink population: A breeding group that does not produce enough offspring to maintain the itself without immigrants from other populations.

Skid trail: An access cut through the woods for skidding logs with ground based equipment. It is not a high enough standard for use by highway vehicles, such as a log truck, and is therefore not a road.

Slash: Woody residue left on the ground after trees are felled, or accumulated there as a result of a storm, fire, or silvicultural treatment.

Slope Stability Management Zone (SMZ): The outer zone of an SSS zone.

Snag: A standing dead tree.

Source population: A breeding group that produces enough offspring to be self-sustaining and that often produces excess young that must disperse to other areas.

Stand: A group of trees that possesses sufficient uniformity in composition, structure, age, spatial arrangement, or condition to distinguish it from adjacent groups.

Stand improvement: An intermediate treatment made to improve the composition, structure, condition, health, and growth of even- or uneven-aged stands.

Steep Streamside Slopes (SSS): Steep slopes located immediately adjacent to a stream channel; defined by: 1) a minimum slope gradient leading to a Class I or Class II watercourse, 2) a maximum distance from a Class I or Class II watercourse, and 3) a reasonable ability for slope failures to deliver sediment to a watercourse.

SSS zone: The area in which default prescriptions for SSS will be applied; consists of an inner zone (the RSMZ) and outer zone (the SMZ).

Stream: A natural watercourse with a well-defined channel with distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil.

Survey area: the area that extends 0.5 mile radius from the perimeter of the project area.

Survey period: the time during which surveys will be counted toward meeting criteria for complete surveys. For the Green Diamond ownership, the survey period is March 1 – August 31.

Sustained yield: The yield of commercial wood that an area can produce continuously at a given intensity of management consistent with required environmental protection and which is professionally planned to achieve over time a balance between growth and removal.

Take: To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 USCA § 1532(19); 50 CFR § 222.102. "Harm" means an act that actually kills or injures fish or wildlife, which act may include significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including for the Service species breeding, feeding or sheltering and for NMFS species breeding, spawning, rearing, migrating, feeding or sheltering. 50 CFR §§ 17.3, 222.102.

Terrestrial deadwood management plan (TDWMP): Habitat retention application guidelines for the Green Diamond ownership prior to this FHCP; foundation for the TREE.

Terrestrial retention of ecosystem elements (TREE): Habitat retention application guidelines for the Green Diamond ownership under this FHCP.

Thinning: A treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality.

Threatened: The classification given to a plant or animal species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Timber felling: Physically cutting a tree from its stump including cutting of the felled tree into predetermined log lengths.

Timber harvesting: All activities necessary to cut, remove, and transport timber products from an area.

Timber harvesting plan (THP): A plan describing a proposed timber harvesting operation pursuant to 14 CCR section 4582 (as in effect on the date of issuance of the Permits).

Tractor logging: Use of a tractor to carry logs from the harvest site to a landing.

Uneven-aged: A stand with trees of three or more distinct age classes, either intimately mixed or in small groups.

Unforeseen Circumstances: Changes in circumstances affecting a species or geographic area covered by the Plan that could not reasonably have been anticipated by Green Diamond and the Services at the time of the Plan's development, and that result in a substantial and adverse change in the status of the covered species." 50 CFR §§ 17.3, 222.102.

Unoccupied owl site: A perennial owl site not occupied by a single owl or a pair of owls during the breeding season. An owl site can be unoccupied without being abandoned (See also Abandoned Owl Site).

Vacant: Under this FHCP this term applies to an NSO site that has been unoccupied for three consecutive breeding seasons. If a vacant site becomes reoccupied during a subsequent breeding season, it becomes an active owl site.

Watercourse: Any well-defined channel with distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil. Watercourse also includes manmade watercourses.

Windthrow: Trees blown down by wind; also called blowdown.

Yarding: (Alternatively: skidding). The movement of forest products from the stump to the landing.

Yellow light threshold: An early warning indicator identifying and rapidly addressing a potential problem. This threshold typically can be exceeded by a single negative monitoring result.

Appendix K. LITERATURE CITED

Andruskiw, M., J.M. Fryxell, I.D. Thompson, and J.A. Baker. 2008. Habitat-mediated variation in predation risk by the American marten. Ecology 89:2273–2280.

Anthony, R.G. and L.S. Andrews. 2004. Summary Report: Winter habitat use by spotted owls on USDI Bureau of Land Management Medford District Lands within the boundaries of the Timbered Rock Fire. Unpublished report, Oregon Cooperative Wildlife Research Unit, Corvallis.

Anthony, R. G., E. D. Forsman, A. B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gerhardt, S. A. Gremel, R. J. Gutiérrez, P. J. Happe, D. R. Herter, J. M. Higley, R. B. Horn, L. L. Irwin, P. J. Loschl, J. A. Reid, and S. G. Sovern. 2006. Status and trends in demography of northern spotted owls, 1985-2003. Wildlife Monographs 163:1-48.

Arthur, S.M., W. B. Krohn, and J. R. Gilbert. 1989. Habitat use and diet of fishers. Journal of Wildlife Management 53:680-688.

Arthur, S. M., T .F. Paragi, and W. B. Krohn. 1993. Dispersal of juvenile fishers in Maine. Journal of Wildlife Management 57:868-874.

Aubry, K.B., M.J. Crites, and S.D. West. 1991. Regional patterns of small mammal abundance and community composition in Oregon and Washington. In: Ruggiero, L.F., K.B. Aubry, A.B. Carey, and M.G. Huff (Tech. Coords.), Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTRPNW- 285.

Aubry, K. B. and D. B. Houston. 1992. Distribution and status of the fisher (Martes pennanti) in Washington. Northwest Naturalist 73:69-79.

Aubry, K. B., and J. C. Lewis. 2003. Extirpation and reintroduction of fishers (Martes pennant) in Oregon: implications for their conservation in the Pacific states. Biological Conservation 114:79-90.

Bailey, L. L., J. A. Reid, E. D. Forsman, and J. D. Nichols. 2009. Modeling co-occurrence of northern spotted owls and barred owls: accounting for detection probability differences. Biological Conservation 142:2983-2989.

Baker, J.M. 1992. Habitat use and spatial organization of pine marten on southern Vancouver Island, British Columbia. Thesis, Simon-Fraser University, Burnaby, British Columbia, Canada.

Beardsley, D., C. Bolsinger, and R. Warbington. 1999. Old-growth forests in the Sierra Nevada: by type in1945 and 1993 and ownership in 1993 (Research Paper PNW-RP-516). Portland, OR: USDA ForestService Pacific Northwest Research Station.

Bellinger, M. R., S. M. Haig, E. D. Forsman, and T. D. Mullins. 2005. Taxonomic relationships among *Phenacomys* voles as inferred by cytochrome *b*. Journal of Mammalogy 86:201-210.

Benson, S. B., and A. E. Borell. 1931. Notes on the life history of the red tree mouse, Phenacomys longicaudus. Journal of Mammalogy 12:226-233.

Berny, P. 2007. Pesticides and the intoxication of wild animals. Journal of Veterinary Pharmacology and Therapeutics 30:93-100.

Beyer, K. M., and R. T. Golightly. 1996. Distribution of Pacific fisher and other forest carnivores in coastal Northwestern California. Unpublished report, Humboldt State University, Arcata, California, USA. Contract No. FG-3156-WM.

Bierregaard, R. O., E. S. Harrold, and M. A. McMillan. 2008. Behavioral conditioning and techniques for trapping barred owls. Journal of Raptor Research 42:210-214.

Bissonette, J.A., D.J. Harrison, C.D. Hargis, and T.G. Chapin. 1997. The influence of spatial scale and scale-sensitive properties on habitat selection by American marten. Pages 368–385 in Bissonette J.A., ed. Wildlife and landscape ecology effects of pattern and scale. Springer, New York.

Blois, J. L. and B. S. Arbogast. 2006. Conservation genetics of the Sonoma tree vole (*Arborimus pomo*) based on mitochondrial and amplified fragment length polymorphism markers. Journal of Mammalogy 87:950-960.

Bond, M.L., R.J. Gutiérrez, A.B. Franklin, W.S. LaHaye, C.A. May, and M.E. Seamans. 2002. Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022–1028.

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management 73:1116-1124.

Brander, R. B., and D. J. Books. 1973. Return of the fisher. Natural History 82:52-57.

Buchanan, J. B., L. L. Irwin, and E. L. McCutchen. 1995. Within stand nest site selection by spotted owls in the eastern Washington Cascades. Journal of Wildlife Management 59:301-310.

Buchanan, J.B. 2004. Managing habitat for dispersing northern spotted owls – are the current management strategies adequate? Wildlife Society Bulletin 32:1333–1345.

Buck, S. G., C. Mullis, A. S. Mossman, I. Show, and C Coolahan. 1994. Habitat use by fishers in adjoining heavily and lightly harvested forest. Pages 368-376 *in* S. W. Buskirk, A. S. Harestad, M. G. Raphael, R. A. Powell, editors. Martens, Sabels, and Fishers: Biology and Conservation. Cornell University Press, Ithica, N.Y., USA.

Bull, E. L., M. G. Henjum, and R. S. Rohweder. 1989. Diet and optimal foraging of great gray owls. Journal of Wildlife Management 53(1):47-50.

Bull, E. L., and T. W. Heater. 2001. Home range and dispersal of the American marten in Northeastern Oregon. Northwestern Naturalist 82:7-11.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edn. Springer, New York.

Buskirk, S.W. and L.L. McDonald. 1989. Analysis of variability in home-range size of the American marten. Journal of Wildlife Management. 53:997–1004.

Buskirk, S.W. and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pages 283-296 in S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, editors. Martens, sables and fishers: biology and conservation. Cornell University Press, Ithaca, NY.

Buskirk, S. W., and L. F. Ruggiero. 1994. Marten. Pages 7-37 in L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. General Technical Report RM-254.

Buskirk, S.W. and W.J. Zielinski. 1997. American marten (Martes americana) ecology and conservation. Pages 17–22 in J.E. Harris and C.V. Ogan, eds. Mesocarnivores of northern California biology, management, and survey techniques. August 12–15, Humboldt State University. The Wildlife Society California North Coast Chapter, Arcata, California.

Buskirk, S.W., and W.J. Zielinski. 2003. Small and mid-sized carnivores. In: Zabel, C.J.; Anthony, R.G., editors. Mammalian community dynamics: Management and conservation in the coniferous forests of western North America. Cambridge, UK: Cambridge University Press: 207-249

Callas, R. L., and P. Figura. 2008. Translocation plan for the reintroduction of fishers (*Martes pennanti*) to lands owned by Sierra Pacific Industries in the northern Sierra Nevada of California. California Department of Fish and Game. 80pp.

Carey, A. B., J. A. Reid, and S. P. Horton. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. Journal of Wildlife Management 54:11-17.

Carey, A. B., S. P. Horton, and B. L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs 62:223-250.

Carey, A. B., and K. C. Peeler. 1995. Spotted owls: resource and space use in mosaic landscapes. Journal of Raptor Research 29:223-239.

Carr, S. M., and S. A. Hicks. 1997. Are there two species of marten in North America? Genetic and evolutionary relationships within *Martes*. In G. Proulx, H. N. Bryant, and P. M. Woodard (editors), Martes: taxonomy, ecology, techniques, and management, Provincial Museum of Alberta, Edmonton, Canada.

Carroll, C., W. J. Zielinski, and R. F. Noss. 1999. Using presence-absence data to build and test spatial habitat models for the fisher in the Klamath Region, U.S.A. Conservation Biology 13: 1344-1359.

Carroll, C. and D.S. Johnson. 2008. The importance of being spatial (and reserved): assessing northern spotted owl habitat relationships with hierarchical Bayesian models. Conservation Biology 22: 1026-1036.

CBD (Center for Biological Diversity), and EPIC (Environmental Protection Information Center). 2010. Petition to list the Humboldt marten (Martes Americana humboldtensis) as threatened or endangered under the Endangered Species Act. 28 March 2010. 47 pp.

CDFG (California Department of Fish and Game). 2008. Evaluation of petition: Request of the Center for Biological Diversity to list the Pacific Fisher (*Martes pennanti*) as threatened or endangered. California Department of Fish and Game, Wildlife Branch, Sacramento, CA.

CDFG (California Department of Fish and Game). 2010. A status review of the fisher (*Martes pennanti*) in California. Report to the California Department of Fish and Game Commission. California Department of Fish and Game 183 pp.

CDFG (California Department of Fish and Game). 2011. Special Animals List. California Department of Fish and Game, Biogeographic Data Branch, 60 pp.

CDFW (California Department of Fish and Wildlife). 2015. A status review of the fisher (*Pekania* [formerly *Martes*] *pennanti*) in California. Report to the California Department of Fish and Game Commission. California Department of Fish and Wildlife 181 pp.

Clark, T. W., E. Anderson, C. Douglas, and M. Strickland. 1987. Martes Americana. Mammalian Species 289. American Society of Mammalogists 8 pp.

Cooperrider, A., R.F. Noss, H.H. Welsh, Jr., C. Carroll, W. J. Zielinski, D. Olson, S.K. Nelson, and B.G. Marcot. 2000. Terrestrial fauna of redwood forests. Pages 119–163 in Noss, R.F, ed. The redwood forest: history, ecology, and conservation of the coast redwoods. Island Press, Covelo, California.

Corn, P.S., Bury, R.B., 1986. Habitat use and terrestrial activity by red tree voles (Arborimous longicaudus) in Oregon. Journal of Mammology 67: 404–406.

Corn, P.S., Bury, R.B., 1991. Small mammal communities in the Oregon Coast Range. In: Ruggiero, L.F., Aubrey, K.B., Carey, A.B., Huff, M.G. (Tech Coords.), wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service, GTRPNW- 285.

Courtney, S. P., J. A. Blakesley, R. E. Bigley, M. L. Cody, J. P. Dumbacher, R. C. Fleisher, A. B. Franklin, J. F. Franklin, R. J. Gutiérrez, J. M. Marzluff, L. Sztukowski. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Crozier, M. L., M. E. Seamans, R. J. Gutiérrez, P. L. Loschl, R. B. Horn, S. G. Sovern, and E. D. Forsman. 2006. Does the presence of barred owls suppress the calling behavior of spotted owls. The Condor. 108:760-769.

Daniel, M. J. 1960. Porcupine quills in viscera of fisher. Journal of Mammalogy 41:133-133.

Davis, F.W., C. Seo, and W.J. Zielinski. 2007. Regional variation in home-range-scale habitat models for fisher (Martes pennanti) in California. Ecological Applications 17(8):2195-2213.

De Vos, A. 1952. Ecology and management of fisher and marten in Ontario. Ontario Department of Lands and Forests; Technical Bulletin, Wildlife Service 1.

Diller, L. V., and D. M. Thome. 1999. Population density of northern spotted owls in managed young-growth forests in coastal northern California. Journal of Raptor Research 33:275-286.

Diller, L. V., J. P. Dumbacher, R. P. Bosch, R. R. Bown, and R. J. Gutierrez. 2014. Removing barred owls from local areas: techniques and feasibility. Wildlife Society Bulletin 3:211-216.

Diller, L. V., K. A. Hamm, D. A. Early, D. W. Lamphear, K. M. Dugger, C. B. Yachulic, C. J. Schwarz, P. C. Carlson, and T. L. McDonald. 2016. Demographic response of northern spotted owls to barred owl removal. The Journal of Wildlife Management 80:691-707.

Douglas, C.W. and M.A. Strickland. 1987. Fisher. Pages 511-530 in M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild Furbearer Management and Conservation in North America. Ontario Ministry of Natural Resources, Toronto.

Drew, R. E., J. G. Hallett, K. B. Aubry, K. W. Cullings, M. Koepfs, and W. J. Zielinski. 2003. Conservation genetics of the fisher (*Martes pennant*) based on mitochondrial DNA sequencing. Molecular Ecology 12:57-62.

Dugger, K. M., F. Wagner, R. G. Anthony, and G. S. Olson. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor 107:863-878.

Dugger, K. M., R. G. Anthony, and E. D. Forsman. 2009. Estimation of norther spotted owl detection probabilities. Updating the USFWS Northern Spotted Owl Survey Protocol. Unpublished report. Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 53 pp.

Dugger, K. M., E. D. Forsman, A. B. Franklin, R. J. Davis, G. C. White, C. J. Schwarz, K. P. Burnham, J. D. Nichols, J. E. Hines, C. B. Yackulic, P. F. Doherty, L. Bailey, D. A. Clark, S. H. Ackers, L. S. Andrews, B. Augustine, B. L. Biswell, J. Blakesley, P. C. Carlson, M. J. Clement, L. V. Diller, E. M. Glenn, A. Green, S. A. Gremel, D. R. Herter, J. M. Higley, J. Hobson, R. B. Horn, K. P. Huyvaert, C. McCafferty, T. McDonald, K. McDonnell, G. S. Olson, J. A. Reid, J. Rockweit, V. Ruiz, J. Saenz, and S. G. Sovern. 2016. The effects of habitat, climate, and barred owls on long-term demography of northern spotted owls. The Condor 118:57-116.

Dunk, J. R., and J. J. Hawely. 2009. Red tree vole habitat suitability modeling: implications for conservation and management. Forest Ecology and Management 258:626-634.

EPIC (Environmental Protection Information Center). 2012. Petition to list the Northern spotted owl as “threatened” or “endangered” under the California Endangered Species Act. 04 September 2012. 35 pp.

EPIC (Environmental Protection Information Center), and CBD (Center for Biological Diversity). 2015. Petition to list the Humboldt marten (*Martes caurina humboldtensis*) as an endangered species under the California Endangered Species Act. 01 June 2015. 39 pp.

Farber, S. L., and A. J. Kroll. 2012. Site occupancy dynamics of northern spotted owls in managed interior Douglas fir forests, California, USA, 1995-2009. The Journal of Wildlife Management 76:1145-1152.

Folliard, L. B. 1993. Nest-site characteristics of northern spotted owls in managed forests of northwest California. M.S. thesis, University of Idaho, Moscow. 106p.

Folliard, L. B., K. P. Reese, and L. V. Diller. 2000. Landscape characteristics of northern spotted owl nest sites in managed forests of northwestern California. Journal of Raptor Research 34:75-84.

Forsman, E.D. 1975. A preliminary investigation of the spotted owl in Oregon. Thesis, Oregon State University, Corvallis.

Forsman, E. D. 1981. Molt of the spotted owl. The Auk 98:735-742.

Forsman, E. D. 1983. Methods and materials for locating and studying spotted owls. USDA Forest Service, General Technical Report PNW-162, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, USA.

Forsman, E. D., E. C. Meslow, and H. M. Wright. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monograph 87:1-64.

Forsman, E. D., I. A. Otto, S. G. Sovern, M. Taylor, D. W. Hays, H. Allen, S. L. Roberts, and D. E. Seaman. 2001. Spatial and temporal variation in diets of spotted owls in Washington. Journal of Raptor Research 35:141-150.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D. E. Seaman. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149:1–35.

Forsman, E. D., R. G. Anthony, E. C. Meslow, and C. J. Zabel. 2004a. Diets and foraging behavior of northern spotted owls in Oregon. Journal of Raptor Research 38:214-230.

Forsman, E. D., R. G. Anthony, and C. J. Zabel. 2004b. Distribution and abundance of red tree voles in Oregon based on occurrence in pellets of northern spotted owls. Northwest Science 78:294-302.

Forsman E.D., J.K. Swingle, and N.R. Hatch. 2009. Behavior of red tree voles (Arborimus longicaudus) based on continuous video monitoring of nests. Northwest Science 83:262–272.

Forsman, E. D., R. G Anthony, K. M. Dugger, E. M. Glenn, A. B. Franklin, G. C. White, C. J. Schwarz, K. P. Burnham, D. R. Anderson, J. D. Nichols, J. E. Hines, J. B. Lint, R. J. Davis, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, S. A. Gremel, D. R. Herter, J. M. Higley, R. B. Horn, J. A. Reid, J. Rockweit, J. Schaberel, T. J. Snetsinger and S. G. Sovern. 2011. Population demography of northern spotted owls. *Studies in Avian Biology* 40:1-106.

Fowler, C. H., and R. T. Golightly. 1994. Fisher and marten survey techniques on the Tahoe National Forest. Final Report. California Department of Fish and Game, Nongame Bird and Mammal Section, Report 94-9. Sacramento, California, 73 pp.

Franklin, J.F., and C.T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Corvallis, OR: Oregon State University Press.

Franklin, A.B. 1992. Population regulation in northern spotted owls: theoretical implications for management. Pages 815–827 in D.R. McCullough and R.H. Barrett, editors. Wildlife 2001: populations. Elsevier Applied Sciences, London, England.

Franklin, A. B., K. P. Burnham, G. C. White, R. G. Anthony, E. D. Forsman, C. Schwartz, J. D. Nichols, and J. Hines. 1999. Range-wide status and trends in northern spotted owl populations. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, and Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Corvallis.

Franklin, A. B., D. R. Anderson, R. J. Gutierrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern Spotted Owl populations in northwestern California. Ecological Monographs 70:539-590.

Freund, J. F. 1961. A bivariate extension of the exponential distribution. The Journal of the American Statistical Association 56:971-976.

Frost, H.C., W.B. Krohn and C.R. Wallace. 1997. Age-specific reproductive characteristics in fishers. Journal of Mammalogy 78(2): 598-612.

Frost, E. J. and R. Sweeney. 2000. Fire regimes, fire history and forest conditions in the Klamath-Siskiyou region: an overview and synthesis of knowledge. World Wildlife Fund, Klamath-Siskiyou Ecoregion Program, Ashland, OR.

Fuller, T. K., E. C. York, S. M. Powell, T. A. Decker, and R. M. DeGraaf. 2001. An evaluation of territory mapping to estimate fisher density. Canadian Journal of Zoology 79:1691-1696.

Gabriel, M. W., L. W. Woods, R. Poppenga, R. A. Sweitzer, C. Thompson, S.M. Matthews, J. M. Higley, S. M. Keller, K. Purcell, R. H. Barrett, G. M. Wengert, B. N. Sacks, and D. L. Clifford. 2012. Anticoagulant rodenticides on our public and community lands: spatial distribution of exposure and poisoning of a rare forest carnivore. PLoS ONE 7:1-15 (e40163).

Gabriel, M. W., L. W. Woods, G. M. Wengert, N. Stephenson, J. M. Higley, C. Thompson, S. M. Matthews, R. A. Sweitzer, K. Purcell, R. H. Barrett, S. M. Keller, P. Gaffney, M. Jones, R. Poppenga, J. E. Foley, R. N. Brown, D. L. Clifford, and B. N. Sacks. 2015. Patterns of natural and human-caused mortality factors of a rare forest carnivore, the fisher (*Pekania pennanti*) in California. PLoS ONE 10:1-19.

Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Effects of the Hatchery Complex Fires on northern spotted owls in the eastern Washington Cascades. Pages 123–129 in J.M. Greenlee, editor. Proceedings of the First Conference on Fire Effects on Rare and Endangered Species and Habitats. International Association of Wildland Fire, Coeur d'Alene, Idaho.

Garza, J. C. and E. G. Williamson. 2001. Detection of reduction in population size using data from microsatellite loci. Molecular Ecology 10:305-318.

Gibilisco, C.J. 1994. Distributional dynamics of modern Martes in North America. Pages 59–70 in S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell, eds. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York, USA. 484 pp.

Gilbert, F.F., and R. Allwine. 1991. Small mammal communities in the Oregon Cascade Range. In: Ruggiero LF, Aubry KB, Carey AB, Huff MH, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. Portland, OR: USDA Forest Service. General Technical Report PNW-GTR-285.

Gilbert, J. H., J. L. Wright, D. J. Lauten, and J. R. Probst. 1997. Den and rest-site characteristics of American marten and fisher in Northern Wisconsin. In G. Proulx, H. N. Bryant, and P. M. Woodard (editors), Martes: taxonomy, ecology, techniques, and management, Provincial Museum of Alberta, Edmonton, Canada.

Gillesberg, A. M., and A. B. Carey. 1991. Arboreal nests of *Phenacomys longicaudus* in Oregon. Journal of Mammology 72:784-787.

Goldman, E. A. 1935. New American mustelids of the genera Martes, Gulo, and Lutra. Proceedings of the Biological Society of Washington 48:175-186.

Golightly, R.T., T.F. Penland, W.J. Zielinski and J.M. Higley. 2006 Fisher diet in the Klamath/North Coast Bioregion. Final Report to U.S. Fish and Wildlife Service and Scotia Pacific. Humboldt State Sponsored Programs Foundation, Arcata, California.

Goodman, D. 1987. The demography of chance extinction. In M. E. Soule (editor), Viable populations for conservation, Cambridge University Press, Cambridge, England.

Green Diamond. 1992. Habitat Conservation Plan for the Northern Spotted Owl on the California Timberlands of Green Diamond Resource Company (formerly Simpson Timber Company). 66 pp.

Green Diamond. 2005. Terrestrial Deadwood Management Plan (TDWMP). 15 pp.

Green Diamond. 2007. Aquatic Habitat Conservation Plan (AHCP). 552 pp.
Green Diamond. 2010. Master Agreement for Timber Operations (MATO). 78 pp.
Green Diamond. 2017. California Timberlands Forest Management Plan. 312 pp.
Green, G.A., L.A. Campbell, and D.C. MacFarlane. 2008. A conservation assessment for fishers (Martes pennanti) in the Sierra Nevada of California. USDA Forest Service, Pacific Southwest Region, Vallejo, California.
Gremel, S. A. 2005. Factors controlling distribution and demography of Northern Spotted Owls in a reserved landscape. M.S. Thesis, University of Washington, Seattle, WA. 56 p.
Grenfell, W. E., and M. Fasenfest. 1979. Winter food habits of fishers, Martes pennanti, in northwestern California. California Fish and Game 65:186-189.
Grinnell, J., and J. Dixon. 1926. Two new races of the pine marten from the Pacific Coast of North America. University of California Publications in Zoology 21:411-417.
Grinnell, J. 1933. Review of the recent mammal fauna of California. University of California Publications in Zoology 40:71-234.
Grinnell, J., J.S. Dixon, and J.M. Linsdale. 1937. Fur-bearing mammals of California. University of California Press. Berkeley, California.
Gutiérrez, R. J., A. B. Franklin, and W. S. LaHaye. 1995. Spotted owl (Strix occidentalis). In The birds of North America, No. 179, A. Poole and F. Gill, eds.
Gutiérrez, R.J. 1996. Biology and distribution of the northern spotted owl. Studies in Avian Biology 17:2–5.
Gutiérrez, R. J., M. Cody, S. Courtney, and D. Kennedy. 2004 Assessment of the potential threat of the northern barred owl. *In* Final Report: scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland OR.
Gutiérrez, R. J., M. Cody, and A. B. Franklin. 2007. The invasion of barred owls and its potential effect on the spotted owl: a conversion conundrum. Biological Invasions 9:181-196.
Hagmeier, E. M. 1956. Distribution of marten and fisher in North America. Canadian Field-Naturalist 70:149-168.
Hagmeier, E. M. 1961. Variation and relationships in North American marten. Canadian Field-Naturalist 75:122-138.
Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. 2 Vols. The Ronald Press, New York. 1162pp.
Hall, E. R. 1981. The mammals of North America, second edition. John Wiley and Sons, New York, New York, USA.
Hamer, T. E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. M.S. thesis, Western Washington University, Bellingham, WA.
Hamer, T. E, E. D. Forsman, A. D. Fuchs, and M. L. Walters. 1994. Hybridization between barred and spotted owls. The Auk 111:487-492.
Hamer, T. E., D. L. Hays, C. M. Senger, and E. D. Forsman. 2001. Diets of northern barred owls and northern spotted owls in an area of sympatry. Journal of Raptor Research 35:221-227.
Hamer, T. E., E. D. Forsman, and E. M. Glenn. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. The Condor 109:750-768.
Hamilton, W. J., III. 1962. Reproductive adaptations of the red tree mouse. Journal of Mammalogy 43:486-504.
Hamlin, R., L. Roberts, G. Schmidt, K. Brubaker and R. Bosch 2010. Species assessment for the Humboldt marten (Martes americana humboldtensis). U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.
Hamm, K. A. 1995. Abundance of dusky-footed woodrats in managed forests of north coastal California. M.S. Thesis, Humboldt State University, Arcata, CA. 46 p.

Hamm, K. A. and L. V. Diller. 2009. Forest management effects on abundance of woodrats in northern California. Northwestern Naturalist 90:97-106.

Hamm, K. A., L. V. Diller, D. W. Lamphear, and D. A. Early. 2012. Ecology and Management of *Martes* on private timberlands in north coastal California. Manuscript in progress.

Heinemeyer, K. S. and J. L. Jones. 1994. Fisher biology and management in the western United States: a literature review and adaptive management strategy. Version 1.1. USDA Forest Service Northern Region and Interagency Forest Carnivore Working Group.

Helley, E. J., and V. C. LaMarche. 1973. Historic flood information for northern California streams from geologic and botanical evidence. United States Geological Survey Professional Paper 485-E:16pp.

Higley, J. M. and S. M. Matthews. 2006. Demographic rates and denning ecology of female Pacific fishers (Martes pennanti) in northwestern California. Preliminary report October 2004 – July 2006. Submitted to U.S. Fish and Wildlife Service Yreka Office, Yreka, CA.

Higley, J. M. and S. Matthews. 2009. Fisher habitat use and population monitoring on the Hoopa Valley Reservation, California. Final Report USFWS TWG U-12-NA-1. Hoopa Valley Tribe. Hoopa, CA.

Higley, J. M. 2015. Barred owl exposure to anticoagulant rodenticides: likely sources of poisons and potential for impacts to northern spotted owls. In M. W. Gabriel (Chair), *Marijuana Cultivation and Its Impacts on Wildlife, Habitats, and the Wildlife Profession*. Symposium preceding the annual meeting of The Wester Section of the Wildlife Society, January 27, 2015, Santa Rosa, CA.

Howell, A.B., 1926. Life history of the red tree mouse Phenacomys longicaudus True. North American Fauna 48: 39–64.

Hughes, K. D. 2005. Habitat associations of dusky-footed woodrats in managed Douglas-fir / hardwood forests or northern California. M.S. Thesis, Humboldt State University, Arcata, CA. 40 p.

Hunter, J. E., R. J. Gutiérrez, and A. B. Franklin. 1995. Habitat configuration around spotted owl sites in northwestern California. Condor 97:684-693.

Jimerson, T.M, E.A. McGee, D.W. Jones, R.J. Svilich, E. Hotalen, G. DeNitto, T. Laurent, J.D. Tenpas, M.E. Smith, K. Hefner-McClelland, J. Mattison. 1996. A field guide to the tanoak and the Douglas-fir plant associations in northwestern California. R5-ECOI-TP-009. USDA Forest Service, Pacific Southwest Region.

Johnson, M. L., and S. B. George. 1991. Species limits within the Arborimus longicaudus species complex (Mammalia: Rodentia) with a description of a new species from California. Contributions in Science 429:1-16.

Johnson, D. H., G. C. White, A. B. Franklin, L. V. Diller, I. Blackburn, D. J. Pierce, G. S. Olson, J. B. Buchanan, J. Thrailkill, B. Woodbridge, and M. Ostwald. 2008. Study design for barred owl removal experiments to evaluate potential effects on northern spotted owls. Report prepared for the U.S. Fish and Wildlife Service, Lacey, Washington, and Yreka, California. Washington Department of Fish and Wildlife, Olympia, Washington. 32p.

Johnson, C.A., J.M. Fryxell, I.D. Tompson, and J.A. Baker. 2009. Mortality risk increases with natal dispersal distance in American martens. Proceedings of the Royal B. Society 276:3361–3367.

Jones, J.L. 1991. Habitat use of fishers in north-central Idaho. Thesis, University of Idaho, Moscow.

Jordan, M. J., R. H. Barrett, and K. L. Purcell. 2011. Camera trapping estimates of density and survival of fishers *Martes pennanti*. Journal of Wildlife Biology 17:266-276.

Kelly, E. G., E. D. Forsman, and R. G. Anthony. 2003. Are barred owls displacing spotted owls? Condor 105:45-53.

Kelly, E. G., and E. D. Forsman. 2004. Recent records of hybridization between barred owls and northern spotted owls. Auk 121:806-810.

Kie, J. G., J. A. Baldwin, and C. J. Evans. 1996. CALHOME: A program for estimating animal home ranges. Wildlife Society Bulletin 24:342-344.

Kilpatrick, H. J. and P. W. Rego. 1994. Influence of season, sex and site availability on fisher (Martes pennanti) rest-site selection in the central hardwood forest. Canadian Journal of Zoology 72:1416-1419.

Kirk, T. A., and W. J. Zielinski. 2009. Developing and testing a landscape habitat suitability model for the American marten (*Martes americana*) in the Cascades mountains of California. Landscape Ecology 24:759-773.

Klug, R.R. 1997. Occurrence of Pacific fisher in the Redwood Zone of northern California and the habitat attributes associated with their detections. Thesis, Humboldt State University, Arcata, California.

Krohn, W.B., W. J. Zielinski, and R. B. Boone. 1997. Relations among fishers, snow and martens in California: results from small-scale spatial comparisons. In: Proulx, G., H. N. Bryant, and P. M. Woodard (eds). Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmington, Alberta, Canada.

Lamberson, R. L., B. R. Noon, C. Voss, and K. S. McKelvey. 1994. Reserve design for territorieal species: the effects of patch size and spacing on the viability of the northern spotted owl. Conservatiion Biology 8:185-195.

Laudenslayer, W. F., Jr. 1985. Candidate old-growth on National Forest System administered lands in California. USDA Forest Service Pacific Southwest Region Report, San Francisco 17 p.

Lehmkuhl, J. F., and M. G. Raphael. 1993. Habitat pattern around northern spotted owl locations on the Olympic Peninsula, Washington. Journal of Wildlife Management 57:302-315.

Leskiw, T. and R. J. Gutierrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29:225-226.

Lewis, J.C. and D.W. Stinson. 1998. Washington State status report for the fisher. Washington Dept. Fish and Wildlife, Olympia, WA. 64 pages.

Lewis, J.C., P.J. Happe, K.J. Jenkins, and D.J. Manson. 2009. Olympic fisher reintroduction project: 2009 progress report. Unpublished report: Washington Department of Fish and Wildlife, Olympic National Park, and US Geological Survey. Olympia Washington.

Livezey, K.B. 2005. Iverson (2004) on spotted owls and barred owls: comments on methods and conclusion. Journal of Raptor Research 39:102–103.

Livezey, K.B. 2007. Barred Owl habitat and prey: a review and synthesis of the literature. Journal of Raptor Research 41:177–201.

Livezey, K.B. and T.L. Fleming. 2007. Effects of barred owls on spotted owls: the need for more than incidental detections and correlational analyses. Journal of Raptor Research 41:319–325.

Livezey, K.B., M.F. Elderkin, P.A. Cott, J. Hobbs, and J.P. Hudson. 2008. Barred owls eating worms and slugs: the advantage in not being picky eaters. Northwestern Naturalist. 89:185-190.

Livezey, K.B. 2009a. Range expansion of Barred Owls, part I: chronology and distribution. American Midland Naturalist 161:49–56.

Livezey, K.B. 2009b. Range expansion of Barred Owls, part II: facilitating ecological changes. American Midland Naturalist 161:323–349.

Livezey, K.B. 2010. Killing barred owls to help spotted owls I: a global perspective. Northwestern Naturalist 91:107-133.

Long, R. A, T. M. Donovan, P. Mackay, W. J. Zielinski, and J. S. Buzas. 2007. Comparing scat detection dogs, cameras, and hair snares for surveying carnivores. The Journal of Wildlife Management 71:2018-2025.

Long, R. A, T. M. Donovan, P. MacKay, W. J. Zielinski, and J. S. Buzas. 2010. Predicting carnivore occurrence with noninvasive surveys and occupancy modeling. The Journal of Landscape Ecology 26:327-340.

Long, R. A. and P. MacKay. 2012. Noninvasive methods for surveying martens, sables and fishers. Pages 320-342 *in* S. W. Buskirk, A. S. Harestad, M. G. Raphael, R. A. Powell, editors. Martens, Sables, and Fishers: Biology and Conservation. Cornell University Press, Ithica, N.Y., USA.

Luikart, G., W. B. Sherwin, B. M. Steele, and F. W. Allendorf. 1998. Usefulness of molecular markers for detecting population bottlenecks via monitoring genetic change. Molecular Ecology 7:963-974.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. A. Bailey, and J. E. Hines. 2006. Occupancy modeling and estimation. Elsevier, San Diego, California, USA.

Martin, S. K. 1994. Feeding ecology of American martens and fishers. Pages 297-315 *in* S. W. Buskirk, A. S. Harestad, M. G. Raphael, R. A. Powell, editors. Martens, Sabels, and Fishers: Biology and Conservation. Cornell University Press, Ithica, N.Y., USA.

Maser, C.O. 1966. Life histories and ecology of Phenacomys albipes, Phenacomys longicaudus, Phenacomys silvicola. Thesis, Oregon State University, Corvallis.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. Natural history of Oregon coast mammals. USDA Forest Service General Technical Report PNW-GTR-133. 496p.

Mazur, K. M., and P. C. James. 2000. Barred owl (Strix varia). A. Poole and F. Gill, editors. The Birds of North America. no. 508. The Birds of North America, Inc., Philadelphia, Pennsylvania, USA.

Mead, R.A. 1994. Reproduction in Martes, in S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell (Eds.) Martens, sables and fishers: biology and conservation. Ithaca, N.Y. Cornell University Press.

Meyer, J.S., L.L. Irwin, and M.S. Boyce. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. Wildlife Monographs No. 139.

Meiselman, N., and A. T. Doyle. 1996. Habitat and microhabitat use by the red tree vole (Phenacomys longicaudus). American Midland Naturalist 135:33-42.

Miles. S. R., and C. B. Goudey. 1997. Ecological subregions of California. USDA General Technical Report R5-EM-TP-005.

Miller, G.S., S.K. Nelson, and W.C. Wright. 1985. Two-year-old female spotted owl breeds successfully. Western Birds 16:69–73.

Miller, G.S. 1989. Dispersal of juvenile spotted owls in western Oregon. Thesis, Oregon State University, Corvallis.

Miller, G. S., R. J. Small, and E. C. Meslow. 1997. Habitat selection by spotted owls during natal dispersal in Western Oregon. Journal of Wildlife Management 61:140-150.

Moen, C. A., A. B. Franklin, and R. J. Gutierrez. 1991. Age determination of subadult northern spotted owls in Northwest California. Wildlife Society Bulletin. 19:4489-493.

Murray, M. A. 1995. Biochemical systematics of the genus Arborimus. Thesis, Humboldt State University, Arcata, California.

Nichols, J. D., J. E. Hines, D. I. Mackenzie, M. E. Seamans, and R. J. Gutierrez. 2007. Occupancy estimation and modeling with multiple states and state uncertainty. Ecology 88:1395-1400.

Nichols, J. D., L. L. Bailey, A. F. O'Connell Jr., N. W. Talancy, E. H. Campbell Grant, A. T. Gilbert, E. M. Annand, T. P. Husband, and J. E. Hines. 2008. Multi-scale occupancy estimation and modelling using multiple detection methods. Journal of Applied Ecology 45:1321-1329.

Nyakatura, K., and O.R.P. Bininda-Emonds. 2012. Updating the evolutionary history of Carnivora (Mammalia): a new species-level supertree complete with divergence time estimates. BMC Biology 10:12.

ODFW (Oregon Department of Fish and Wildlife). 2008. Sensitive Species List, 13 pp.

Olson, G. S., E. M. Glenn, R. G. Anthony, E. D. Forsman, J. A. Reid, P. J. Loschl, and W. J. Ripple. 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039-1053.

Olson, G. S., R. G. Anthony, E. D. Forsman, S. H. Ackers, P. J. Loschl, J. A. Reid, K. M. Dugger, E. M. Glenn, and W. J. Ripple. 2005. Modeling of site occupancy dynamics for northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918-932.

Paragi, T.F., S.M. Arthur, and W.B. Krohn. 1996. Importance of tree cavities as natal dens for fishers. Northern Journal of Applied Forestry 13:79-83.

Pearson, R. R., and K. B. Livezey. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265-275.

Phillips, D.M. 1994. Social and spatial characteristics and dispersal of marten in a forest preserve and industrial forest. Thesis, University of Maine, Orono.

Pollock, K. H. 1982. A capture-recapture design robust to unequal probability of capture. The Journal of Wildlife Management 46:757-760.

Poole, K.G, A.D. Porter, A. de Vries, C. Maundrell, S.D. Grindal, and C.C. St. Clair. 2004. Suitability of a young deciduous-dominated forest for American marten and the effects of forest removal. Canadian Journal of Zoology 82:423-435.

Powell, R.A. 1993. The fisher: life history, ecology and behavior. Second edition. University of Minnesota Press, Minneapolis, Minnesota, USA.

Powell, R.A. and W.J. Zielinksi. 1994. Fisher. Pages 38-73 in L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski, eds. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, wolverine in the western United States. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. General Technical Report RM-254.

Powell, R. A., S. W. Buskirk, and W. J. Zielinski. 2003. Fisher and marten. Pp. 634-649 in G. A. Feldhamer, B.C. Thompson, and J. A. Chapman, eds. Wild Mammals of North America: Biology, management, and conservation. John Hopkins University Press, Baltimore, MD.

Powell, R. A. 2010. Ecological studies of fishers (Martes pennant) on managed landscapes in Northern California: working draft document located online at http://ucanr.org/sites/UCCE-Plumas-Sierra/files/61034.rtf

Primack, R.B. 1993. Essentials of Conservation Biology. Sinauer Associates Inc., Sunderland, Massachusetts.

Purcell, K. L., A. K. Mazzoni, S. R. Mori, and B. B. Boroski. 2009. Resting structures and resting habitat of fishers in the southern Sierra Nevada, California. Forest Ecology and Management 258:2696-2706.

Ramsey, D. S. L., P. A. Caley, and A. Robley. 2015. Estimating population density from presence-absence data using a spatially explicit model. The Journal of Wildlife Management 79:491-499.

Raphael, M. G. 1988. Long-term trends in abundance of amphibians, reptiles, and mammals in douglas-fir forests of northwestern California. Pages 23-31 *in* Szaro, R. C., K. E. Severson, and D. R. Patton (technical coordinators). Management of Amphibians, reptiles, and small mammals in North America: July 19-21, 1998, Flagstaff, Arizona. USDA Forest Service General Technical Report RM-166.

Raphael, M. G. and L. C. Jones. 1997. Characteristics of resting and denning sites of American martens in Central Oregon and Western Washington. In: Proulx, G., H. N. Bryant, and P. M. Woodard (eds). Martes: taxonomy, ecology, techniques, and management. Provincial Museum of Alberta, Edmington, Alberta, Canada.

Ripple, W. J., D. H. Johnson, K. T. Hershey, and E. C. Meslow. 1991. Old-growth and mature forests near spotted owl nests in western Oregon. Journal of Wildlife Management 55:316-318.

Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777-790.

Ruggiero, L.F., D.E. Pearson, S.E. Henry. 1998. Characteristics of American marten den sites in Wyoming. Journal of Wildlife Management 62:663–673.

Sakai, H. F. and B. R. Noon. 1993. Dusky-footed woodrat abundance in different-aged forests in northwestern California. Journal of Wildlife Management 57(2):373-382.

Sato, J.J., M. Wolsan, F.J. Prevosti, G. D'Elia, C. Begg, K. Begg, T. Hosoda, K.L. Campbell, and H. Suzuki. 2012. Evolutionary and biogeographic history of weasel-like carnivorans (Musteloidea). Molecular Phylogenetics and Evolution 63:745-757.

Sawyer, J.O., S.C. Silett, W.J. Libby, T.E. Dawson, J.H. Popenoe, D.L. Largent, R. Van Pelt, S.D. Veirs Jr., R.F. Noss, D.A. Thornburgh, and P.D. Tredici. 2000c. Redwood trees, communities, and ecosystems: a closer look. Pages 81–118 in Noss, R.F, ed. The redwood forest: history, ecology, and conservation of the coast redwoods. Island Press, Covelo, California.

Scheffer, V. B. 1938. Notes on wolverine and fisher in the state of Washington. Murrelet 19:8-10.

Schempf, P. F. and M. White. 1977. Status of six furbearer populations in the mountains of Northern California. Berkeley (CA): USDA Forest Service, Pacific Southwest Region.

Seglund, A.E. 1995. The use of resting sites by the Pacific fisher. Thesis, Humboldt State University, Arcata, California.

Self, S. and R. Callas. 2006. Pacific Fisher Natal and Maternal Den Study: Progress Report No. 1. Redding: Sierra Pacific Industries and California Department of Fish and Game.

Shaffer, M. L. and F. B. Samson. 1985. Population size and extinction: A note on determining critical population sizes. The American Naturalist 125:144-152.

Shaffer, M. L. 1987. Minimum viable populations: coping with uncertainty. In M. E. Soule editor, Viable Populations for Conservation. Cambridge University Press, Cambridge, pp. 69-86.

Sisco, C.L. 1990. Seasonal home range and habitat ecology of spotted owls in northwestern California. Thesis, Humboldt State University, Arcata, California.

Skinner, C. N., and A. H. Taylor. 2006. Southern Cascade bioregion. Pages 195-224 *in* N. S. Sugihar, J. W. van Wagtendonk, K. E. Shaffer, J. Fites-Kaufman, and A. E. Thode, editors. Fire in California's ecosystems, University of California Press: Berkeley, CA.

Skinner, C. N., A. H. Taylor, and J. K. Agee. 2006. Klamath Mountains Bioregion. Pages 170-194 *in* N. G. Sugihara, J. W. van Wagtendonk, J. Fites-Kaugmann, K. E. Shaffer, and A. E. Thode, editors. Fire in California's ecosystems, University of California Press, Berkely, CA.

Slatkin, M. 1985. Rare alleles as indicators of gene flow. Evolution 39:53-65.

Slauson, K.M. 2003. Habitat selection by a remnant population of American martens in coastal Northwestern California. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Slauson, K.M., Zielinski, W.J. and G.W. Holm. 2003. Distribution and habitat associations of the Humboldt marten (Martes americana humboldtensis), and Pacific fisher (Martes pennanti pacifica) in Redwood National and State Parks: A report to Save-the-

Redwoods League. USDA Pacific Southwest Research Station, Redwood Sciences Laboratory. Arcata, CA. 29 pp.

Slauson, K.M. and W.J. Zielinski. 2004. Conservation status of American martens and fishers in the Klamath-Siskiyou bioregion. Pages 60–70 in Merganther K, J. Williams, and E. Jules, 31 eds. Proceedings of the 2nd conference on Klamath-Siskiyou ecology, Cave Junction, Oregon.

Slauson, K.M. and W.J. Zielinski. 2007a. The relationship between the understory shrub component of coastal forests and the conservation of forest carnivores. Pages 241–244 in R.B. Standiford, G.A. Giusti, Y. Valachovic, W.J. Zielinski, M.J. Furniss, eds. Proceedings of the redwood region forest science symposium: what does the future hold? Gen Tech Rep PSW-GTR-194, Pacific Southwest Research Station, Forest Service, USDA, Albany, California.

Slauson, K.M. and W.J. Zielinski. 2007b. Strategic surveys for Martes populations in northwestern California: Mendocino National Forest, Final Report. Unpublished report dated February 2007. USDA FS, PSW, Redwood Sciences Laboratory, Arcata, California.

Slauson, K. M., W. J. Zielinski, and J. P. Hayes. 2007. Habitat selection by American martens in coastal California. The Journal of Wildlife Management 71:458-468.

Slauson, K.M. and W.J. Zielinski. 2009. Characteristics of summer and fall diurnal resting habitat used by American martens in coastal northwestern California. Northwest Science 83(1):35–45.

Slauson, K.M., J.A. Baldwin, W.J. Zielinski, and T.A. Kirk. 2009. Status and estimated size of the only remnant population of the Humboldt subspecies of the American marten (Martes americana humboldtensis) in northwestern California, Final report. Unpublished report dated November 25, 2009. USDA FS, PSW, Redwood Sciences Laboratory, Arcata, California.

Slauson, K.M. and W.J. Zielinski. 2010. Carnivore use of forest roads in the redwood region of northwestern California. Pages 77–78 in The Western Section of The Wildlife Society, Annual conference program and abstracts, Fostering resilient wildlife populations. January 26–29, Visalia, California.

Slauson, K. M., J. M. Higley, and S. M. Matthews. 2011. Fisher (*Martes pennant*) conservation on the Hoopa Valley Reservation California: fall-winter diet of fishers on the Hoopa Valley Indian Reservation. Unpublished report to Humboldt County Fish and Game Advisory Commission No. 2008-2 15 pages.

Solis, D. M., Jr., and R. J. Gutiérrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92:739-748.

Sovern, S. G., E. D. Forsman, B. L. Biswell, D. N. Rolph, and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200-202.

Spencer, W.D. 1987. Seasonal rest-site preferences of pine martens in the northern Sierra Nevada. Journal of Wildlife Management 51(3):616–621.

Spencer, W. D., H. L. Rustigian, R. M. Scheller, A. Syphard, J. Strittholt, and B. Ward. 2008. Baseline evaluation of fisher habitat and population status, and effects of fires and fuels management on fishers in the southern Sierra Nevada. Unpublished report prepared for USDA Forest Service, Pacific Southwest Region, 133 pp.

Steger, G. N., L. R. Werner, and T. E. Munton. 2006. First documented record of the barred owl in the southern Sierra Nevada. Western Birds 37:106-109.

Stone, K. D., R. W. Flynn, and J. A. Cook. 2002. Post-glacial colonization of northwestern North America by the forest-associated American marten (*Martes americana*, mammalia: carnivore: mustelidae). Molecular Ecology 11:2049-2063.

Storfer, A., J. M. Eastman, and S. F. Spear. 2009. Modern Molecular Methods for Amphibian Conservation. BioScience 59: 559-571.

Strickland, M.A., C.W. Douglas, M. Novak, and N.P. Hunziger. 1982. Marten. Pages 599–612 in Chapman, J.A. and G.A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. Johns Hopkins University Press, Baltimore, Maryland.

Strickland, M.A. and C.W. Douglas. 1987. Marten. Pages 530–546 in Novak, M., J.A. Baker, and M.E. Obbard, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay, Ontario.

Strickland, M.A. 1994. Harvest management of fishers and martens. Pages 149–164 in Buskirk, S.W., A.S. Harestad, M.G. Raphael, eds. Martens, sables, and fishers: biology and conservation. Cornell University Press, Ithaca, New York. 484 pp.

Stuart, J. D., and S. L. Stephens. 2006. North Coast Bioregion. Pages 147-169 *in* N. G. Sugihara, J. W. van Wagtendonk, J. Fites-Kaugmann, K. E. Shaffer, and A. E. Thode, editors. Fire in California's ecosystems, University of California Press, Berkely, CA.

Swingle, J. K. 2005. Daily activity patterns, survival, and movements of red tree voles (*Arborimus longicaudus*) in Western Oregon. M. S. Thesis, Oregon State University, Corvallis, OR. 135pp.

Swingle, J.K., and E.D. Forsman. 2009. Home range areas and activity patterns of red tree voles (Arborimus longicaudus). Northwest Science 83:273-286.

Taylor, W.P., 1915. Description of a new subgenus (Arborimus) of Phenacomys, with a contribution to knowledge of the habits and distribution of Phenacomys longicaudus. Proceedings of the California Academy of Sciences 5: 111–161.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. A report by the Interagency Scientific Committee to address the conservation of the northern spotted owl. USDA, Forest Service, and U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Portland, OR.

Thomas, J.W., M.G. Raphael, R.G. Anthony, E.D. Forsman, A.G. Gunderson, R.S. Holthausen, B.G. Marcot, G.H. Reeves, J.R. Sedell, and D.M. Solis. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. U.S. Forest Service, Portland, Oregon.

Thompson, J.L. 2008. Density of fisher on managed timberlands in north coastal California. Thesis, Humboldt State University, Arcata, California.

Thompson, I.D. and P.W. Colgan. 1987. Numerical responses of martens to a food shortage in north central Ontario. Journal of Wildlife Management 51:824-835.

Thompson, J. L., and L. V. Diller. 2002. Relative abundance, nest site characteristics, and nest dynamics of Sonoma tree voles on managed timberlands in coastal northwest California. Northwest Naturalist 83:91-100.

Truex, R.L., W.J. Zielinski, R.T. Golightly, R.H. Barrett, and S.M. Wisely. 1998. A meta-analysis of regional variation in fisher morphology, demography, and habitat ecology in California. Draft report submitted to California Department of Fish and Game, Wildlife Management Division, Nongame Bird and Mammal Section.

Twining, H. and A. Hensley. 1947. The status of pine martens in California. California Fish and Game 33(3):133–137.

USFWS (U.S. Fish and Wildlife Service). 1983a. Endangered and threatened species listing and recovery priority guidelines. Federal Register 48:43098–43105.

USFWS (U.S. Fish and Wildlife Service). 1983b. Endangered and threatened species listing and recovery priority guidelines: correction. Federal Register 48:51985.

USFWS (U.S. Fish and Wildlife Service). 1989. The northern spotted owl; a status review supplement. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1990a. The 1990 status review: northern spotted owl: Strix occidentalis caurina. U.S. Fish and Wildlife Service, Portland, Oregon. 95 pp.

USFWS (U.S. Fish and Wildlife Service). 1990b. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl. Federal Register 55:26114–26194.

USFWS (U.S. Fish and Wildlife Service). 1992a. Draft final recovery plan for the northern spotted owl. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1992b. Final rule for the designation of critical habitat for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. 43 pp.

USFWS (U.S. Fish and Wildlife Service). 2004a. Northern spotted owl: Five Year Review Summary and Evaluation. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2004b. Endangered and threatened wildlife and plants; 60-day finding on a petition to list the West Coast Distinct Population Segment of the fisher. Federal Register 69: 18769-18792.

USFWS (U.S. Fish and Wildlife Service). 2008a. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. xii + 142 pp.

USFWS (U.S. Fish and Wildlife Service). 2008b. Final rule for the revised designation of critical habitat for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. 197 pp.

USFWS (U.S. Fish and Wildlife Service). 2008c. Endangered and threatened wildlife and plants; 90-day finding on a petition to list the dusky tree vole (*Arborimus longicaudus silvicola*) as threatened or endangered. Federal Register 73: 63919-63926

USFWS (U.S. Fish and Wildlife Service). 2009. Endangered and threatened wildlife and plants; 90-day finding on a petition to list the Fisher (*Martes Pennanti*) as a distinct population segment. Federal Register 74: 57804-57878.

USFWS (U.S. Fish and Wildlife Service). 2011a. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. xii + 142 pp.

USFWS (U.S. Fish and Wildlife Service). 2011b. Northern Spotted Owl Survey Protocol. U.S. Fish and Wildlife Service, Sacramento, California. 38 pp.

USFWS (U.S. Fish and Wildlife Service). 2012a. Final rule for the revised designation of critical habitat for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. 193 pp.

USFWS (U.S. Fish and Wildlife Service). 2012b. Endangered and threatened wildlife and plants; 90-day finding on a petition to list the Humboldt marten as endangered or threatened. Federal Register 77:1900-1908.

USFWS (U.S. Fish and Wildlife Service). 2013. Final environmental impact statement for experimental removal of barred owls to benefit threatened northern spotted owls. U.S. Fish and Wildlife Service, Portland, Oregon. 505 pp.

USFWS (U.S. Fish and Wildlife Service). 2014a. Draft Species Report for Fisher (Pekania pennant), West Coast Population. U.S. Fish and Wildlife Service, 243pp.

USFWS (U.S. Fish and Wildlife Service). 2014b. Endangered and threatened wildlife and plants; 12-month finding on a petition to list the Humboldt marten as endangered or threatened. Federal Register 79:35509-35511.

USFWS (U.S. Fish and Wildlife Service). 2015. Endangered and threatened wildlife and plants; 12-month finding on a petition to list the Humboldt marten as endangered or threatened. Federal Register 80:18741-18772.

USFWS (U.S. Fish and Wildlife Service). 2016a. Endangered and threatened wildlife and plantsl; withdrawal of the proposed rule to list the West Coast Distinct Population Segment of fisher. Federal Register 81:22710-22808.

USFWS (U.S. Fish and Wildlife Service). 2016b. Habitat conservation planning and incidental take permit processing handbook. 409 pp.

Van Lanen, N. J., A. B. Franklin, K. P. Huyvaert, R. F. Reiser II, and P. Carson. 2011. Who hits and hoots at whom? Potential for interference competition between barred and northern spotted owls. Biological Conservation 144:2194-2201.

Verts, B.J. and L.N. Carraway. 1998. Land mammals of Oregon. University of California Press. Berkeley, California.

Ward, J. P., Jr., R. J. Gutiérrez, and B. R. Noon. 1998. Habitat selection by northern spotted owls: The consequences of prey selection and distribution. Condor 100:79-92.

Weir, R.D. 1995. Diet, spatial organization, and habitat relationships of fishers in south-central British Columbia. Thesis, Simon Fraser University, Burnaby, British Columbia.

Weir, R.D. and A.S. Harestad. 2003. Scale-dependent habitat selectivity by fishers in south-central British Columbia. Journal of Wildlife Management 67: 73-82.

Weir, R. D., A. S. Harestad, and R. C. Wright. 2005. Winter diet of fishers in British Columbia. Northwestern Naturalist 86:12-19.

Wilbert, C. J. 1992. Spatial scale and seasonality of habitat selection by martens in southeastern Wyoming. Thesis, University of Wyoming, Laramie.

Wiens, J. D., R. G. Anthony, and E. D. Forsman. 2011. Barred owl occupancy surveys within the range of the northern spotted owl. The Journal of Wildlife Management 75:531-538.

Wiens, J. D., R. G. Anthony, and E. D. Forsman. 2014. Competitive interactions and resource partitioning between northern spotted owls and barred owls in western Oregon. Wildlife Monographs 185:1-50.

Wisely, S. M., S. W. Buskirk, G. A. Russell, K. B. Aubry, and W. J. Zielinski. 2004. Genetic diversity and structure of the fisher (*Martes pennant*) in a peninsular and peripheral metapopulation. Journal of Mammalogy. 85:640-648.

Wright, P. L. and M.W. Coulter. 1967. Reproduction and growth in Maine fishers. Journal of Wildlife Management 31(1):70-87.

Wright, S. 1930. Evolution in Mendelian population genetics. Genetics 16:97-158.

Yaeger, J. S. 2005. Habitat at fisher resting sites in the Klamath Province of northern California. Thesis, Humboldt State University, Arcata, California

Zabel, C. J., K. McKelvey, and J. P. Ward, Jr. 1995. Influence of primary prey on home range size and habitat use patterns of spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433-439.

Zabel, C. J., J.R. Dunk, H.B. Stauffer, L.M. Roberts, B.S. Mulder, and A. Wright. 2003. Northern spotted owl habitat models for research and management application in California (USA). Ecological Applications 13:1027–1040.

Zielinski, W.J., G. A. Schmidt, and K. N. Schmidt. 1995. Six rivers National Forest fisher study: progress report II. U.S. Forest Service, Pacific Southwest Research Station, Albany, California.

Zielinski, W. J., and R. T. Golightly. 1996. The status of marten in redwoods: is the Humboldt marten extinct? In LeBlanc, J., editor. Conference on coast redwood forest ecology and management, 18-20 June, 1996, Humboldt State University, Arcata, CA. Pages 115-119.

Zielinski, W.J., C. R. Carroll, and K. M. Slauson. 1998. Coast range carnivore surveys in California and Oregon: American marten results. U.S. Forest Service, Pacific Southwest Research Station, Arcata, California, 7 pp.

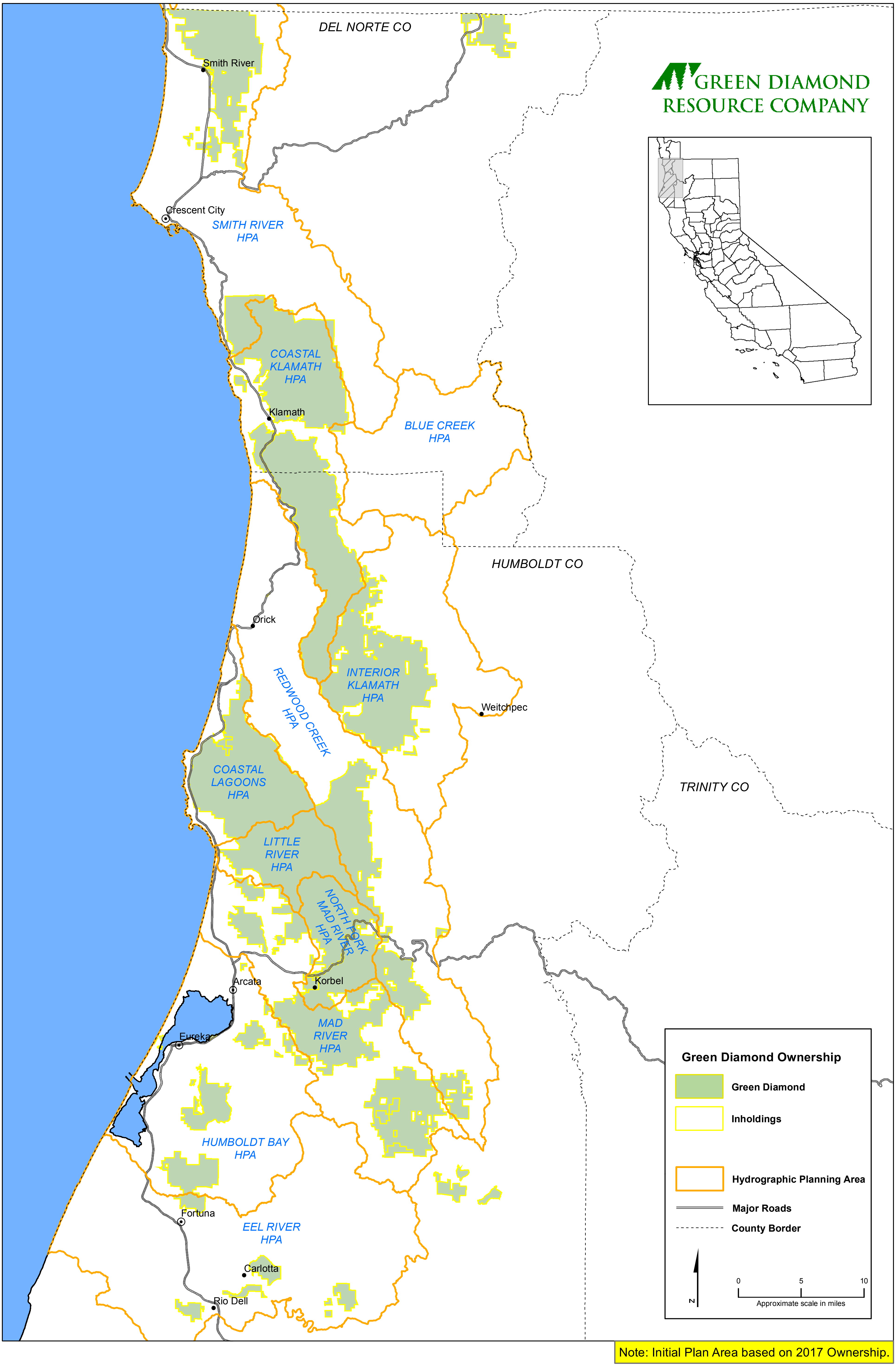
Zielinski, W. J., N. P. Duncan, E. C. Farmer, R. L. Truex, A. P. Clevenger, and R. H. Barrett. 1999. Diet of fishers (*Martes pennant*) at the southernmost extent of their range. Journal of Mammalogy 80:961-971.

Zielinski, W.J., K.M. Slauson, C.R. Carroll, C.J. Kent, and D.G. Kudrna. 2001. Status of American martens in coastal forests of the Pacific States. Journal of Mammalogy 82(2):478–490.

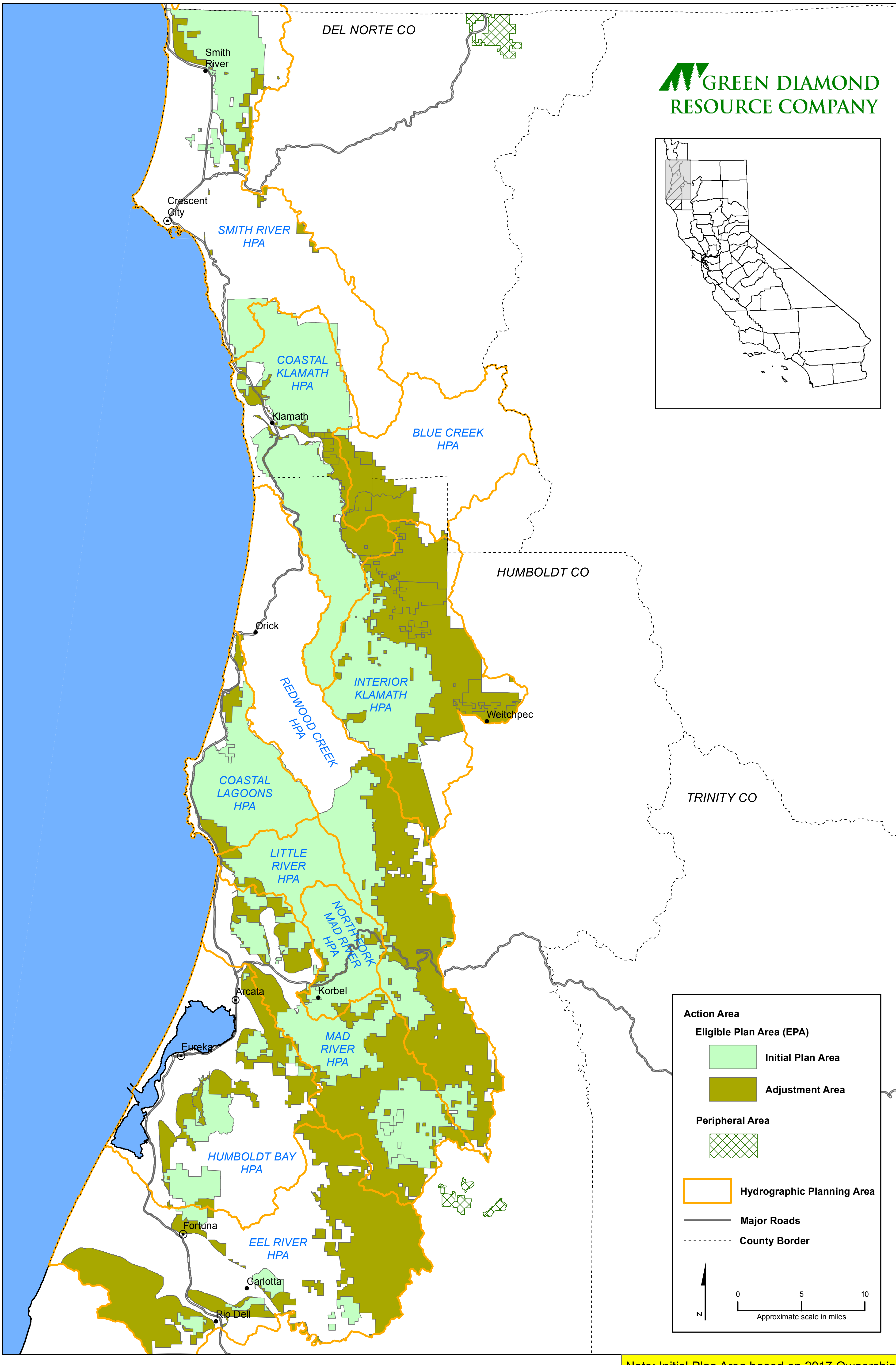
Zielinski, W. J., and N. P. Duncan. 2004. Diets of sympatric populations of American martens (*Martes Americana*) and fishers (*Martes pennant*) in California. Journal of Mammalogy 85:470-477.

Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004a. Resting habitat selection by fishers in California. Journal of Wildlife Management. 68(3):475-492.

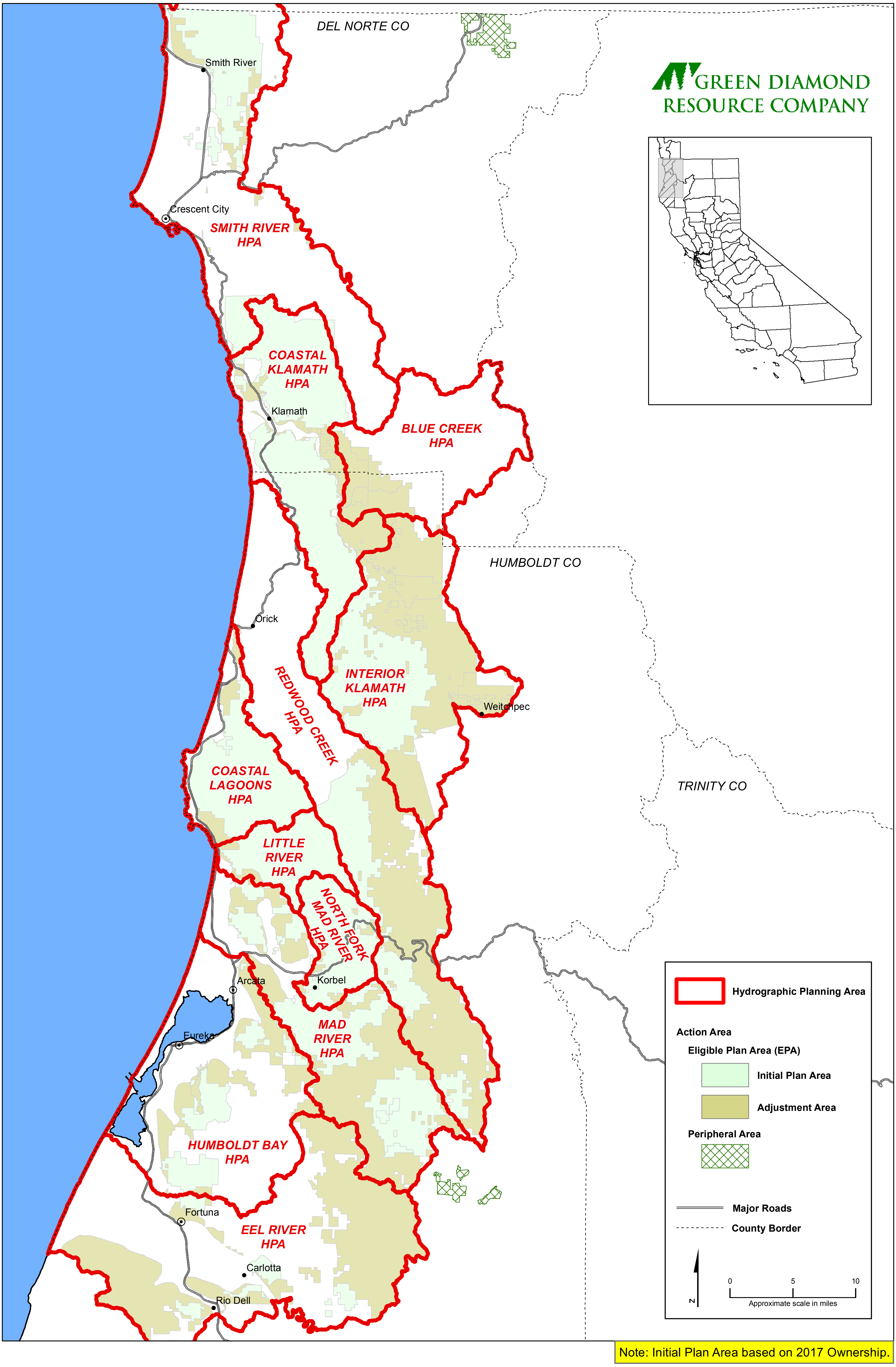
Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004b. Home range characteristics of fishers in California. Journal of Mammalogy, 85(4):649–657.



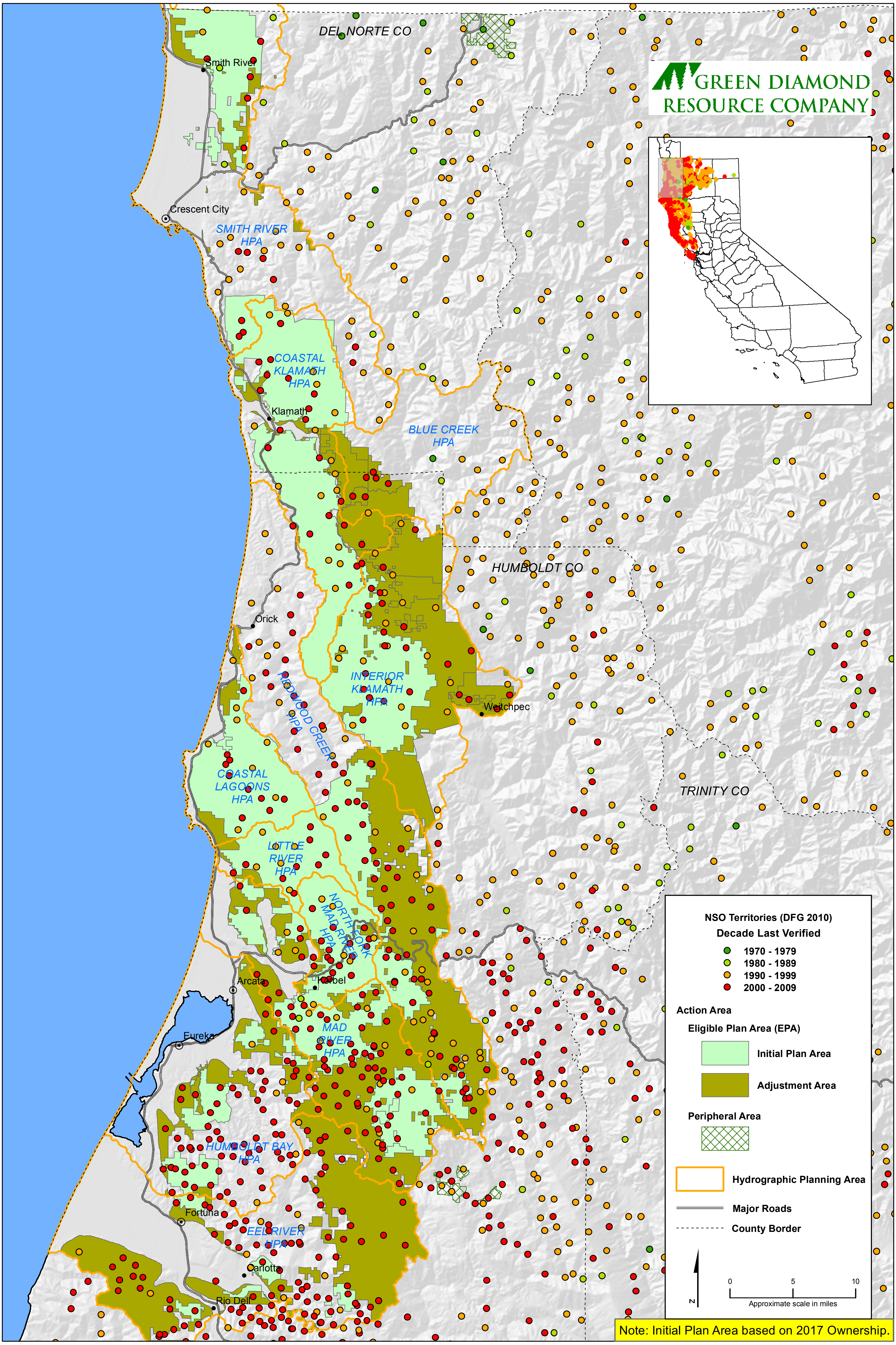
Map 1-1. Ownership and Hydrographic Planning Areas in California



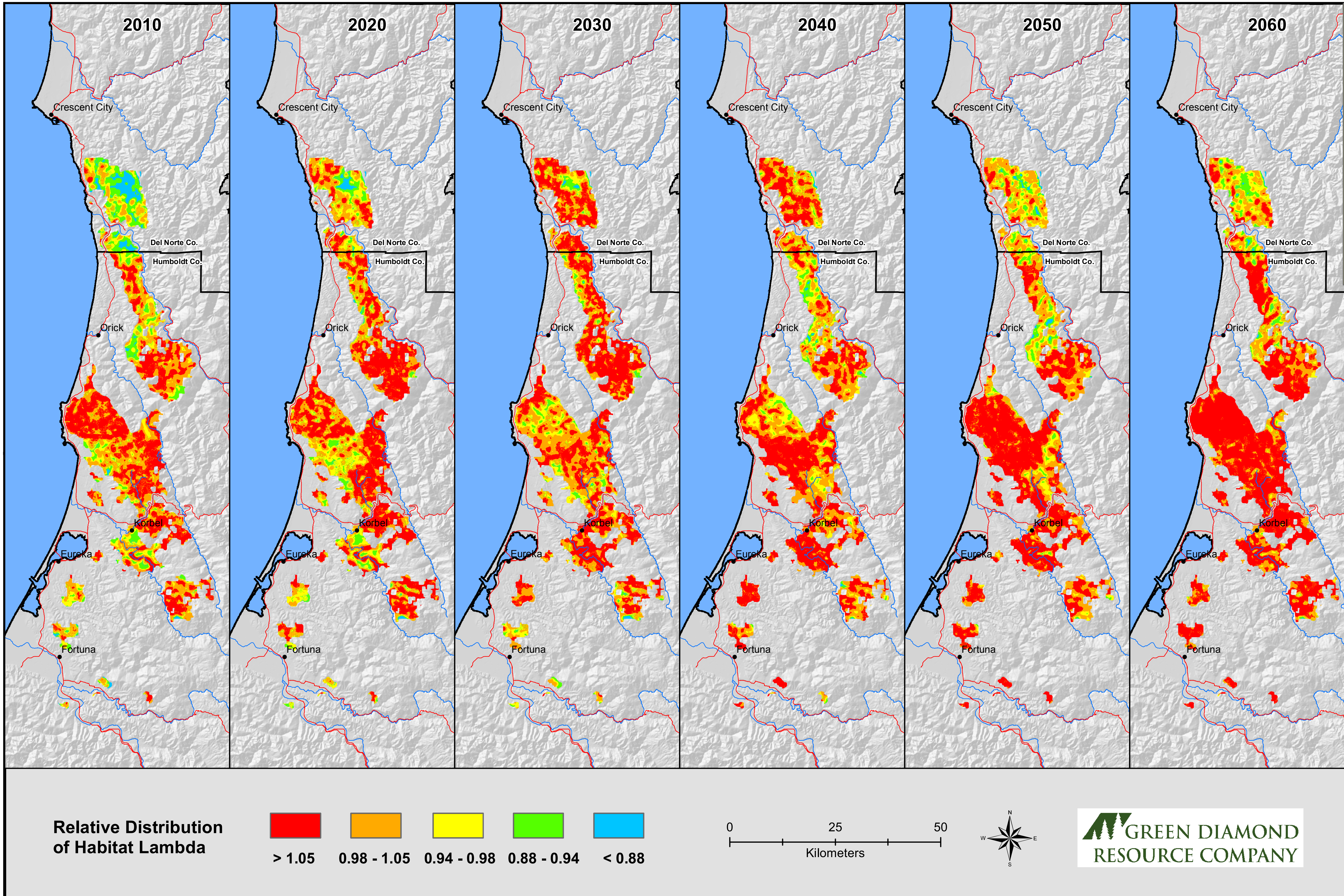
Map 1-2. Initial Plan Area, Adjustment Area, and Peripheral Areas in California



Map 4-1. Location of the Hydrographic Planning Areas used to describe forest conditions relative to the Plan Area



Map 4-2. Distribution of northern spotted owl activity centers within the Plan Area and nearby regions of northern California. Activity centers were determined from the California Natural Diversity Database (2010)



Map 4-3. Relative Distribution of Northern Spotted Owl Habitat Fitness Potential on Green Diamond Resource Company Land in 2010, 2020, 2030, 2040, 2050 and 2060. The mapped area is limited to regions considered in habitat fitness analysis

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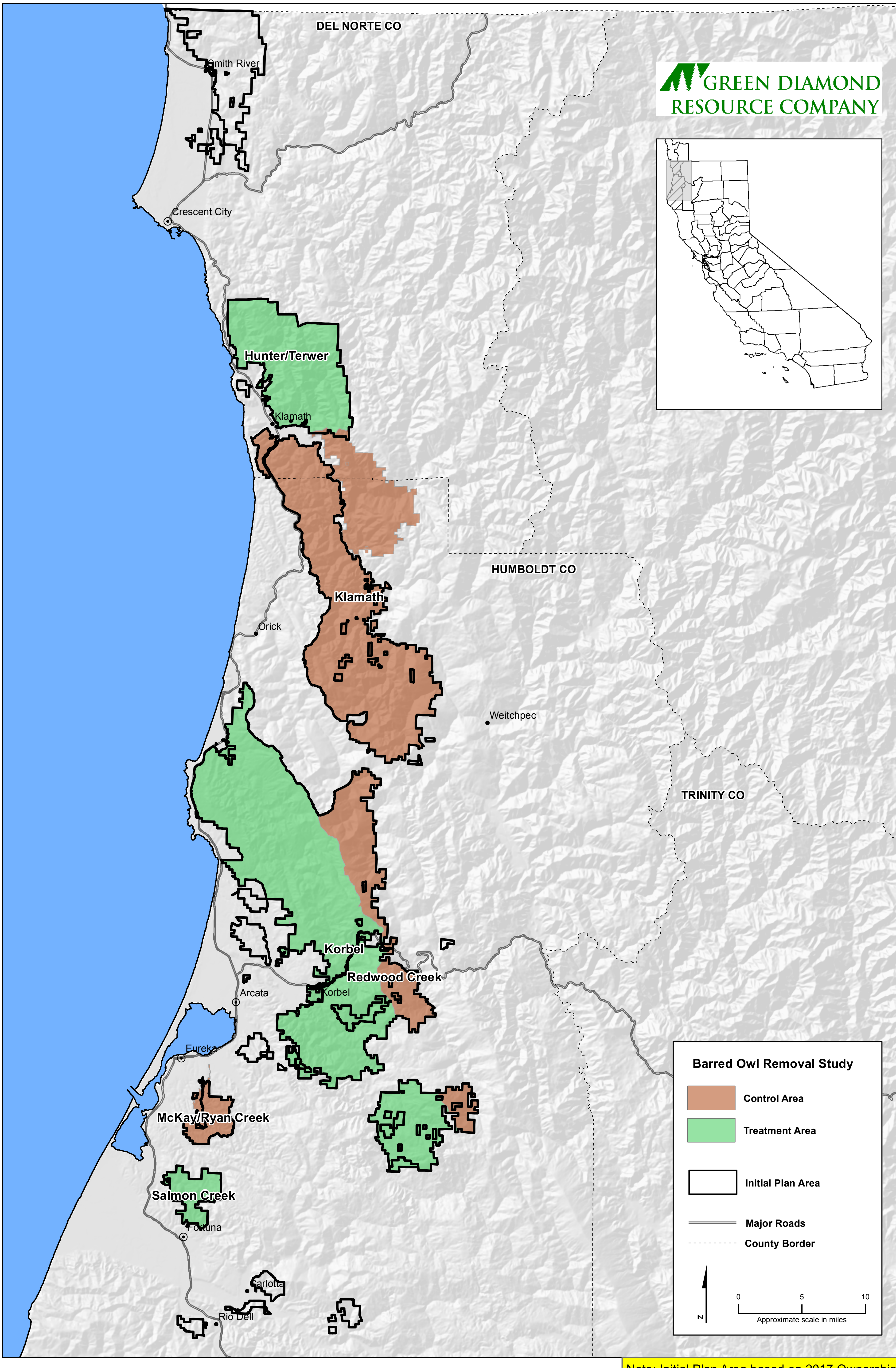

Map 4-4. Barred Owl Removal Study Treatment and Control areas

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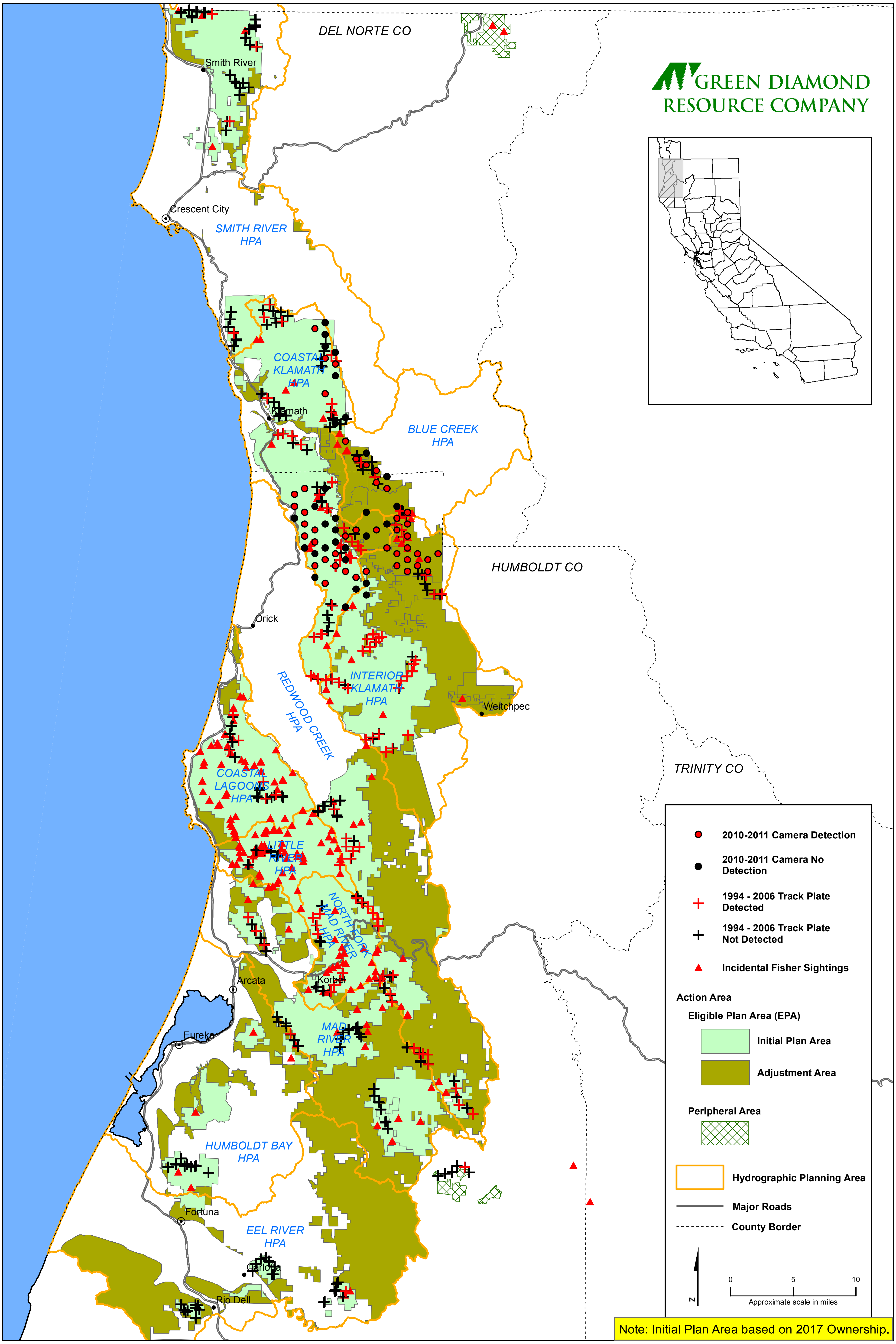
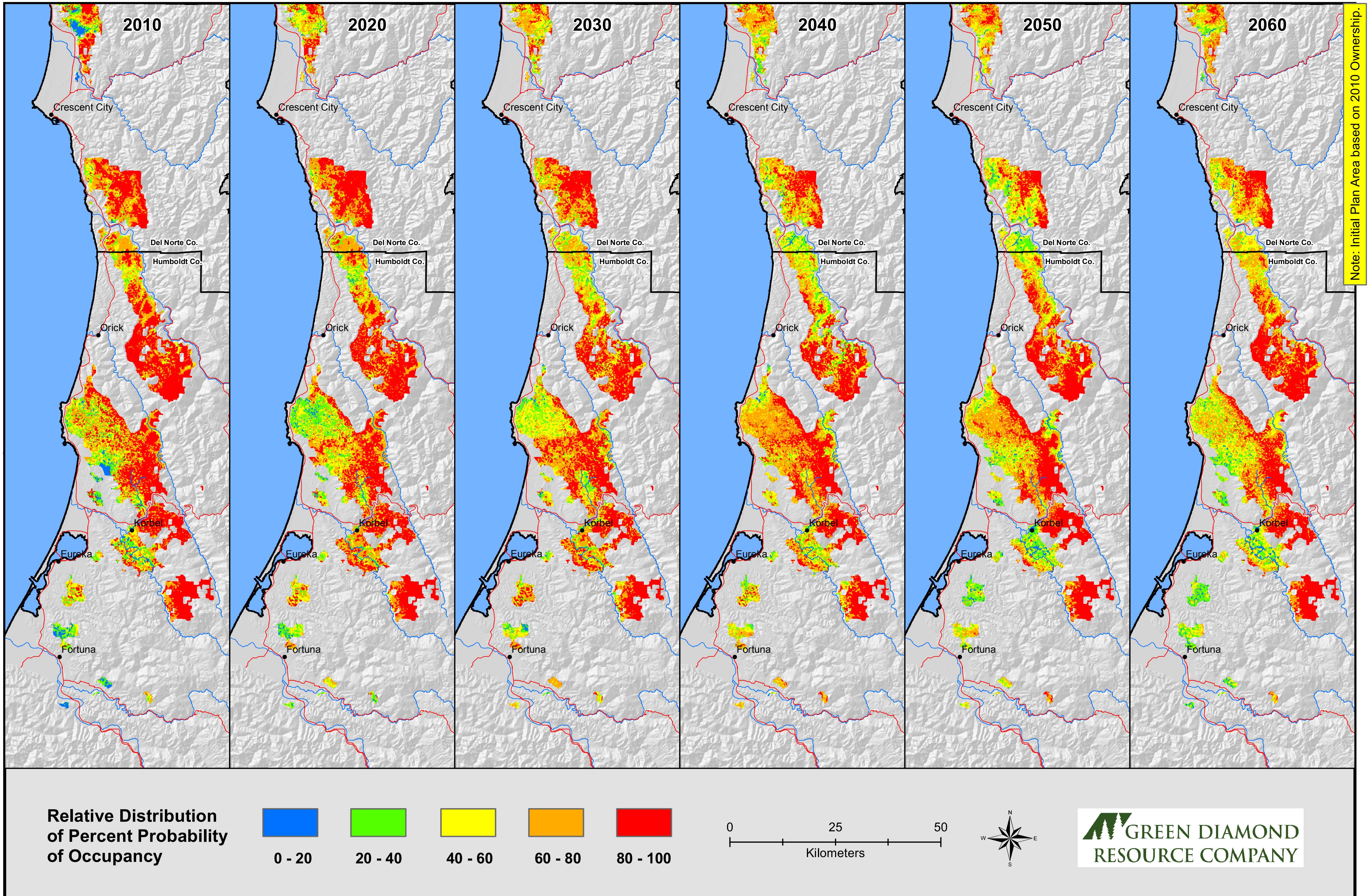
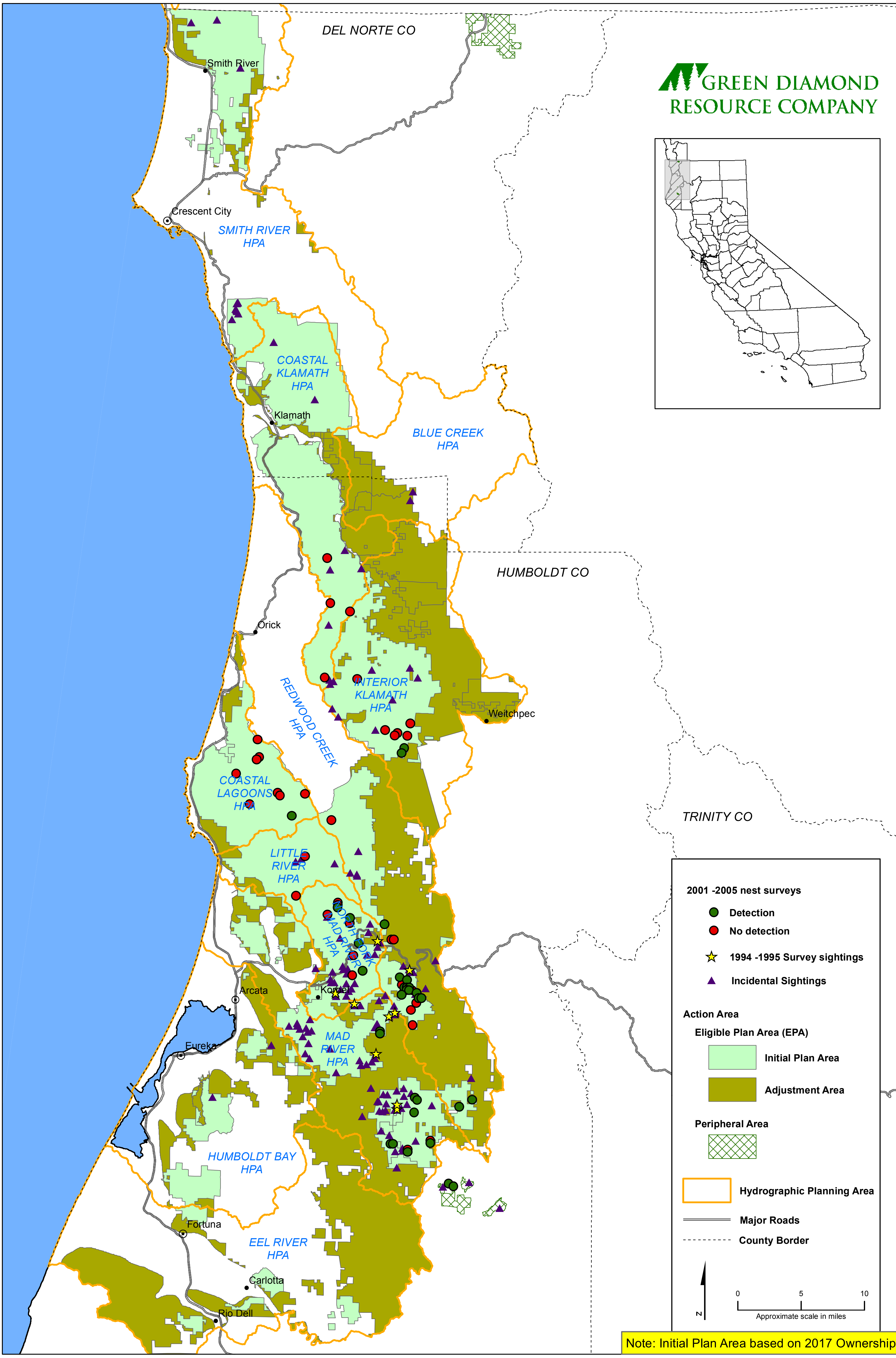


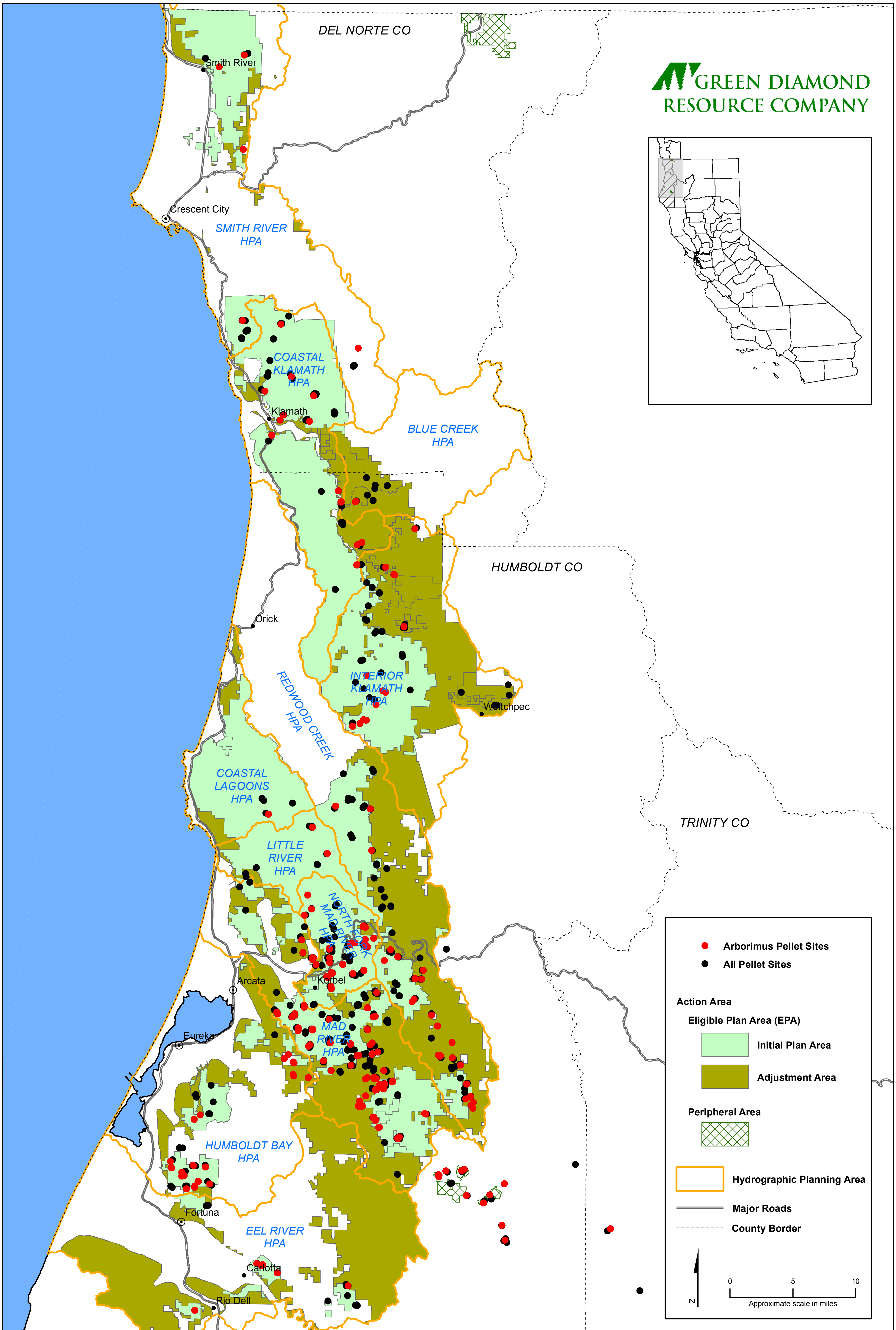
Map 4-5. Distribution of fishers on Green Diamond Lands. Detections from 1994, 1995, 2004 and 2006 track plates surveys and 2010-2011 camera surveys. Incidental sightings from 1993-2008 resulted from direct visual observations, road kills and identification of tracks in snow by trained biologis



Map 4-6. Relative distribution of fisher probability of occupancy on Green Diamond Resource Company land in 2010, 2020, 2030, 2040, 2050 and 2060. Mapped area is limited to regions considered in fisher occupancy analysis



Map 4-7. Distribution of red and Sonoma tree voles based on stand-level surveys in 1994-1995 and 2001-2005 and incidental sightings of tree vole nests



Note: Initial Plan Area based on 2017 Ownership.

Map 4-8. Distribution of tree voles determined from analysis of spotted owl pellet collections 1990-2009

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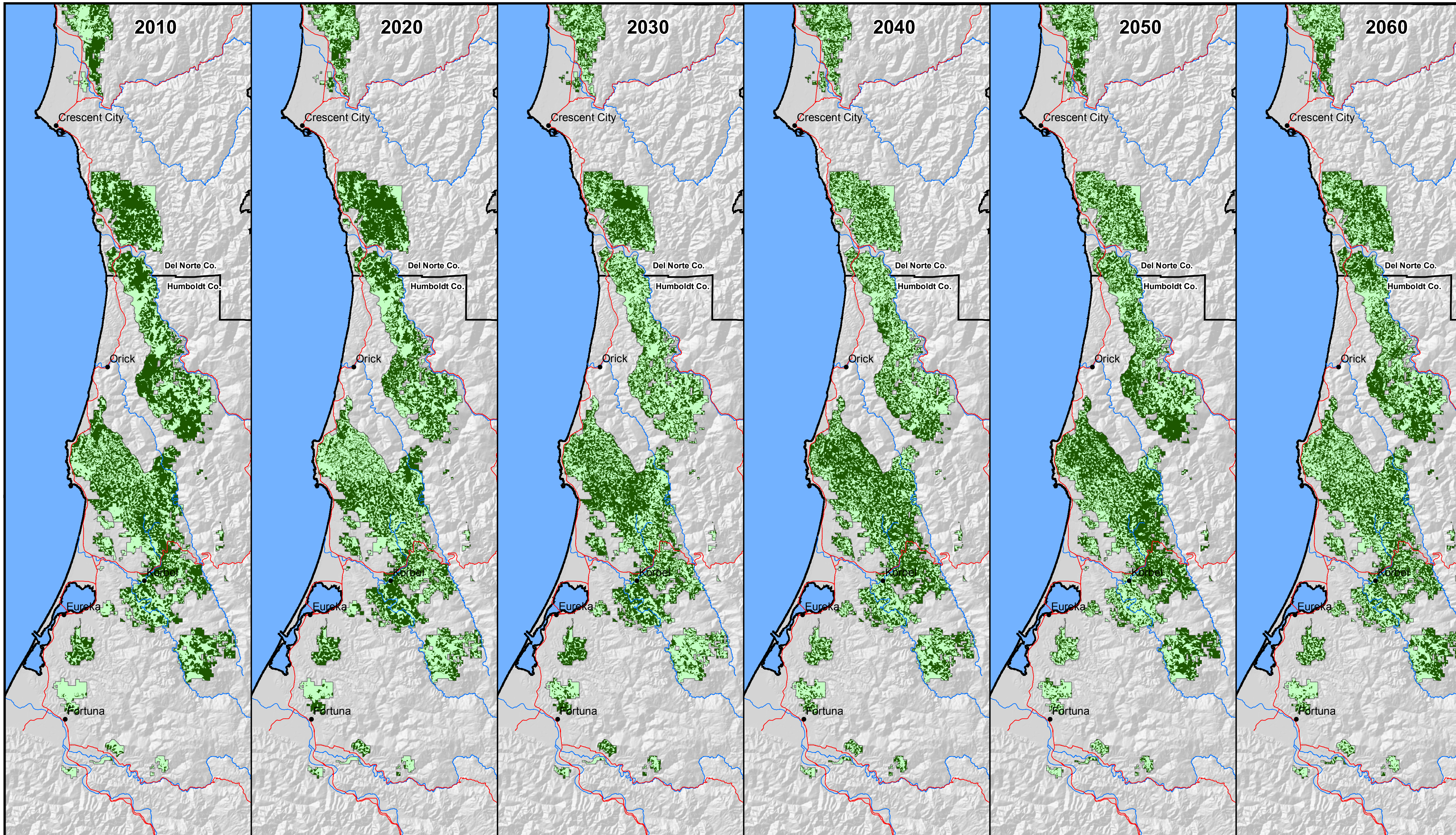

Note: Initial Plan Area based on 2010 Ownership.

Relative Distribution of Estimated Vole Habitat across the Initial Plan Area for 6 Decadel Periods

Estimated Vole Habitat

Initial Plan Area

0 25 50
Kilometers

N
W E
S

GREEN DIAMOND RESOURCE COMPANY

Map 4-9. Relative Distribution of Estimated Vole Habitat across the Initial Plan Areain 2010, 2020, 2030, 2040, 2050 and 2060.

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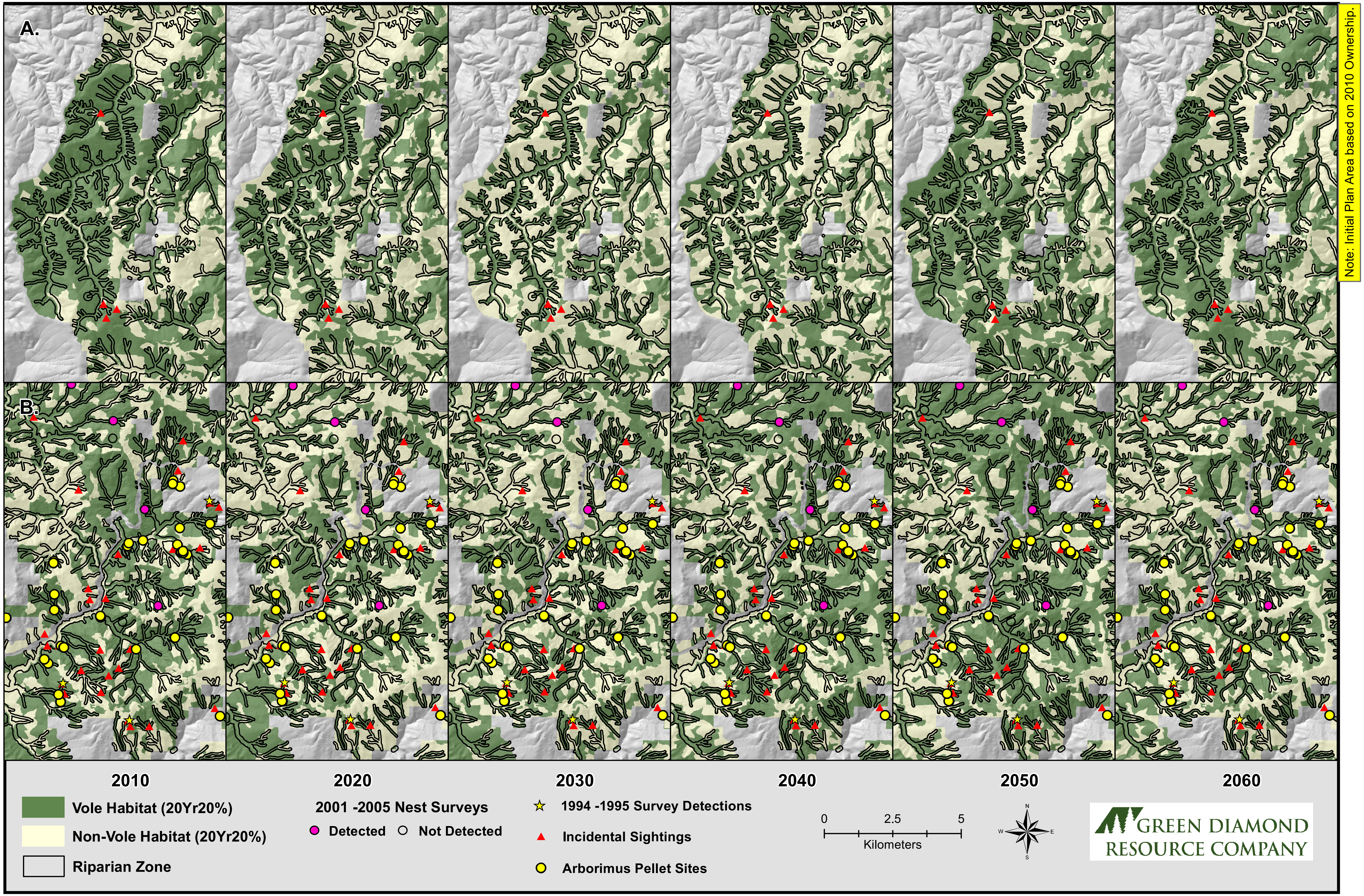

Map 4-10. Projections of tree vole habitat within two selected watersheds (A, top, B, bottom) of Green Diamond Ownership in 2010, 2020, 2030, 2040, 2050 and 2060 based on models of forest stands with 20% whitewood basal area and trees ≥20 yrs of age

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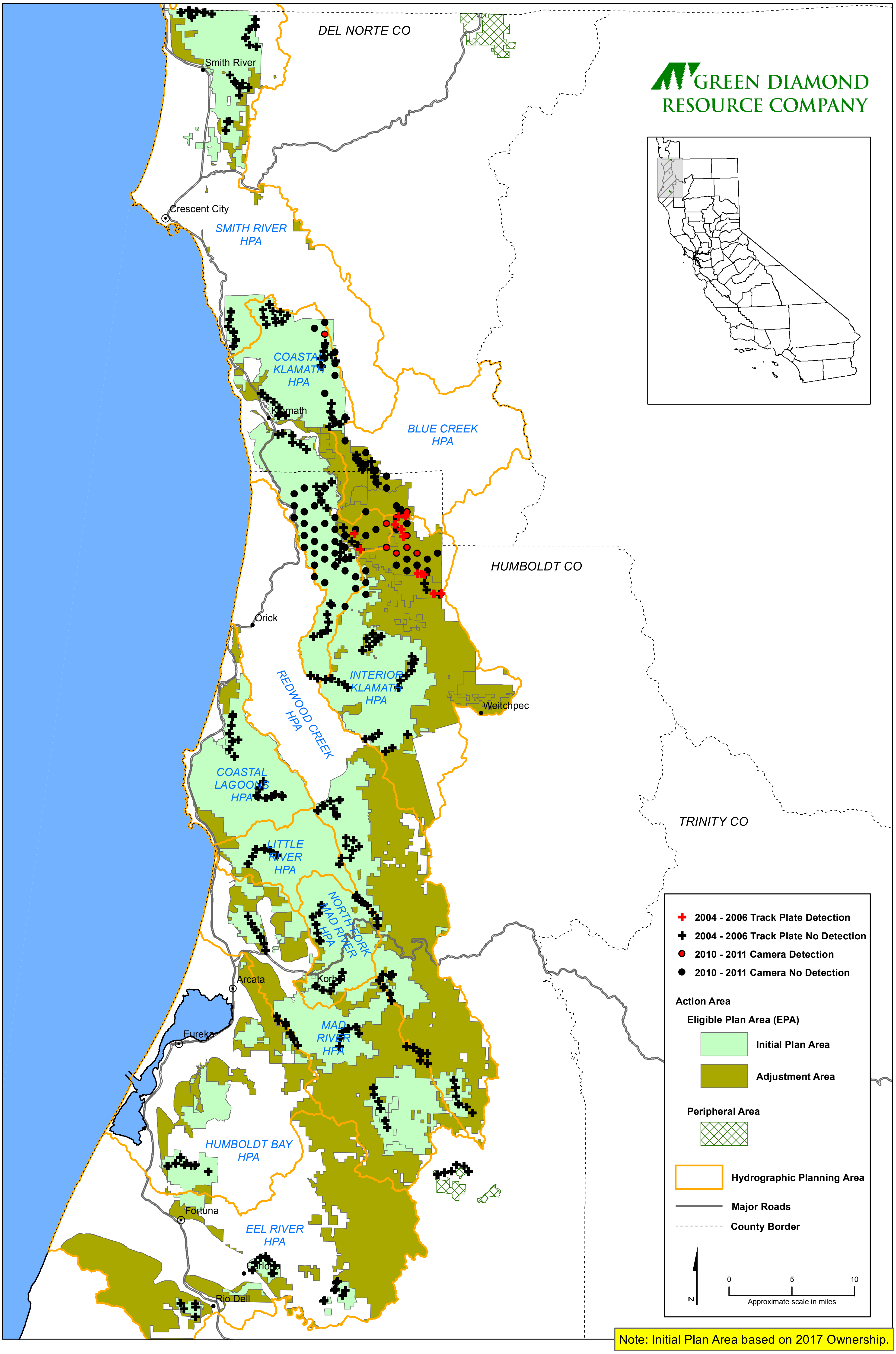
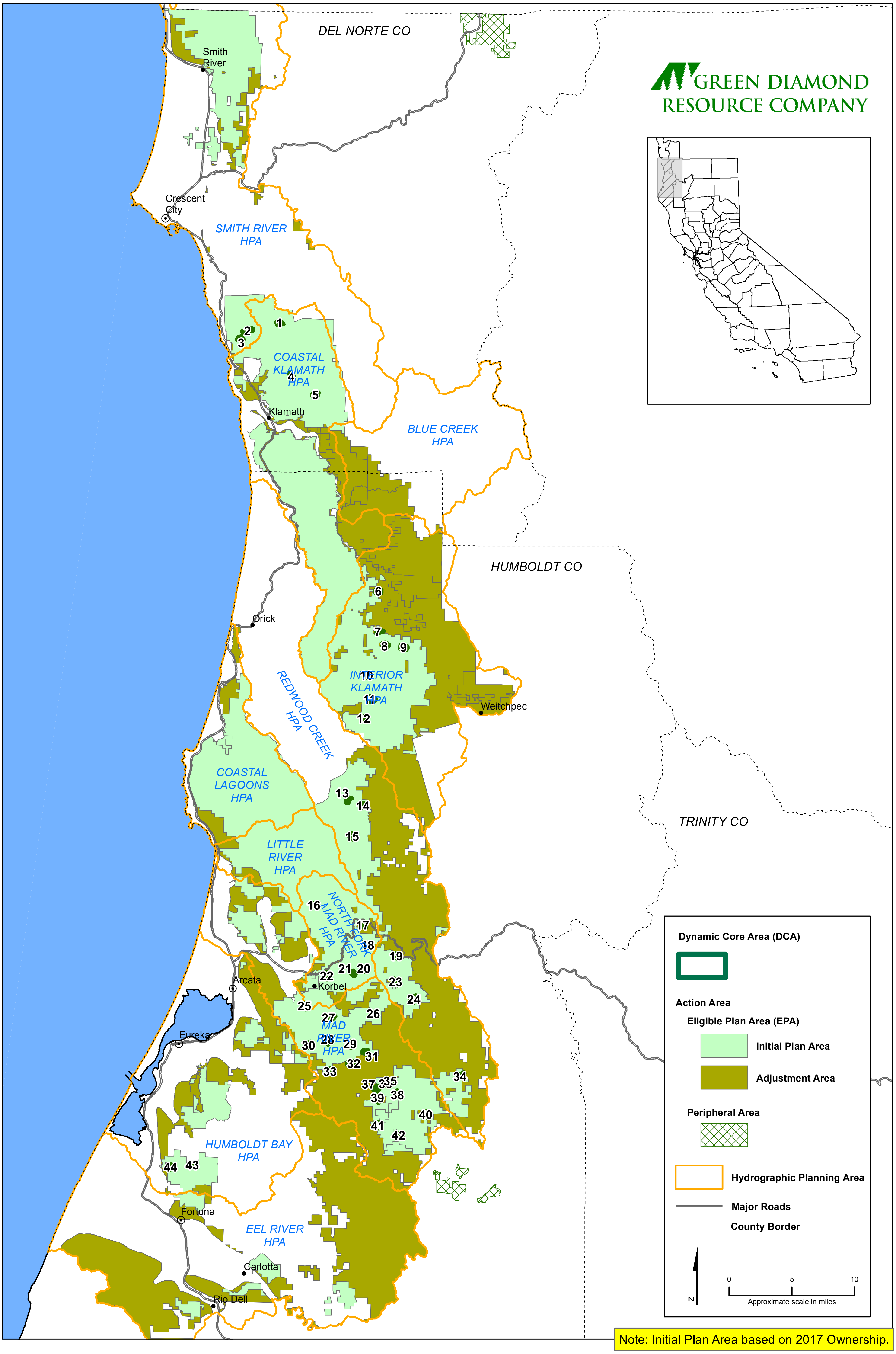
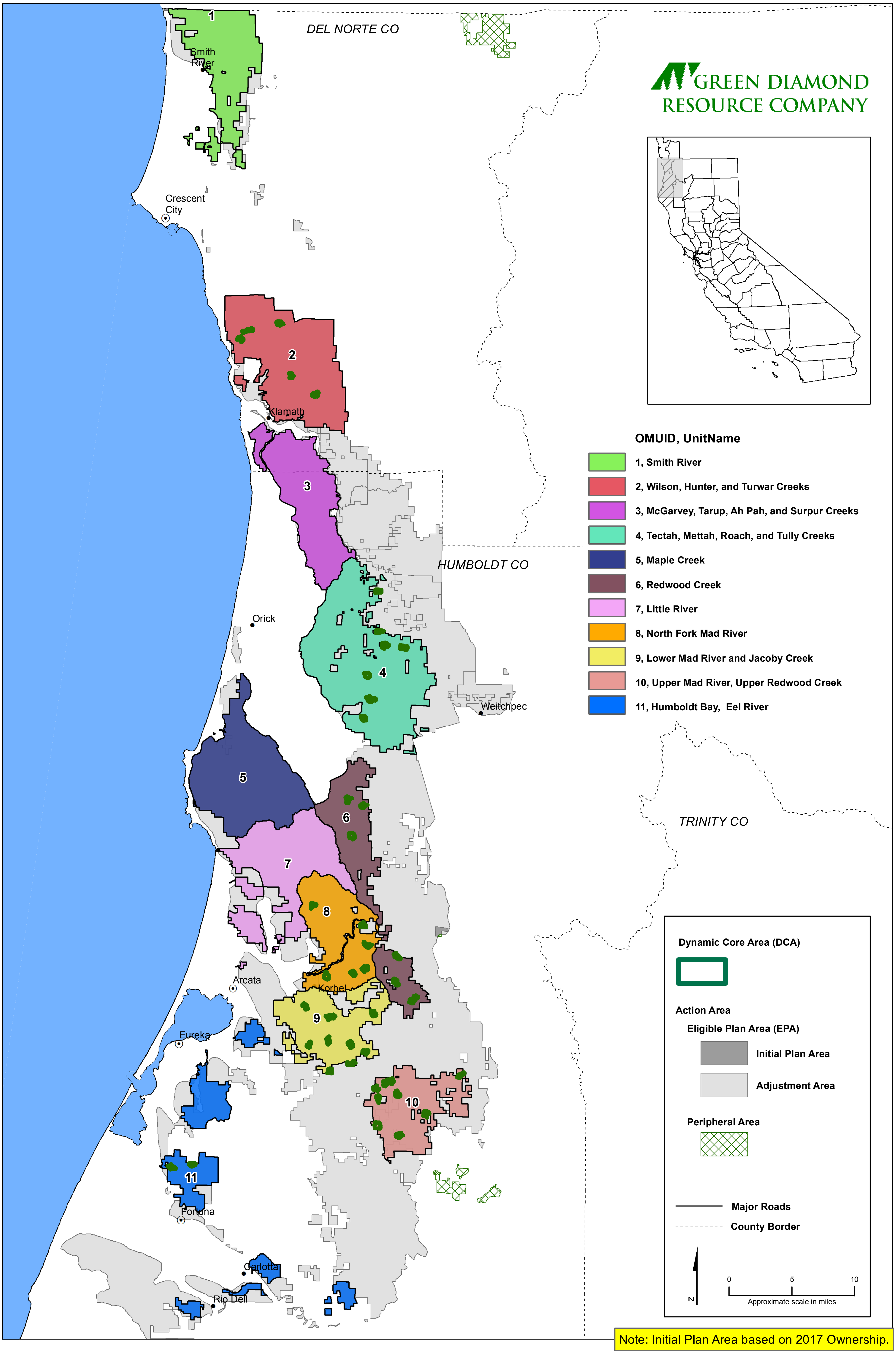


Map 4-11. Distribution of marten detections on Green Diamond Ownership resulting from sooted track plate surveys (2004, 2006) and remote camera stations (2010-2011)



Map 5-1. Location of 44 Northern Spotted Owl Dynamic Core Areas within the Initial Plan Area for Green Diamond Resource Company's Forest Habitat Conservation Plan



Map 5-2. Location of 11 Owl Management Units of 20,000 to 60,000 acres and will serve as the basis for distribution of NSO Dynamic Core Areas and habitat fitness model validation