

**DRAFT RECOVERY PLAN FOR THE
MEXICAN SPOTTED OWL,
FIRST REVISION
(*Strix occidentalis lucida*)**



Original Approval: October 16, 1995

**Southwest Region
U.S. Fish and Wildlife Service
Albuquerque, New Mexico**

June 2011

Approved: DRAFT
Regional Director, Region 2
U.S. Fish and Wildlife Service

Date: _____

Approved: DRAFT
Regional Director, Region 6
U.S. Fish and Wildlife Service

Date: _____

**DRAFT RECOVERY PLAN FOR THE
MEXICAN SPOTTED OWL,
FIRST REVISION
(*Strix occidentalis lucida*)**

Prepared by:
Mexican Spotted Owl Recovery Team

Prepared for:
Region 2, Southwest Region
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

Original Approval: October 16, 1995
Final Approval: 2011

DISCLAIMER

The Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 et seq.), requires the development of recovery plans for listed species, unless such a plan would not promote the conservation of a particular species. In accordance with Section 4(f)(1) of the Act and to the maximum extent practicable, recovery plans delineate actions which the best available science indicates are required to recover and protect listed species. Recovery plans are published by the U.S. Fish and Wildlife Service (USFWS), and are sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Recovery plans do not necessarily represent the views or the official positions or approval of any individuals or agencies involved in the plan formulation, other than the FWS. They represent the official position of FWS only after they have been signed by the Regional Director. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions. Please check for updates or revisions at www.fws.gov/southwest/es/arizona before using.

LITERATURE CITATION OF THIS DOCUMENT SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 2011. Draft Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*), First Revision. U.S. Fish and Wildlife Service. Albuquerque, New Mexico, USA. Xxpp.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

U.S. Fish and Wildlife Service
Arizona Ecological Services Office
2321 West Royal Palm Road, Suite 103
Phoenix, Arizona 85303

U.S. Fish and Wildlife Service
Southwest Region
500 Gold Avenue, S.W.
Albuquerque, New Mexico 87102

On-line: <http://www.fws.gov/southwest/es/arizona/> and <http://www.fws.gov>.

ACKNOWLEDGEMENTS

Numerous people helped with the development of this recovery plan. We thank everybody who contributed valuable time, information, and insight. This includes numerous biologists and land managers who shared expertise on owl ecology and management, and many dedicated field workers who gathered the data upon which the plan is based. Indeed, the plan would have been impossible to complete without those contributions.

USFWS Policy Review: Wendy Brown, Brady McGee, and Julie McIntyre provided insightful USFWS policy reviews of earlier drafts.

Past Recovery Team Members: This revised recovery plan is based heavily on the initial plan which was completed in 1995. Some team members are no longer with the team but deserve recognition, namely Regis Cassiday (USFS), Pat Christgau (AGFD), Fernando Clemente (Colegio De Postgraduados, Campus San Luis Potisi), Jerry Craig, (CDOW), James Dick (USFS), Alan Franklin (Colorado State University), Wil Moir (USFS RMRS), Thomas Spalding (AGFD), Steven Thompson (San Carlos Apache Tribe), Dean Urban (Duke University), and Sartor O. Williams III (NMGFD).

Recovery Unit Working Teams: Since publication of the 1995 Mexican Spotted Owl Recovery Plan, Working Teams representing each of the 6 U.S. Recovery Units have been instrumental at transferring the spirit and intent of the plan to land managers, noting parts of the plan that were difficult to implement, and reviewing earlier drafts of this revision. Their assistance and feedback has been invaluable. Members of these working teams are too numerous to list, but we acknowledge each and every one and are grateful for their contributions.

Technical Assistance: The following people provided technical and logistical support for fire modeling efforts: Kari Gromatzky (USFWS), Tessa Nicolet (USFS), Charles McHugh (USFS, RMRS), and Mark Finney (USFS, RMRS). John Anhold, Joel McMillin, Ryan Hanavan, and Marylou Fairweather (all Forest Health Protection, USFS) provided valuable information on insects and disease. Jim Youtz (USFS) provided advice on forest types and forest management. R. J. Gutiérrez (University of Minnesota), Mark Seamans (USFWS), and Chris May (The Nature Conservancy) generously shared data critical to developing population monitoring. Dan Spotskey (USGS) and Mary Richardson (USFWS) provided ongoing GIS support throughout the process of revising the recovery plan. Chris Witt (USFS, RMRS) conducted analyses using FIA data to quantify the amount of forested and wooded lands subject to recovery plan recommendations. Troy Corman (AGFD), Larry Semo (Colorado Field Ornithologists), Clifford Shackelford (Texas Parks and Wildlife Department), John Kendall (Bureau of Land Management), Marikay A. Ramsey (USDI BLM), Tom Watts (Jicarilla Game and Fish Department), William Hornsby and Jennifer Smith (Mescalero Agency – Bureau of Indian Affairs Branch of Natural Resources), Carol Finley (Kirtland Air Force Base), Brian Locke (Fort Bliss Directorate of Public Works – Environmental Division), Charles Hathcock (Los Alamos National Laboratory), and James Hirsch (NMDGF), and Steven Cary and Shawn Knox (New Mexico State Parks) provided information for various parts of the plan. Charles van Riper III (USGS) provided timely advice, and RV Ward and Tim Bowden (NPS) provided feedback and support for canyon work. Jay Rotella (Montana State University) and Rudy King (RMRS) provided statistical expertise on various topics.

Editorial Assistance: We thank Carly Johnson (Journal of Wildlife Management), Lane Eskew (USFS, RMRS), and Melinda Myers (contractor) for editorial assistance. Citlali Cortés Montaña (Northern Arizona University) and Ana Lilla Reina (USFWS) translated various parts of the plan from Spanish to English.

Logistical Support: Margie Valenzuela, Margie Ryckman, and Julie Key of USFWS, and Brenda Strohmeier, Kerry Cobb, and Barbara Walters of USFS RMRS provided key administrative support. Don DeLorenzo, Bobbi Barrera, and Ronnie Maes of USFS were instrumental in obtaining financial support to the team. Michael Morrison (Texas A&M) facilitated some team meetings.

EXECUTIVE SUMMARY

Current Species' Status: In 1993 the U.S. Fish and Wildlife Service (USFWS) listed the Mexican spotted owl as threatened under the Endangered Species Act (ESA). Critical habitat for the Mexican spotted owl was designated in 2004, comprising approximately 3.5 million ha (8.6 million ac) on Federal lands in Arizona, Colorado, New Mexico, and Utah (69 FR 53182). Within the critical habitat boundaries, critical habitat only includes protected and restricted habitats as defined in the original Mexican Spotted Owl Recovery Plan, completed in 1995. The species' recovery priority number is 9C, pursuant to the Endangered and Threatened Species Listing and Recovery Priority Guidelines (48 FR 43098). The Mexican spotted owl meets the species recovery priority 9C category due to its moderate degree of threat, high recovery potential, taxonomic classification as a subspecies, and conflict with construction or other economic activities. Surveys since the 1995 Recovery Plan have increased our knowledge of owl distribution but not necessarily owl abundance. Population estimates recorded 758 owl sites from 1990 to 1993, and 1,222 owl sites from 1990 to 2004 in the United States (U.S.). An owl site is an area used repeatedly by a single or a pair of owls for nesting, roosting, or foraging (Box 1). For this revision, the Recovery Team compiled 1,301 owl sites known today in the U.S. portion of the owl's range (Table 2; Table B.2 in Appendix B). This increase is mainly a product of new surveys being completed within previously unsurveyed areas (e.g., several National Parks within southern Utah, Grand Canyon in Arizona, Guadalupe National Park and Guadalupe Mountains in southeastern New Mexico and West Texas, Dinosaur National Monument in Colorado, Cibola National Forest in New Mexico), with only a few additions to numbers of sites recorded for previously well-surveyed National Forests. Thus, an increase in abundance cannot be inferred from these data.

Habitat Requirements and Limiting Factors: Two primary reasons were cited for the original listing of the Mexican spotted owl in 1993: historical alteration of its habitat as the result of timber-management practices and the threat of these practices continuing as evidenced in existing national forest plans. The danger of stand-replacing fire was also cited as a looming threat at that time. Since publication of the 1995 Recovery Plan, we have acquired new information on the biology, threats, and habitat needs of the spotted owl. Threats to its population in the U.S. (but likely not in Mexico) have transitioned from commercial-based timber harvest to the risk of stand-replacing wildfire. Recent forest management has moved from a commodity focus and now emphasizes sustainable ecological function and a return toward pre-settlement fire regimes, both of which have potential to benefit the owl. Southwestern forests have experienced larger and more severe wildfires from 1995 to the present than those fires recorded in history. Climate variability combined with unhealthy forest conditions may also synergistically result in increased negative effects to habitat from fire. The intensification of natural drought cycles and the ensuing stress placed upon overstocked forested habitats could result in even larger and more severe fires in owl habitat. Several mortality factors have been identified as potentially important to the Mexican spotted owl, including predation, starvation, accidents, disease, and parasites. All national forest plans were amended in 1996 to incorporate management recommendations presented in the 1995 Mexican Spotted Owl Recovery Plan. As the Recovery Plan was implemented, we learned what worked and what did not. Given these changes and new information, it is timely to revisit and revise the 1995 Recovery Plan.

Recovery Strategy: This Recovery Plan presents realistic and attainable goals for recovering the owl and its ultimate delisting, involving forest habitat management and vigilant monitoring. The goals are flexible in that they allow local land managers to make site-specific decisions. Although the Mexican spotted owl was originally listed due to threats from destruction and modification of habitat caused by timber harvest and fires (Listing Factor A), increased predation associated with habitat fragmentation (Listing Factor C), and lack of adequate protective regulations (Listing Factor D), the threats of timber harvest and inadequate regulations have been largely addressed since the time of listing. Currently, the Mexican spotted owl is threatened primarily by habitat degradation and loss of old growth nesting habitats through stand-replacing wildfire (Listing Factor A); with threats of predation, disease, parasites (Listing Factor C) and starvation, accidents, and potential interactions of threat factors with climate change (Listing Factor E) considered comparatively minor. To accomplish the recovery of the Mexican spotted owl, the recovery strategy has six key elements designed to conserve the Mexican spotted owl throughout its range: 1) protecting existing populations, 2) managing for replacement nest/roost habitat, 3) managing threats, 4) monitoring population trends and habitat, 5) monitoring plan implementation, and 6) building partnerships to facilitate recovery.

Success of the plan, however, hinges on the commitment and coordination among the Mexican government, U.S. Federal and State land-management organizations, sovereign Indian nations, and the private sector to ensure that the spirit and intent of the plan is executed as envisioned by the Recovery Team. Although much of the recovery strategy is focused on the U.S. range of the bird, this strategy can and should be implemented in Mexico. Under the proposed recovery criteria, the owl could be delisted within 10 years of implementing this revised Recovery Plan. Maintaining and restoring forest health to reduce the threat of stand-replacing wildfire, while creating a mosaic of suitable Mexican spotted owl habitats and protecting existing populations, will be achieved by land use management, facilitated by section 7 consultations and agreements. The recovery criteria require monitoring. Without careful and rigorous application of monitoring, there would be no objective basis for delisting the owl.

Recovery Goal: The ultimate goal of the Recovery Plan is to sustain owl populations to the point that the owl can be removed from the list of endangered and threatened species.

Recovery Objectives: To support the Mexican spotted owl throughout its range in perpetuity, and to maintain habitat conditions necessary to provide roosting and nesting habitat for the Mexican spotted owl. This will be accomplished through protecting populations, managing for habitat, managing threats, monitoring population and habitat, monitoring plan implementation, and building partnerships to facilitate recovery.

Recovery Criteria: Two criteria must be met before the Mexican spotted owl can be delisted:

1. *Owl occupancy rates must show a stable or increasing trend after 10 years of monitoring.* The study design to verify this criterion must have a power of 90% (Type II error rate $\beta = 0.10$) to detect a 25% decline in occupancy rate with a Type I error rate (α) of 0.10. The monitoring approach recommended in Part V.2 and in Appendix F (Monitoring Recommendations) describes how this might be determined. (Listing Factors A, C, and E).

2. *Indicators of habitat conditions (key habitat variables) are stable or improving for 10 years in roosting and nesting habitat* (for key habitat variables, see Table 1 or Table C.1 in Appendix C). Habitat monitoring should be conducted concurrently with owl occupancy monitoring. Trends in all key habitat variables must be shown stable or increasing with a power of 90% (Type II error rate $\beta = 0.10$) to detect a 25% decline with a Type I error rate (α) of 0.10. (Listing Factors A, C, and E).

By design, these criteria are redundant and dependent; progress on one relates to progress on the other. However, to be proposed for delisting, we recommend both criteria be met. In addition, anthropogenic and non-anthropogenic threats to the Mexican spotted owl must be sufficiently moderated and/or regulated for the foreseeable future, as evidenced by the best scientific information available. The best scientific information is derived from research, management experiments, and monitoring conducted at the appropriate scale and intensity. An analysis of the five ESA listing factors must be conducted to verify that threat levels are acceptable for likely persistence of owl populations into the future.

Actions Needed: Actions required to ensure the recovery of the Mexican spotted owl include:

1. *Management.* Given that the owl is a widespread species with a disjunct and somewhat fragmented distribution, management must proceed with a landscape approach. Landscape modeling and analysis are critical in evaluating the distribution of owls and habitats, identifying areas where threats are greatest, and then applying plan recommendations in such a way as to sustain and improve owl habitat. Three levels of management are provided:

- Protected Activity Centers (PACs). These encompass about 600 acres surrounding known owl sites. Management is the most conservatively oriented toward owl management within PACs, but is by no means "hands off". The Recovery Team recognizes situations exist where management is needed to sustain or enhance desired future conditions for the owl, including fire-risk reduction. Mechanical treatments to achieve these objectives require a landscape analysis to determine where the needs are greatest.
- Recovery habitat. These are primarily pine-oak, mixed-conifer, and riparian forests that have potential for becoming replacement nest-roost habitat or for providing foraging, dispersal, or wintering habitats. Nesting/roosting habitat typically occurs either in well-structured forests with high canopy cover, large trees, and other late seral characteristics, or in steep and narrow rocky canyons formed by parallel cliffs with numerous caves and/or ledges within specific geologic formations. From 10-25% of forest recovery habitat should be managed as replacement nest-roost habitat varying by forest type and Ecological Management Unit (EMU). The remainder can be managed for other needs provided that key habitat elements are retained across the landscape.
- Other forest and woodland types, such as ponderosa pine forest, spruce-fir forest, and pinyon-juniper woodland. No specific management is suggested for these types, recognizing that current emphasis for ecological restoration should be compatible with needs of the owl.

2. *Monitoring.* As management proceeds, monitoring assesses the efficacy of management actions and provides the adaptive framework for more successful management guidelines. Thus, it is critically important to monitor owl populations and habitat to understand whether or not both are stable or improving. Monitoring population status provides a real-time assessment of the

owl's situation, whereas habitat monitoring allows us to project into the future to determine if there will be adequate habitat to support a viable owl population. As a surrogate for evaluating trends in actual owl numbers, owl occupancy will be monitored at a sample of fixed sites randomly selected throughout the U.S. range of the bird. We also recommend that Mexico undertake a monitoring effort consistent with the one recommended for the U.S. No specific design is proposed for monitoring habitat, although Forest Inventory and Assessment data might have application to the owl. Combining owl occupancy and habitat monitoring provides an opportunity to examine relationships between habitat features and populations to indicate whether a review of current management is warranted.

3. *Research.* The Recovery Team used all available data, published papers, unpublished reports, and scientific expertise covering the U.S. and Mexico when developing the Recovery Plan. During the process, it became clear that critical knowledge gaps exist. Four general areas require additional research: (1) habitat relations, (2) biological interactions, (3) population structure, and (4) ecosystem structure. Included within these general areas are research recommendations to better understand effects of implementation of the management recommendations on the owl and ecosystem composition, structure, and function.

4. *Implementation.* An implementation schedule is provided that details recovery tasks, those responsible for implementing them, and the associated costs. These guidelines call for assembly of working teams for each EMU to oversee implementation of the Recovery Plan and to provide feedback on aspects that work and do not work.

Estimated Date and Cost to Recovery:

Estimated date: 2021

Total Cost of Recovery (minimum): \$42,628,000

Costs, in thousands of dollars:

<u>Year</u>	<u>Minimum Costs: (\$000s)</u>
2012	3,770
2013	3,707
2014	3,687
2015	3,687
2016	3,687
2017 - 2021	24,110

Date of Recovery: The date of recovery for the Mexican spotted owl is estimated at 2021 if actions delineated in this recovery plan are implemented.

RESUMEN EJECUTIVO

Estado actual de la especie: En 1993, el Servicio de Pesca y Vida Silvestre de los Estados Unidos (USFWS, por sus siglas en inglés) incluyó al búho moteado mexicano en la categoría de amenazado en la Ley de Especies Amenazadas (ESA, por sus siglas en inglés). En 2004 se designaron aproximadamente 3.5 millones de hectáreas (8.6 millones de acres) de hábitat crítico para la especie en tierras federales en Arizona, Colorado, Nuevo México y Utah (69 FR 53182). Dentro de sus límites, cada hábitat crítico sólo incluye hábitats protegidos y restringidos definidos en el Plan de Recuperación del Búho Moteado Mexicano, concluido en 1995. El número de prioridad de recuperación de la especie es 9C, de acuerdo a las Directrices para Enlistado y Priorización de la Recuperación de Especies En Peligro y Amenazadas (48 FR 43098). El búho moteado mexicano tiene la categoría de prioridad de recuperación 9C debido al grado moderado de sus amenazas, su alto potencial de recuperación, su clasificación taxonómica como subespecie, y su conflicto con la construcción y otras actividades productivas. Estudios elaborados a partir de la elaboración del Plan de Recuperación en 1995 han incrementado nuestro conocimiento sobre la distribución del búho, aunque no necesariamente sobre su abundancia. Entre 1990 y 1993 las estimaciones de la población registraron 758 sitios con presencia de búhos y 1,222 entre 1990 y el 2004 en los Estados Unidos (EEUU). Un sitio con presencia de búhos es un área usada repetidamente para anidamiento, perchado o forrajeo por un individuo o una pareja de búhos (Recuadro 1). Para esta revisión, el Equipo de Recuperación compiló información sobre 1,301 sitios con presencia de búhos registrados a la fecha en la porción estadounidense del rango de distribución de esta especie (Tabla 2; Tabla B.2 en el Apéndice B). Este incremento se debe principalmente a los resultados de información generada en áreas no estudiadas previamente (parques nacionales en el sur de Utah, el Gran Cañón en Arizona, Parque Nacional Guadalupe y Montañas de Guadalupe en el sureste de Nuevo México y el oeste de Texas, el Monumento Nacional del Dinosaurio en Colorado, y el Bosque Nacional de Cíbola en Nuevo México), que resultó en la adición de pocos sitios nuevos a los registrados previamente en los bosques nacionales. Por esta razón, no es posible inferir incrementos en la abundancia a partir de estos datos.

Requisitos de hábitat y factores limitantes: Las dos razones principales para incluir al búho moteado mexicano en la lista de especies amenazadas en 1993 fueron: alteración histórica de su hábitat como resultado de las prácticas de manejo para producción de madera y la amenaza continua de estas prácticas presentes en los planes de manejo existentes para los bosques nacionales. Desde entonces se citó el peligro inminente de los incendios catastróficos. A partir de la publicación de Plan de Recuperación de 1995, se ha obtenido nueva información sobre la biología, amenazas y requerimientos de hábitat del búho moteado. En los EEUU las amenazas a las poblaciones de la especie dejaron de estar asociadas a la cosecha comercial de árboles para la producción de madera y actualmente están centradas en el riesgo de incendios forestales catastróficos. Es poco probable que esta situación sea similar en México. El manejo ha cambiado su enfoque de una producción de bienes a otro que hace énfasis en la sustentabilidad de las funciones ecológicas y el regreso a regímenes de incendios históricos (previos a la colonización europea). Estos dos cambios recientes en el enfoque del manejo forestal pueden traer beneficios potenciales a la especie. Desde 1995 hasta la actualidad los bosques del suroeste de los Estados Unidos han experimentado incendios catastróficos más grandes y severos que aquéllos registrados en el pasado. También, la variación climático combinado con condiciones

no saludables del bosque pueden sinérgicamente resultar en un aumento de efectos negativos en el hábitat debido al incendio. La intensificación de ciclos de sequía naturales y el estrés resultante en el hábitat de bosque rellenos podía resultar en incendios aún mas grandes y severos en hábitat del búho. Entre los factores importantes de mortalidad potencial para el búho moteado mexicano están la depredación, hambruna, accidentes, enfermedades y parásitos. En 1996 los planes de manejo de los bosques nacionales se enmendaron para incorporar recomendaciones de manejo presentadas en el Plan de Recuperación del Búho Moteado Mexicano de 1995. A medida que este plan se implementó hemos aprendido cuáles medidas funcionaron y cuáles no. Es oportuno revisar el Plan de Recuperación de 1995 para incorporar estos cambios y la información generada recientemente.

Estrategia de Recuperación: Este Plan de Recuperación presenta metas realistas y obtenibles para la recuperación del búho y su remoción de la lista de especies en peligro de extinción, a través del manejo del hábitat forestal y el monitoreo continuo. Las metas son flexibles, ya que requieren que los manejadores locales tomen decisiones específicas a nivel de sitio. Aunque el búho moteado mexicano fue listado originalmente debido a amenazas de destrucción y modificación a hábitat causado por cosecha de madera e incendios (Factor de enlistado A), aumento de depredación asociado con fragmentación de hábitat (Factor de enlistado C), y falta de regulaciones adecuados de protección (Factor de enlistado D), se han tratado las amenazas de cosecha de madera y regulaciones no adecuados desde la fecha de enlistamiento. Ahora, el búho moteado mexicano es amenazado principalmente por degradación de hábitat y pérdida de hábitat de anidación de bosque maduro por incendios catastróficos (Factor de enlistado A); con amenazas de depredación enfermedades, parásitos (Factor de enlistado C) e hambruna, accidentes, e interacciones potenciales de factores de amenazas con cambio climático (Factor de enlistado E) considerada relativamente menor. Para realizar la recuperación del búho moteado mexicano, la estrategia de recuperación tiene seis elementos claves diseñados para conservar el búho moteado mexicano por todo su rango: 1) proteger poblaciones existentes (PACs por sus siglas en ingles), 2) manejo por el reemplazo de hábitat de anidación/perchado, 3) manejo de amenazas, 4) monitoreo de tendencias poblacionales e hábitat, 5) monitoreo de la implementación del plan, y 6) construyendo alianzas para facilitar recuperación.

Sin embargo, el éxito del plan y su ejecución con el espíritu y las intenciones previstas por el Equipo de Recuperación depende del compromiso y la coordinación entre el gobierno de México, las agencias de manejo de tierras federales y estatales en los EEUU, las naciones indígenas soberanas, y el sector privado. Aunque la estrategia de recuperación está enfocada principalmente en el rango estadounidense del búho, la estrategia puede y debe de ser implementada de manera coordinada en México. Según los criterios para remover especies de la lista de especies en peligro, el búho podría ser removido a diez años de la implementación de este Plan de Recuperación revisado. El mantenimiento y restauración de la salud del bosque para reducir la amenaza de incendios catastróficos, mientras crean un mosaico de hábitat adecuado para el búho moteado mexicano y la protección de las poblaciones será logrado por el manejo del uso de terreno, facilitado por consultaciones de sección 7 y acuerdos. Los criterios de remoción requieren de actividades de monitoreo. Sin la aplicación de protocolos de monitoreo cuidadosos y rigurosos, no habría bases objetivas para remover el búho de la lista de especies en peligro de extinción.

Meta de Recuperación: La meta final del Plan de Recuperación es que las poblaciones de búho sean sostenibles al punto de que la subespecie pueda ser removida de la lista de especies amenazadas y en peligro de extinción.

Objetivos de Recuperación: Promover la perpetuidad del búho moteado mexicano por todo su rango distribucional y mantener las condiciones necesarias para proporcionar hábitat de perchado y anidamiento a la especie. Esto puede lograrse a través de la protección a poblaciones, manejo de amenazas, mantenimiento de hábitat, monitoreo del progreso, y construcción de alianzas para facilitar su recuperación.

Criterios de Recuperación: Para remover al búho moteado mexicano de la lista de especies en peligro de extinción deben de cumplirse dos criterios:

1. Las tasas de ocupación de los búhos deben de mostrar una tendencia estable o incrementando durante 10 años. El diseño de los estudios para verificar este criterio debe de tener una confiabilidad de 90% (tasa de error Tipo II ó $\beta = 0.10$) para detectar una declinación de 25% en la ocupación con una tasa de error Tipo I (α) de 0.10. El enfoque del monitoreo recomendado en la Parte V.2 y el Apéndice F (Recomendaciones de Monitoreo) describe cómo puede ser determinado. (Factor de enlistado A, C, y E).
2. Los indicadores de las condiciones de hábitat (variables clave de hábitat) deberán de mantenerse estables o mejorar por 10 años en el hábitat de perchado y anidamiento (por los variables clave de hábitat ver Tabla 1 o Tabla C.1 el Apéndice C). El monitoreo de hábitat deberá llevarse a cabo de forma simultánea con el monitoreo de ocupación de hábitat del búho. Las tendencias de todas las variables clave de hábitat deberán de tener valores estables o incrementar con una confiabilidad del 90% (tasa de error Tipo II $\beta = 0.10$) para detectar una declinación de 25% con una tasa de error Tipo I (α) de 0.10. (Factor de enlistado A, C, y E).

Estos criterios son redundantes y dependientes por diseño, y su progreso es interdependiente. Sin embargo, para proponer remoción del búho de la lista de especies amenazadas y en peligro de extinción, recomendamos que se cumpla con ambos. Además, las amenazas para la especie, antropogénicas y no antropogénicas, deberán de ser moderadas o reguladas suficientemente en el futuro inmediato con base a la mejor información científica disponible. Esta información científica se deriva de experimentos de investigación, experimentos de manejo y monitoreo conducido a escalas e intensidades adecuadas. Se deberá llevar a cabo un análisis de los cinco factores de la inclusión en el listado de especies amenazadas, para verificar que los niveles de amenaza son aceptables para incrementar la probabilidad de persistencia en el futuro de las poblaciones de búhos moteados mexicanos.

Acciones necesarias: Las acciones requeridas para asegurar la recuperación del búho moteado mexicano incluyen las siguientes:

1. Manejo. Dado que el búho es una especie generalista con una distribución dispersa y algo fragmentada, su manejo debe de tener un enfoque de paisaje. Los modelos y análisis de paisaje son críticos para la evaluación de la distribución del búho y su hábitat, identificando

áreas en las que las amenazas son mayores, utilizando las recomendaciones del plan de forma que se mantenga y mejore el hábitat del búho. Existen tres niveles de manejo:

- Centros de Actividades de Protección (PACs, por sus siglas en inglés). Estos cubren aproximadamente 600 acres alrededor de sitios con presencia de búhos identificados en los Estados Unidos. Su manejo es activo, aunque es muy conservador y está orientado al manejo de los búhos en los PACs. El Equipo de Recuperación reconoce que existen situaciones en las que es necesario desarrollar actividades de manejo para mantener o mejorar las condiciones deseadas para el búho, incluyendo la reducción del riesgo de incendios. Los tratamientos mecánicos para alcanzar estos objetivos requieren del análisis del paisaje para determinar los sitios prioritarios.
 - Hábitat de recuperación. Estos son principalmente bosques de pino-encino, coníferas mixtas y ribereños que tienen potencial para convertirse en reemplazos de hábitat de anidamiento y perchado o para proporcionar hábitat de forrajeo, dispersión o hibernación. Hábitat de anidamiento y perchado usualmente ocurre en bosques estructurados con una copa alta de los árboles, árboles grandes, y otras características de una etapa serial maduro, o en cañones rocosas muy inclinadas y angostas formados por acantilados paralelos con varias cuevas y/o salientes dentro de formaciones geológicas muy específicos. Un 10 a 25% del hábitat de bosque de recuperación deberá de ser manejado como reemplazo del hábitat de anidación y perchado, con variaciones de acuerdo al tipo de bosque y la Unidad Ecológica de Manejo (EMU, por sus siglas en inglés). El resto del hábitat puede manejarse para otras necesidades, siempre y cuando se retengan elementos clave de hábitat a lo largo del paisaje.
 - Otros tipos de bosque y vegetación forestal, como bosque de pino ponderosa, picea-abeto y pino piñonero-junípero. No existen recomendaciones específicas para estos tipos de bosque, reconociendo que el énfasis actual para la restauración ecológica debe de ser compatible con las necesidades de los búhos.
2. Monitoreo. A medida que se avanza en el manejo, el monitoreo permite evaluar la eficacia de las acciones de manejo y proporciona el marco adaptativo para contar con guías de manejo más exitosas. El monitoreo del estado de las poblaciones de búhos y su hábitat es crítico para determinar si éstas son estables o mejoran. El monitoreo del estado de la población proporciona una evaluación en tiempo real de la situación del búho, mientras que el monitoreo del hábitat permite determinar a futuro, si habrá hábitat adecuado para mantener poblaciones viables de búhos. Para sustituir la evaluación de tendencias a través de cifras reales de las poblaciones de búhos, su ocupación será monitoreada a través de una muestra de sitios fijos seleccionados aleatoriamente a lo largo del rango de distribución del ave en los Estados Unidos. No se proporciona un diseño específico para el monitoreo de hábitat, aunque los datos del Inventario Forestal pueden utilizarse para evaluar el hábitat del búho. La combinación de los modelos de ocupación del búho y el monitoreo de su hábitat

proporciona una oportunidad para examinar las relaciones entre las características del hábitat y las poblaciones para indicar si se justifica la revisión del manejo actual.

3. Investigación. El Equipo de Recuperación utilizó los datos disponibles, artículos científicos publicados, reportes no publicados e información de expertos científicos en los Estados Unidos y México para el desarrollo del Plan de Recuperación. Durante el proceso, se determinó que existen vacíos críticos de conocimiento. Cuatro áreas generales que requieren investigación adicional en los Estados Unidos son: 1) relaciones de hábitat, 2) interacciones biológicas, 3) estructura de las poblaciones, y 4) estructura de los ecosistemas. Dentro de estas áreas generales existen recomendaciones de investigación para entender mejor los efectos de la implementación de las recomendaciones de manejo sobre los búhos y la composición, estructura y función de los ecosistemas.
4. Implementación. Se anexa un calendario de implementación que detalla las tareas de recuperación, señala a los responsables y los costos asociados. Estas guías requieren la integración de equipos de trabajo en cada EMU para supervisar la implementación del Plan de Recuperación y proporcionar retroalimentación sobre su funcionamiento.

Fecha y Costos Estimados de la Recuperación:

Fecha aproximada: 2021

Costo total de la Recuperación (mínimo): \$42,628,000

Costos, en miles de dólares

Año	Costo mínimo (miles de USD)
2012	3,770
2013	3,707
2014	3,687
2015	3,687
2016	3,687
2017 - 2021	24,110

Fecha de recuperación: Se estima que las poblaciones de búho moteado mexicano estarán recuperadas para el 2021 si se implementan las acciones indicadas en este plan de recuperación.

TABLE OF CONTENTS

DISCLAIMER.....	iii
LITERATURE CITATION OF THIS DOCUMENT	iii
ADDITIONAL COPIES.....	iii
ACKNOWLEDGEMENTS	iv
EXECUTIVE SUMMARY	vi
Current Species' Status.....	vi
Habitat Requirements and Limiting Factors	vi
Recovery Strategy	vi
Recovery Goal	vii
Recovery Objectives	vii
Recovery Criteria	vii
Actions Needed.....	vii
Estimated Date and Cost to Recovery	ix
RESUMEN EJECUTIVO (Spanish Translation of Executive Summary).....	x
TABLE OF CONTENTS	xv

PART I. RECOVERY PLANS AND PLAN REVISIONS..... 1

1. Recovery Plans	1
2. Recovery Teams	1
3. Recovery Plan Revisions.....	2
4. Revised Mexican Spotted Owl Recovery Plan.....	2
5. Primary Differences from the 1995 Recovery Plan	4
6. Final Remarks on Recovery Plans.....	4

PART II. BACKGROUND (also see Appendix B) 5

1. Taxonomy	5
2. Description.....	6
A. Appearance	6
B. Vocalizations.....	6
3. Distribution.....	7
A. Ecological Management Units (EMUs).....	8
a. UNITED STATES – Ecological Management Units	8
i. Colorado Plateau (CP).....	11
ii. Southern Rocky Mountains (SRM).....	12
iii. Upper Gila Mountains (UGM)	13
iv. Basin and Range – West (BRW).....	14
v. Basin and Range – East (BRE)	15
b. MEXICO – Ecological Management Units	21
i. Sierra Madre Occidental – Norte	23
ii. Sierra Madre Oriental – Norte	23
iii. Sierra Madre Occidental – Sur.....	23
iv. Sierra Madre Oriental – Sur	24
v. Eje Neovolcanico	24
4. Definitions of Forest Types and Canyon Habitat.....	25

A.	Forest Types.....	25
B.	Plan Definitions of Forest Types	25
a.	Ponderosa Pine Forest Type.....	26
b.	Pine-oak Forest Type	26
c.	Mixed-conifer Forest Type	27
d.	High-elevation Forest Type	27
e.	Quaking Aspen Forest Type	27
f.	Riparian Forest Type.....	28
C.	Key to Forest Types Referenced in the Recovery Plan	28
D.	Rocky - Canyon Habitat.....	30
E.	Definition of the Rocky – Canyon Habitat	30
5.	Habitat Use	31
A.	Nesting and Roosting Habitat	31
B.	Foraging Habitat	32
C.	Home Range and Territoriality	32
D.	Juvenile Dispersal	33
E.	Migration and Wintering Areas	33
F.	Key Habitat Variables.....	34
6.	Life History.....	36
A.	Prey	36
B.	Reproductive History	36
C.	Mortality Factors.....	37
7.	Population Trends.....	38
8.	Critical Habitat	40
A.	Primary Constituent Elements Related to Forest Structure	40
B.	Primary Constituent Elements Related to Maintenance of Adequate Prey Species	41
C.	Primary Constituent Elements Related to Canyon Habitat.....	41
9.	Threats and Threats Assessment.....	41
A.	Reasons For Listing	41
a.	Present or threatened destruction, modification, or curtailment of the habitat or range	41
b.	Overutilization for commercial, recreational, scientific, or educational purposes	42
c.	Disease or predation.....	42
d.	Inadequacy of existing regulatory mechanisms.....	42
e.	Other natural or manmade factors affecting the species’ continued existence.....	42
B.	Current Threats	43
C.	Federal Actions Affecting the Mexican Spotted Owl.....	43
D.	Factors Affecting the Mexican Spotted Owl in the United States	43
a.	Present or threatened destruction, modification, or curtailment of the habitat or range	43
i.	<i>Stand-replacing Fire</i>	44
ii.	<i>Fire Suppression</i>	46
iii.	<i>Burned Area Response</i>	46
iv.	<i>Wildland-urban Interface (WUI) Treatments</i>	47

v.	<i>Silvicultural Treatments</i>	48
vi.	<i>Insects and Disease</i>	49
vii.	<i>Grazing</i>	51
viii.	<i>Energy Development</i>	53
ix.	<i>Influences on Riparian Habitats</i>	54
x.	<i>Roads and Trails</i>	54
xi.	<i>Land Development</i>	54
xii.	<i>Recreation</i>	57
xiii.	<i>Water Development</i>	58
b.	Overutilization for Commercial, Recreational, Scientific, or Educational Purposes	59
i.	<i>Commercial Exploitation</i>	59
ii.	<i>Recreational Exploitation</i>	59
iii.	<i>Scientific Exploitation</i>	59
iv.	<i>Educational Exploitation</i>	60
c.	Disease or Predation	60
i.	<i>West Nile Virus</i>	60
ii.	<i>Predation</i>	61
d.	Inadequacy of Existing Regulatory Mechanisms	61
i.	<i>National Fire Plan and Policy</i>	62
ii.	<i>Healthy Forests Initiative</i>	62
iii.	<i>Healthy Forests Restoration Act of 2003</i>	63
iv.	<i>Omnibus Public Land Management Act of 2009, Title IV Forest Landscape Restoration Act</i>	64
v.	<i>Stewardship Contracting Authority</i>	64
e.	Other Natural or Manmade Factors Affecting the Mexican Spotted Owl's Continued Existence	65
i.	<i>Noise and Disturbance</i>	65
ii.	<i>Barred Owls</i>	66
iii.	<i>Direct Mortality</i>	67
iv.	<i>Climate Change</i>	67
E.	Factors Affecting the Status of the Mexican Spotted Owl in Mexico	71
10.	Conservation Measures and Management in the United States and Mexico for the Mexican Spotted Owl (also see Appendix H)	77
PART III. RECOVERY STRATEGY, GOAL, OBJECTIVES, CRITERIA		81
1.	Recovery Strategy	81
2.	Recovery Goal	81
3.	Recovery Objectives	82
4.	Objective and Measurable Recovery Criteria	82
5.	Delisting Process	83
6.	Post-Delisting Monitoring	84
PART IV. RECOVERY PROGRAM		84
1.	Recovery Action Outline and Narrative	84

PART V. IMPLEMENTATION AND OVERSIGHT.....	91
1. Implementation Schedule.....	91
2. Monitoring Procedures.....	104
A. Monitoring Mexican Spotted Owl Occupancy Rates	105
a. Steps to Monitoring.....	105
b. Time Period for Monitoring.....	106
B. Monitoring Mexican Spotted Owl Habitat	107
3. Ecological Management Unit Working Teams	107
4. Continued Duties of the Recovery Team	108
5. Centralized Mexican Spotted Owl Information Repository	108
6. Research Needs.....	108
A. Habitat and Demography	109
B. Biological Interactions.....	110
C. Population Structure.....	111
D. Ecosystem Functions	111
PART VI. LITERATURE CITED	112
PART VII. APPENDICES	157
APPENDIX A: Recovery Team Members.....	157
APPENDIX B: Ecology of the Mexican Spotted Owl.....	162
1. Taxonomy and Genetics	162
2. Description	165
3. Distribution	167
4. Habitat Use.....	168
5. Prey Ecology.....	203
6. Population Ecology.....	205
7. Movements and Migration.....	226
8. Metapopulation Ecology.....	230
9. Conclusions.....	233
APPENDIX C: General Management Recommendations.....	250
1. Assumptions and Guiding Principles.....	250
2. Management Recommendations.....	251
3. Protected Activity Centers (PACs).....	252
A. Where Should PACs Be Established?.....	253
B. How Should PACs and Core Areas Within PACs Be Established?	253
C. What Activities are Allowed in PACs Outside of Core Areas?.....	254
D. What Activities are Allowed Within Nesting and Roosting Core Areas in PACs?	255
E. Should Salvage Logging Occur in PACs Impacted by Disturbance?.....	256
F. Can PACs be Decommissioned?	257
G. How Can PACs be Decommissioned?.....	257
H. Rationale Underlying PAC Guidelines.....	258
4. Recovery Habitat	258
A. Forested Recovery Habitat.....	259

B. Riparian Recovery Habitat.....	263
5. Other Forest and Woodland Types	264

APPENDIX D: Threat-specific Management Recommendations..... 278

1. Fire Management	278
2. Insects and Disease	281
3. Grazing.....	281
4. Energy-Related Development.....	284
5. Land Development.....	286
6. Water Development	286
7. Recreational Exploitation.....	287
8. Recreational Disturbance	287
9. Scientific Exploitation	288
10. Noise	289
11. Climate Change.....	290
12. West Nile Virus.....	291

APPENDIX E: Mexican Spotted Owl Survey Protocol..... 293

Introduction.....	293
1. Survey Design.....	295
2. Survey Methods	296
3. Number and Timing of Surveys.....	398
4. Methods After Detecting a Mexican Spotted Owl.....	300
5. Conducting Daytime Follow-up Surveys.....	301
6. Methods if Mexican Spotted Owls are Located on a Daytime Follow-up Visit.....	302
7. Determining Status From Nighttime Surveys and Daytime Follow-up Visits ...	303
8. Determining Nesting Status and Reproductive Success	304
9. Annual Reporting.....	307
10. Disposition of Dead, Injured, or Sick Mexican Spotted Owls.....	307
Glossary for Appendix E.	309
Literature Cited for Appendix E	313
Suggested Reading for Appendix E.....	314
Mexican Spotted Owl Survey Protocol Outline.....	315

APPENDIX F: Monitoring Procedures 317

1. Occupancy Monitoring	317
2. Potential Experiments	326
3. Alternative Designs for Occupancy Monitoring.....	327
4. Habitat Monitoring.....	329
5. Relating Habitat and Owl Occupancy Monitoring	331
6. Conclusions.....	331

APPENDIX G: Laws, Regulations, and Authorities for Recovery Plan

Implementation	332
1. Endangered Species Act	332
2. National Forest Management Act	335

3.	National Environmental Policy Act.....	336
4.	Migratory Bird Treaty Act.....	337
5.	Tribal Lands.....	337
6.	State and Private Lands.....	337
7.	Mexico.....	337

APPENDIX H: Conservation Measures and Management in the United

	States and Mexico	341
1.	Conservation Measures and Management in the United States.....	341
A.	Federal Agencies.....	341
a.	U.S. Fish and Wildlife Service	341
b.	U.S. Forest Service	341
i.	<i>U.S. Forest Service Southwestern Region (Region 3)</i>	341
ii.	<i>U.S. Forest Service Rocky Mountain Region (Region 2)</i>	342
iii.	<i>U.S. Forest Service Intermountain Region (Region 4)</i>	343
c.	National Park Service	343
i.	<i>Bandelier National Monument, New Mexico</i>	344
ii.	<i>Bryce Canyon National Park, Utah</i>	344
iii.	<i>Canyon de Chelly National Monument, Arizona</i>	344
iv.	<i>Canyonlands National Park, Utah</i>	345
v.	<i>Capitol Reef National Park, Utah</i>	345
vi.	<i>Carlsbad Caverns National Park, New Mexico</i>	346
vii.	<i>Chiricahua National Monument, Arizona</i>	346
viii.	<i>Coronado National Memorial, Arizona</i>	346
ix.	<i>Dinosaur National Monument, Colorado</i>	347
x.	<i>Gila Cliff Dwellings National Monument, New Mexico</i>	347
xi.	<i>Glen Canyon National Recreation Area, Arizona and Utah</i>	347
xii.	<i>Grand Canyon National Park, Arizona</i>	347
xiii.	<i>Guadalupe Mountains National Park, Texas</i>	348
xiv.	<i>Mesa Verde National Park, Colorado</i>	348
xv.	<i>Navajo National Monument, Arizona</i>	348
xvi.	<i>Saguaro National Park, Arizona</i>	349
xvii.	<i>Walnut Canyon National Monument, Arizona</i>	349
xviii.	<i>Zion National Park, Utah</i>	350
d.	Bureau of Land Management.....	351
i.	<i>Arizona</i>	351
ii.	<i>New Mexico</i>	351
iii.	<i>Utah</i>	352
iv.	<i>Colorado</i>	353
e.	Department of Defense	353
i.	<i>Fort Huachuca Military Reservation, Arizona</i>	353
ii.	<i>Camp Navajo Garrison Training Center, Arizona</i>	354
iii.	<i>U.S. Naval Observatory Flagstaff Station, Arizona</i>	354
iv.	<i>Kirtland Air Force Base, New Mexico</i>	354
v.	<i>Other Military Involvement</i>	355
f.	Department of Energy.....	355
i.	<i>Los Alamos National Laboratory, New Mexico</i>	355

B.	States	356
a.	Arizona.....	356
b.	Colorado.....	356
c.	New Mexico.....	357
d.	Texas.....	358
e.	Utah	358
C.	Tribes	358
a.	Mescalero Apache Tribe (New Mexico).....	359
b.	White Mountain Apache Tribe (Arizona).....	359
c.	San Carlos Apache Tribe (Arizona).....	359
d.	Jicarilla Apache Tribe (New Mexico).....	360
e.	Navajo Nation (Arizona, New Mexico, Utah).....	360
f.	Southern Ute (Colorado).....	361
g.	Northern and Southern Pueblos Agencies (New Mexico).....	361
2.	Conservation Measures and Management in Mexico	362
A.	Protection Status	362
B.	Records from Natural Protected Areas	362
3.	Binational Conservation Efforts	362

APPENDIX I: Acronyms Used in the Mexican Spotted Owl Recovery Plan..... 364

APPENDIX J: Latin Names of Species Used in the Mexican Spotted Owl Recovery Plan..... 366

APPENDIX K: Glossary 368

LIST OF BOXES IN RECOVERY PLAN

Box 1 in Part II of Recovery Plan: Definition of Mexican spotted owl sites	9
--	---

LIST OF BOXES IN APPENDICES

Box B.1 in Appendix B: Habitat of canyon-dwelling Mexican spotted owls	175
Box B.2 in Appendix B: Rates of wildland fire severity in Mexican spotted owl habitat	190
Box C.1 in Appendix C: Spatial interpretation of Mexican spotted owl management guidelines.....	270
Box C.2 in Appendix C: Defining owl sites	271
Box C.3 in Appendix C: High-elevation mixed conifer forest.....	272
Box C.4 in Appendix C: Criteria useful in designating core areas in absence of next locations	273
Box C.5 in Appendix C: Assessing treatment activities within PACs but outside of core areas	274
Box C.6 in Appendix C: Defining and using reference conditions for Mexican spotted owl nesting/roosting habitat	276

LIST OF FIGURES IN RECOVERY PLAN

Figure 1 in Part II of Recovery Plan: Conceptual Flowchart of Approach to recovery in the Mexican Spotted Owl Recovery Plan, First Revision 3

Figure 2 in Part II of Recovery Plan: Map of Ecological Management Units (EMUs) in the United States 10

Figure 3 in Part II of Recovery Plan: Map of Colorado Plateau EMU 16

Figure 4 in Part II of Recovery Plan: Map of Southern Rocky Mountains EMU 17

Figure 5 in Part II of Recovery Plan: Map of Upper Gila Mountains EMU 18

Figure 6 in Part II of Recovery Plan: Map of Basin and Range - West EMU 19

Figure 7 in Part II of Recovery Plan: Map of Basin and Range - East EMU 20

Figure 8 in Part II of Recovery Plan: Map of Ecological Management Units in Mexico 22

Figure 9 in Part II of Recovery Plan: Photograph of Mexican spotted owl sites within rocky-canyon habitat 31

LIST OF FIGURES IN APPENDICES

Figure B.1 in Appendix B: Mean percentage of PAC habitat burned annually 195

Figure B.2 in Appendix B: Percentage of habitat projected to burn by high-severity fire in 9 National Forests through year 2105..... 196

Figure B.3 in Appendix B: Range map of 3 subspecies of spotted owls..... 244

Figure B.4 in Appendix B: Photographs of spotted and barred owls 245

Figure B.5 in Appendix B: Photographs of tail feathers at different ages 246

Figure B.6 in Appendix B: Map of occupied areas in 5 EMUs in U.S..... 247

Figure B.7 in Appendix B: Maps of predicted Mexican spotted owl habitat and management guidelines..... 248

Figure B.8 in Appendix B: Maps of predicted Northern goshawk habitat and species diversity of other breeding birds 249

Figure C.1 in Appendix C: Conceptual model describing which management guidelines should be followed 269

Figure E.1 in Appendix E: Generalized reproductive chronology for Mexican spotted owls 308

LIST OF TABLES IN RECOVERY PLAN

Table 1 in Part II of Recovery Plan: Key habitat variables and Desired Future Conditions (DFCs) 35

Table 2 in Part II of Recovery Plan: Population data of Mexican spotted owls..... 39

Table 3 in Part II of Recovery Plan: Crosswalk Between Threats and Management Recommendations..... 73

Table 4 in Part II of Recovery Plan: Cumulative range-wide number of breeding sites occupied at least once in the United States since 1989 by land ownership. 77

Table 5. in Part II of Recovery Plan: Amount of area within each Ecological Management Unit in the United States by land jurisdictions/ownerships 78

Table 6 in Part II of Recovery Plan: Federal and State Protected Areas in Mexico with records of Mexican spotted owl..... 79

Table 7 in Part II of Recovery Plan: Protected Areas in Mexico with potential distribution of Mexican spotted owl. 80

Table 8 in Part II of Recovery Plan: Implementation Table..... 94

LIST OF TABLES IN APPENDICES

Table B.1 in Appendix B: PAC area of Mexican spotted owl habitat burned by different fire severities (1996-2005) 193

Table B.2 in Appendix B: Site records by EMU and land ownership..... 235

Table B.3 in Appendix B: Characteristics of study areas where radio-marked Mexican spotted owls were monitored 236

Table B.4 in Appendix B: Size of home ranges or activity centers during breeding and non-breeding seasons. 237

Table B.5 in Appendix B: Spatial overlap among seasonal activity centers 238

Table B.6 in Appendix B: Summary of estimates of reproductive output..... 239

Table B.7 in Appendix B: Summary of estimates of annual survival 240

Table B.8 in Appendix B: Estimates of adult annual survival..... 241

Table B.9 in Appendix B: Numbers of radio-marked Mexican spotted owls migrating during winter 242

Table B.10 in Appendix B: Distance, duration, elevation of movements by migrating Mexican spotted owls..... 243

Table C.1 in Appendix C: Key habitat variables and Desired Future Conditions..... 266

Table C.2 in Appendix C: Minimum conditions for mixed-conifer and pine-oak forest management for nesting/roosting in recovery habitat..... 268

I. RECOVERY PLANS AND PLAN REVISIONS

1. Recovery Plans

The purposes of the Endangered Species Act (ESA) are to provide a means whereby the ecosystems upon which threatened and endangered species depend may be conserved and to provide a program for the conservation of such threatened and endangered species. Section 4(f)(1) of the ESA of 1973, as amended (ESA; 16 U.S.C. 1531), requires a recovery plan be prepared for each listed species, unless such plan will not promote its conservation.

Recovery plans describe the process by which the decline of a threatened or endangered species can be reversed and threats to its survival neutralized so that long-term survival can be ensured. Section 4(f)(1)(B) of the ESA specifies the contents of a recovery plan. Sections of this Revised Recovery Plan meeting these requirements are:

- (1) A description of such site-specific management actions as may be necessary to achieve the Plan's goal for the conservation and survival of the species (Appendix C: General Management Recommendations and Appendix D: Threat-specific Management Recommendations);
- (2) Objective, measurable criteria which, when met, would result in a determination that the species be removed from the list (Part III);
- (3) Estimates of the time required and the cost to carry out those measures needed to achieve the Plan's goal and intermediate steps toward that goal (Part V.1).

Recovery plans are neither self-implementing nor legally binding. Rather, approved recovery plans effectively constitute a USFWS guidance document on that listed species or group of species, thereby serving as a logical path from what is known about the species' biology, life history, and threats to a recovery strategy and program. In some cases, recovery plans are followed by other Federal agencies in order to meet the provisions of 2(c)(1) and 7(a)(1) of the ESA, which require Federal agencies to utilize their authorities in carrying out programs for the conservation of endangered and threatened species. Agency regulations and policies (e.g., those implementing the National Forest Management Act) may also require management under recovery plan guidelines. In addition, international, state, and local governments often follow the recommendations of recovery plans in species-conservation efforts.

2. Recovery Teams

To develop scientifically credible recovery plans for listed species, the U.S. Fish and Wildlife Service (USFWS) may appoint recovery teams comprised of scientists and resource specialists with expertise either on the species being considered or with other relevant knowledge. In the case of the Mexican spotted owl, the USFWS appointed the Mexican Spotted Owl Recovery Team (Recovery Team). A list of Recovery Team members and their areas of expertise can be found in Appendix A.

3. Recovery Plan Revisions

The recovery planning guidance states: “A revision is a substantial rewrite of at least a portion of a recovery plan and is usually required if major changes are required in the recovery strategy, objectives, criteria, or actions” (USDC NMFS and USDI USFWS 2010). A revision may be required when new threats to the species are identified, when research uncovers new life history traits or threats that have significant recovery ramifications, or when the current plan is not achieving its objectives. In some cases, a revision may be undertaken when a significant amount of time has passed and a number of updates have been completed. Section 4(f)(4) of the ESA requires that, prior to approval of a revised recovery plan, the public shall be notified and allowed the opportunity to review and comment on the revision.

4. Revised Mexican Spotted Owl Recovery Plan

The subject of this plan is the Mexican spotted owl. The U.S. Department of the Interior (USDI) USFWS added the Mexican spotted owl (spotted owl or owl) to the List of Threatened and Endangered Wildlife (50 CFR 17.11) as a threatened species, effective 15 April 1993. The Recovery Plan for the Mexican Spotted Owl (Recovery Plan; USDI USFWS 1995) was completed by USFWS Region 2 (Southwest Region) on 16 October 1995. Since that time, we have acquired new information on the biology, status, distribution, and other aspects of the Mexican spotted owl’s life history. This Recovery Plan for the Mexican Spotted Owl, First Revision, revises the 1995 plan, incorporating new information on the species biology, threats, and recovery needs, and outlines a comprehensive program for the species’ recovery.

A conceptual flowchart depicting the philosophy underlying the Recovery Plan is provided by Figure 1, below. As a more specific guide through this plan revision, Table 1 (Part II.8.B) displays an index of the “crosswalk” from the threats identified in Part II of the Recovery Plan to the management recommendations presented in Appendices C and D of the Recovery Plan. Implementing the recovery actions in the original Recovery Plan has resulted in various updates, clarifications, and changes to Recovery Plan recommendations that will lead the species to recovery (see Part I.5. below). There have been changes in land management emphasis, relevant statutes and regulations, and specific threats to the species necessitating re-examination and, ultimately, further revision of the management recommendations (Appendix C: General Management Recommendations and Appendix D: Threat-specific Management Recommendations). Monitoring recommendations in the original Recovery Plan have been modified (Part V.2 and Appendix F - Monitoring), and the implementation and cost schedule has been updated (Part V.1). A summary of changes and rationales for them is provided in Parts I.1.5 and I.1.6 below.

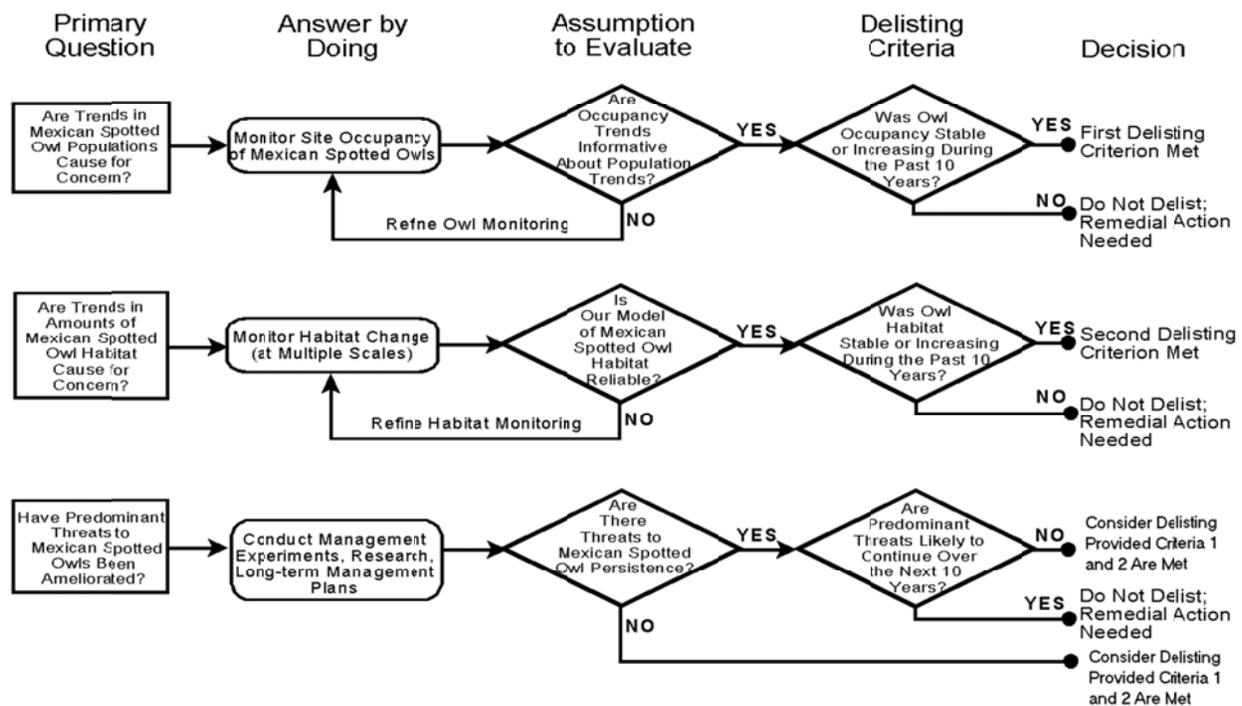


Figure 1. Conceptual flowchart depicting the Recovery Plan’s approach to recovering the Mexican spotted owl

5. Primary Differences From the 1995 Recovery Plan

With new knowledge and experience garnered from implementation of the 1995 Recovery Plan, a number of substantive changes were made in the revision. These include:

Part II:

- Includes an ESA five-factor listing analysis
- Changes Recovery Units to Ecological Management Units to conform to FWS policy.
- Provides a more explicit definition of an owl site
- Merges Southern Rocky Mountain (SRM)-Colorado and SRM-New Mexico EMUs into one (SRM)
- Revises boundary between Colorado Plateau and SRM to reflect ecological differences between the two EMUs
- Extends boundary of Basin and Range East EMU into Texas to incorporate verified sightings and suspected habitat
- Reduces the size of the Basin and Range West EMU by removing much of the western part where there are no records of owls and little, if any, known owl habitat
- Adds descriptions of canyon cover types as they relate to the owl
- Provides a clearer definition of riparian habitats as they relate to the owl

Parts III-V:

- Revise delisting criteria to reflect changes in monitoring requirements (Part III)

Appendices A – H:

- Provide a more explicit definition of an owl site (Appendix C)
- Update management recommendations given new information (Appendices C and D)
- Remove reserved lands from automatic inclusion as protected areas (Appendix C)
- Remove steep slopes from automatic inclusion as protected areas (Appendix C)
- Delineate activities that can be conducted inside of PACs and further specifies activities to occur within and outside of cores. This involves allowing up to 20% of the total PAC area (external to the core) within an EMU to be treated to meet restoration and fuels-reduction objectives.
- Provide guidance for removing PAC status from areas so designated
- Rename “restricted habitat” to “recovery habitat” to more appropriately reflect the intent
- Develop desired future conditions (DFCs) for owls as targets to guide management
- Provide threat-specific management recommendations for noise, recreation, energy development, land development, water development, grazing, insects and disease, fire suppression and related activities, prescribed-fire and wildland-fire use, research, West Nile virus (Appendix D).
- Describe a new approach to monitor owl populations based on owl occupancy (Appendix F)
- Describe a new approach to monitor owl habitat using Forest Inventory Assessment (FIA) data (Part V.2 and Appendix F)
- Include a survey protocol as an appendix (Appendix E).

6. Final Remarks on this Recovery Plan

The Mexican Spotted Owl Recovery Plan, First Revision is based on the best available science. When published papers were not available, the Recovery Team conducted analyses and modeling to inform the development of management recommendations. The management recommendations should not be considered the end point. Rather, they represent a starting point whereby they can be adjusted and improved as new information is acquired.

The Recovery Plan sets forth recommendations for management and monitoring of the spotted owl. Both are key to the eventual recovery of the owl as management proceeds within an adaptive framework whereby monitoring is used to assess the efficacy of management actions. The Recovery Plan requires a landscape approach. Landscape modeling and analysis are critical in evaluating the distribution of owls and habitats, identifying areas where threats are greatest, and then applying plan recommendations in such a way as to sustain and improve owl habitat.

Management recommendations represent a combination of protective and proactive measures. Areas currently occupied by owls require the greatest protection to ensure continued occupancy, reproduction, and survival. By no means, however, does this translate to a hands-off approach. In some cases, protection of these areas requires active intervention to sustain desired future conditions and to reduce risk of habitat-reducing wildfire. These interventions should be done after careful analysis and planning to ensure that actions taken are necessary and prudent.

Forests do not retain their characteristics in perpetuity. They become established, grow, and then enter senescence and lose characteristics favored by owls. As a result, landscapes are dynamic and management must look into the future. As nest/roost stands are lost to natural and unnatural causes, replacement areas should be in the queue ready for owls to occupy them. This is the intent of nest/roost replacement habitat within recovery habitats. Their development will require a balance between intervention and being allowed to develop naturally in absence of intervention. Management should strive to plan well into the future to ensure that an adequate proportion of the landscape in suitable nest/roost conditions to sustain owl populations.

II. BACKGROUND

The following summarizes the biology and ecological relationships of Mexican spotted owls. We intend for this to be an overview of biological characteristics of this subspecies, including those germane to recovering its populations. We emphasize information developed since the original Recovery Plan was published (USDI FWS 1995). Although information gaps still exist, our understanding of the Mexican spotted owl's natural history has increased since 1995. For example, the number of Mexican spotted owls known to dwell in rocky canyon environments has increased greatly. We also have new information on how to predict spotted owl habitat, effects of fire on the owls and their habitat, and estimates of demographic parameters for a few populations. Because the following summary is a brief overview, we urge interested readers to explore Appendix B – Ecology of the Mexican Spotted Owl for a more comprehensive review of scientific literature addressing ecological relationships of Mexican spotted owls.

1. Taxonomy

The Mexican spotted owl (*Strix occidentalis lucida*) is one of three subspecies of spotted owl recognized by the American Ornithologists' Union (AOU) in the last checklist to include subspecies designations (AOU 1957:285). The other two subspecies are the northern (*S. o. caurina*) and the California (*S. o. occidentalis*) spotted owls (Figure B.3 in Appendix B). The Mexican subspecies is geographically isolated from both the California and northern subspecies. Studies suggest that the Mexican spotted owl has been isolated genetically from the other subspecies for considerable time (Barrowclough and Gutiérrez 1990; but see also Funk et al. 2008).

Two other species within the genus *Strix* occur north of Mexico: barred (*S. varia*), and great gray owls (*S. nebulosa*). The great gray owl is a northern species that does not occur within the range of the Mexican spotted owl. Historically, barred owls also did not occur in sympatry with Mexican spotted owls within the United States. However, unconfirmed sightings of both species have been reported from the vicinity of Big Bend National Park in southern Texas in recent times (Wauer 1996), and there are recent confirmed records of barred owls in northern New Mexico (Williams 2005, cited in Cartron 2010). Whether these confirmed records indicate a range expansion by barred owls or simply vagrant individuals is unknown at this time.

Barred owls recently have expanded their range into the Pacific Northwest and California (Gutiérrez et al. 2004, Haig et al. 2004b); they appear to be both displacing territorial spotted

owls and hybridizing with spotted owls there, are seen as a significant threat to continued viability of northern spotted owls (Gutiérrez et al. 2004). Given the situation in the Pacific Northwest with northern spotted owl/barred owl hybrids, it seems likely that hybridization between Mexican spotted owls and barred owls could occur if barred owls expand their range into the range of the Mexican spotted owl.

In Mexico, barred owls and another member of the *Strix* genus, fulvous owls (*S. fulvescens*), are found. The ranges of the Mexican spotted and barred owl may or may not overlap in Mexico (Williams and Skaggs 1993, Howell and Webb 1995); little is known about local distributional patterns and habitats occupied in this zone of apparent overlap (Enriquez-Rocha et al. 1993). The fulvous owl does not appear to be sympatric with spotted owls in Mexico (but it may overlap the distribution of the barred owl slightly; Holt et al. 1999).

2. Description

Mexican spotted owls are identified by sight and sound. Surveys imitating their calls at night often are used to find general areas occupied by the owls, followed by surveys during the day to visually confirm occupancy of sites and record a specific location. In addition, plumage can be used to categorize the age of individuals.

A. Appearance

The Mexican spotted owl is a medium-sized owl without ear tufts. Spotted owls are mottled with irregular white spots on its brown abdomen, back, and head (Figure B.4 in Appendix B). The three subspecies of spotted owls also exhibit color variation in their plumage. The white spots of the Mexican spotted owl are generally larger and more numerous than in the other two subspecies, giving it a lighter appearance. Wing and tail feathers are dark brown barred with lighter brown and white and, unlike most owls in North America, spotted owls have dark eyes (Gutiérrez et al. 1995).

Adult male and female spotted owls are similar in plumage; however, females are larger, on average, than males. Juveniles, subadults, and adults can be distinguished by plumage characteristics (Forsman 1981, Moen et al. 1991). Juvenile spotted owls (hatchling to approximately five months) have a downy appearance (Figure B.4 in Appendix B). Subadults (5 to approximately 26 months) closely resemble adults, but they have pointed tail feathers with a pure white terminal band (Forsman 1981, Moen et al. 1991). The tail feathers of adults (>27 months) have rounded tips, and the terminal band is mottled brown and white (Figure B.5 in Appendix B).

B. Vocalizations

The spotted owl, being territorial and primarily nocturnal, is heard more often than seen. It has a wide repertoire of calls (Forsman et al. 1984, Ganey 1990). Most calls are relatively low in pitch and composed of pure tones (Fitton 1991), thus are well-suited for accurate, long-distance communication through areas of relatively dense vegetation (Fitton 1991, see also Morton 1975, Forsman et al. 1984). Male and female spotted owls can be distinguished by their calls (Figure

B.5 in Appendix B). Males have a deeper voice than females (Forsman et al. 1984) and generally call more frequently than females (Ganey 1990:Fig. 2). The most common vocalization, used more often by males than females (Ganey 1990, Kuntz and Stacey 1997), is a series of four unevenly spaced hoots (see also Forsman et al. 1984, Fitton 1991). Females frequently use a clear whistle ending with an upward inflection as well as a series of sharp barks (Forsman et al. 1984, Ganey 1990:Fig. 1).

Mexican spotted owls call mainly during March to November and are relatively silent from December to February (Ganey 1990), although spontaneous calling has been heard during all months (J. L. Ganey, Rocky Mountain Research Station, unpublished data). Calling activity increases from March through May (although nesting females are largely silent during April and early May) and then declines from June through November (Ganey 1990:Fig. 3). Ganey (1990:Fig. 4) reported that calling activity was greatest during a two-hour period following sunset, with smaller peaks four to eight hours after sunset and again just before sunrise.

3. Distribution

The Mexican spotted owl occurs in forested mountains and canyonlands throughout the southwestern United States and Mexico (Gutiérrez et al. 1995, Ward et al. 1995; Appendix B - 3: Distribution). It ranges from Utah, Colorado, Arizona, New Mexico, and the western portions of Texas south into several States of Mexico (Figure 2; Figure B.3 in Appendix B). Whereas this owl occupies a broad geographic area, it does not occur uniformly throughout its range (USDI USFWS 1995). Instead, the owl occurs in disjunct areas that correspond with isolated mountain ranges and canyon systems. In the United States, the majority of owls are found in National Forests; however, in some areas of the Colorado Plateau Ecological Management Unit, owls are found only in rocky-canyon habitats, which primarily occur on NPS and BLM lands (Table B.2 in Appendix B).

The current distribution of Mexican spotted owls generally follows its historical extent, with a few exceptions (Ward et al. 1995). Although we know of recent winter records, the owl has not been reported recently as a nesting species in riparian corridors outside of prominent canyons along low-elevation or mid-elevation rivers and creeks in Arizona, New Mexico, and historically documented areas in southern Mexico (Williams 1993, Ward et al. 1995). Previously occupied riparian communities in the southwestern United States and southern Mexico have undergone significant habitat alteration since the historical sightings (USDI USFWS 1993). For example, in southern Utah and northern Arizona, inundation of Glen Canyon by Lake Powell created a 299 km (186 mi) long and 40 km (25 mi) wide reservoir that may have flooded habitat for a potentially large subpopulation in the canyonlands region (MacDonald et al. 1991, Willey and Spotskey 2000). Lake Powell may represent a landscape barrier isolating subpopulations in Utah from subpopulations in Arizona (Barrowclough et al. 1999).

In Mexico, information on the status of Mexican spotted owls is limited (Tarango et al. 2001). As in the United States, owl distribution in Mexico appears disjunct (Williams 1993, USDI FWS 1995). The majority of spotted owls has been located in the Sierra Madre Occidental Mountain range (Williams 1993), which includes the states of Chihuahua, Sonora, Sinaloa, Durango, San Luis Potosi, Aguascalientes, Zacatecas, Jalisco, Nayarit, Queretaro, and Guanajuato. It is not

known if the distribution of spotted owls in Mexico has changed nor how many additional sites have been recorded since 1995.

A. Ecological Management Units (EMUs)

The Mexican spotted owl occupies many habitat types scattered across a diverse landscape. In addition to this natural variability in habitat influencing owl distribution, human activities also vary across the owl's range. The combination of natural variability, human influences on owls, international boundaries, and logistics of implementation of the Recovery Plan necessitates subdivision of the owl range into smaller management areas. The 1995 Recovery Plan subdivided the owl's range into 11 "Recovery Units" (RUs): six in the United States and five in Mexico. In this revision of the Recovery Plan, we renamed RUs as "Ecological Management Units" (EMUs) to be in accord with current FWS guidelines (USDC NMFS and USDI USFWS 2010). We divide the owl range within the United States into five EMUs: Colorado Plateau (CP), Southern Rocky Mountains (SRM), Upper Gila Mountains (UGM), Basin and Range-West (BRW), and Basin and Range-East (BRE) (Figure 2). The SRM EMU was created by merging the former Southern Rocky Mountain-New Mexico and Southern Rocky Mountain-Colorado RUs. We also continue to recognize the five EMUs identified in the original recovery plan (USDI USFWS 1995) for Mexico: Sierra Madre Occidental-Norte, Sierra Madre Oriental-Norte, Sierra Madre Occidental-Sur, Sierra Madre Oriental-Sur, and Eje Neovolcanico (Figure 8).

As with RUs in the original Recovery Plan, we use EMUs as geographical subdivisions of the owl range to organize owl recovery efforts. The EMUs allow localized Working Teams of resource managers to coordinate their efforts and share information about owls and owl habitat across administrative boundaries. These Working Teams (see Appendix A) provide an opportunity for interested parties to participate in discussions affecting owl management in a more local area. In addition to activities described in this Plan, the Working Teams may choose to develop and recommend actions they deem necessary to gather information or further owl recovery at the local level.

The boundaries of the 1995 EMUs and the estimate of the species' range extent were based on the best information available when the Recovery Plan was written. Since 1995, additional information has clarified the expected extent of the species range and led to changes in U.S. EMU boundaries. These changes are discussed below.

a. UNITED STATES – Ecological Management Units

In the following sections, we describe dominant physical and biotic characteristics, patterns of owl distribution and habitat use, and the dominant patterns of land ownership and land use within each EMU. We primarily emphasize the U.S. portion of the owl range, with briefer discussion of the Mexico portion. To assist with the transition from the 1995 Plan to this new version, each narrative starts with a brief description of the changes to the EMU configuration since 1995.

We identified the five EMUs based on the following considerations (in order of importance):

- (1) physiographic provinces,
- (2) biotic regimes,

- (3) perceived threats to owls or their habitat,
- (4) administrative boundaries, and
- (5) known patterns of owl distribution.

It is important to note that owl distributional patterns were a minor consideration in EMU delineation, and EMUs do not necessarily represent discrete populations of owls. In fact, movement of individuals between EMUs has been documented (Ganey and Dick 1995). We used four major physiographic provinces in delineating EMUs in the United States: the Colorado Plateau, Basin and Range, Southern Rocky Mountains, and Upper Gila Mountains (Wilson 1962, Bailey 1980). We considered both administrative boundaries of federal agencies and locations of major highways to simplify implementation of the Plan for the Working Teams described above.

Box 1. DEFINING OWL SITES

Our definition of an owl site strives to achieve a balance between being overly inclusive and overly exclusive. An overly inclusive definition could result in PACs where they are not needed; an example might be the detection of a transient owl. In contrast, an overly exclusive definition could result in failure to designate a PAC in an area occupied by ≥ 1 spotted owl. While recognizing the need for balance, we also recognize serious consequences of failing to properly manage occupied owl habitat as the result of an overly exclusive definition. With those considerations in mind, we consider a site to be occupied if any of the following scenarios occur:

1. One daytime location (visual or auditory) of ≥ 1 Mexican spotted owl within the breeding season (Mar-Aug);
2. Two nighttime auditory detections within 500 m (0.31 mi) of each other during the breeding season (Mar-Aug), separated by at least one week;
3. Two owls of different sexes heard on the same night within 500 m (0.31 mi) of each other; or
4. Locating one or more owls born during that breeding season (young-of-the-year) prior to 1 September.

The above criteria assume that daytime detections provide stronger evidence of owl residency than nocturnal detections, and that little dispersal occurs during the survey season. These assumptions are supported in the literature (see Part II and Appendix B). The 500 m (0.31 mi) distance seems reasonable based on current knowledge of movement patterns of radio-marked owls and results of demographic studies involving uniquely banded owls (see Part II and Appendix F).

PACs are intended to protect the activity center of a single owl territory. Therefore, these criteria should *not* be interpreted to mean that multiple PACs need be drawn in areas where multiple detections may represent a single owl territory. In such cases, biologists should use their professional judgment in determining whether or not additional PACs are necessary or in creating PACs larger than 243 ha (600 ac). If biologists from land-management agencies are unsure how best to proceed, we encourage them to work with the appropriate FWS offices and the state wildlife agency in designating PACs.



Figure 2. Ecological Management Units in the United States

i. *Colorado Plateau (CP)*

In this revision of the 1995 Recovery Plan, we have significantly enlarged the CP EMU (Figure 3). We moved the eastern boundary farther east to approximate a physiographic province line in Colorado. We based this change on our assumption that the EMUs should reflect areas of similar habitat, if possible. We moved the northern extent of the EMU to include known owls at Dinosaur National Monument and in similar canyon habitats nearby.

The CP EMU roughly coincides with the Colorado Plateau Physiographic Province, with the exception that the southern end of the plateau is included in the Upper Gila Mountains EMU (see below). It includes most of eastern and southern Utah plus portions of northern Arizona, northwestern New Mexico, southwestern Wyoming, and western Colorado. Major landforms are interior basins and high plateaus dissected by deep canyons, including the canyons of the Colorado River and its tributaries (Williams 1986).

Grasslands and shrubsteppes dominate the CP EMU at lower elevations, with woodlands and forests predominant at higher elevations (Bailey 1980, West 1983). Pinyon pine and various juniper species are the primary tree types in the woodland zone (see Appendix I for scientific names of tree species). A montane zone extends over areas on the high plateaus and mountains (Bailey 1980). Forest types in this zone include ponderosa pine, mixed-conifer, and spruce-fir. Conifers may extend to lower elevations in canyons. Deciduous woody species dominate riparian communities found along streams.

Figure 3 illustrates the currently known distribution of Mexican spotted owls in this EMU; the owl reaches the northern limit of its documented range here. Owl habitat appears to be naturally fragmented in this EMU, with most owls found in disjunct canyon systems or on isolated mountain ranges. In Utah, breeding owls primarily inhabit deep, steep-walled canyons and hanging canyons. These canyons typically are surrounded by terrain that does not appear to provide nest/roost habitat but may provide foraging habitat for spotted owls (Willey 1993). Owls also apparently prefer canyon terrain in southwestern Colorado, such as the known owl locations in and around Mesa Verde National Park. In northern Arizona and northwest New Mexico, owls have been reported in both canyon and montane forest situations (Ganey and Dick 1995).

Looking simply at land ownership, and not at presumed owl habitat, Federal lands account for 46% of the CP EMU (Table 5 and Figure 3). Tribal lands collectively total 27%, with the largest tribal entity being the Navajo Reservation. Private ownership accounts for 19%, and State lands 4%. Approximately 15% of all known owl sites recorded since 1989 occur in the CP EMU. Of the 197 owl sites documented for this EMU, most have been located on NPS lands (62.4%), followed by BLM lands (22.8%), and then USFS lands (14.2%; Table B.2 in Appendix B). One owl site has been documented on Utah Department of Natural Resources lands and an unknown number occur on Tribal lands.

Recreation ranks as a primary land use within CP because of high recreation pressure on public lands. The potential for recreation to affect owl presence and recovery is compounded by the terrain, with owls established in narrow canyons having less opportunity to move away from

human activity. Activities such as hiking, camping, hunting, rock climbing, mountain biking, and off-road vehicle use occur in owl habitat within the EMU. Forest and fire management are important land activities on Forest Service, National Park Service, and Tribal lands. In addition, commercial enterprises take place in the EMU; particularly important are livestock grazing, timber cutting, coal and uranium mining, and oil and natural gas development. Roads, clearing of vegetation, and human disturbance accompany these activities and have the potential to impact owls here.

ii. *Southern Rocky Mountains (SRM)*

We made two principal changes to the SRM EMU in this revision. First, we merged the former Southern Rocky Mountain – Colorado and the Southern Rocky Mountain – New Mexico EMUs (Figure 4). This change was deemed appropriate because management of owls and their habitat did not differ significantly between the two states, and the habitat is similar enough to allow managers to find common solutions to owl management issues. Second, we adjusted the new boundary on the western extent to better follow ecological breaks in habitat between the SMR and CP EMUs.

The SRM EMU falls partly within the Southern Rocky Mountains Physiographic Province and partly within the Colorado Plateau Ecoregion (Bailey 1980). Mountain ranges characterize the EMU. Vegetation varies from grasslands at low elevations through pinyon-juniper woodlands, interior shrublands, ponderosa pine, mixed-conifer and spruce-fir forests, to alpine tundra on the highest peaks (Daubenmire 1943).

This EMU boundary extends to the Wyoming state line based on historical owl records and similarity of habitat (Webb 1983); further owl surveys would help define a more ecologically appropriate range line here. Though found primarily in canyons in this EMU, the owls also occupy forest habitat types. The canyon habitat often has mature Douglas-fir, white fir, and ponderosa pine in canyon bottoms and on the north- and east-facing slopes. Ponderosa pine grows on the more xeric south and west-facing slopes, with pinyon-juniper growing on the mesa tops.

Federal lands encompass 50% of the SRM EMU, with the majority administered by the U.S. Forest Service (USFS), followed by the BLM and NPS (Table 5 and Figure 4). Approximately 43% is private lands, 4% is State lands, and 3% is Tribal lands. Approximately 6% of all Mexican spotted owl sites occur in SRM EMU (Table B.2 in Appendix B). Most of the 71 owls reported for this EMU were documented on USFS lands (83.1%), followed by BLM lands (14.1%). Two sites are known for privately owned lands (Table B.2 in Appendix B). We do not know how many occur on Tribal lands.

Land-use practices throughout the SRM EMU include recreation, ecological restoration, firewood cutting, livestock production, mining, forest fuels management, and energy development, including the associated human presence and development that accompany these uses. Recreational activities include downhill and cross-country skiing, off-road driving, rock climbing, backpacking, camping, hiking, and mountain biking. Transportation and urban development are also considered likely threats to spotted owl habitat in the SRM EMU. In

particular, urban development along the Front Range of Colorado may threaten owl wintering habitat.

iii. Upper Gila Mountains (UGM)

We did not deem any changes necessary to the configuration of the UGM EMU in this revision.

This EMU (Figure 5) primarily is based on the Upper Gila Mountains Forest Province (Bailey 1980), but also includes the southern end of the Colorado Plateau Ecoregion. Williams (1986) refers to this area as the Datil-Mogollon Section, part of a physiographic subdivision transitional between the Basin and Range and Colorado Plateau Provinces. This complex area consists of steep mountains and deep, entrenched river drainages dissecting high plateaus. The Mogollon Rim, a prominent fault scarp, bisects the UGM EMU.

McLaughlin (1986) described a “Mogollon” floral element in this region. The vegetation ranges from grasslands at lower elevations through pinyon-juniper woodlands, ponderosa pine, mixed-conifer, and spruce-fir forests at higher elevations. Many canyons contain stringers of deciduous riparian forests, particularly at low and middle elevations. The UGM EMU contains the largest contiguous ponderosa pine forest in North America, an unbroken band of forest 40 to 64 km (25 to 40 mi) wide and approximately 483 km (300 mi) long extending from north-central Arizona to west-central New Mexico (Cooper 1960).

Mexican spotted owls are widely distributed and use a variety of habitats within the UGM EMU. Spotted owls are most common in mixed-conifer forests dominated by Douglas-fir and/or white fir and canyons with varying degrees of forest cover (Ganey and Balda 1989a, Ganey and Dick 1995, Ward et al. 1995). Spotted owls also occur in ponderosa pine-Gambel oak forest, where they are typically found in stands containing well-developed understories of Gambel oak (Ganey and Dick 1995, Ganey et al. 1999).

Federal lands, mostly USFS, encompass 67% of the UGM EMU (Table 5 and Figure 5). Tribal lands account for 17%, privately owned lands 12%, and State lands 4%. The largest known population of Mexican spotted owls occurs in this EMU, accounting for approximately 63% of all known owl sites (Table B.2 in Appendix B). All of the 684 known owl sites occur on USFS lands within unknown numbers occurring on Tribal lands (Table B.2 in Appendix B). Many spotted owls are found in wilderness areas in this EMU; the Gila Wilderness supports the largest known wilderness population (Ganey et al. 2008).

Major land uses within the UGM EMU include fuels reduction, ecological restoration, livestock production, and recreation. Fuelwood harvest, for both personal and commercial use, occurs across much of the UGM EMU. Livestock grazing is common on USFS lands and large portions of the Fort Apache and San Carlos Indian Reservations. In addition, recreational activities such as hiking, camping, and hunting attract many people to this EMU.

iv. *Basin and Range-West (BRW)*

We made one significant change to the BRW EMU in this revision. Because the southwestern extent of the previous BRW EMU included large areas that did not provide spotted owl habitat, we modified the EMU boundary to omit this area (Figure 6). For convenience, we used highways to define the new southwestern boundary. This boundary does not necessarily denote the true ecological extent of owl occurrence

The Basin and Range Area Province (Bailey 1980) provided the basis for two EMUs. We subdivided the Basin and Range area into eastern and western EMUs using the Continental Divide as the partition. We based the division on differences in climatic and floristic characteristics between these areas. The BRW EMU flora is dominated by Madrean elements, while the BRE EMU shows more Rocky Mountain affinities (Brown et al. 1980, Dick-Peddie 1993).

Geologically, the BRW EMU exhibits numerous fault-block mountains separated by valleys (Wilson 1962). Complex faulting and canyon carving define the physical landscape within these mountains. Vegetation transitions from desert scrubland and semi-desert grassland in the valleys upward to montane forests. Montane vegetation includes interior chaparral, encinal (evergreen oak) woodlands, and Madrean pine-oak woodlands at low and middle elevations, with ponderosa pine, mixed-conifer, and spruce-fir forests at higher elevations (Brown et al. 1980). Isolated mountain ranges are surrounded by Sonoran and Chihuahuan desert basins.

Mexican spotted owls occupy a wide range of habitat types within the BRW EMU. The majority of owls occur in isolated mountain ranges where they inhabit encinal oak woodlands, mixed-conifer, pine-oak, and riparian forests, and rocky canyons (Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992, Ganey and Dick 1995).

Federal lands encompass 40% of the BRW EMU, mostly administered by the USFS followed by the BLM and a small portion by Department of Defense (DoD) and NPS (Table 5 and Figure 6). Privately owned lands amount to 27%, State lands 25%, and Tribal lands (mainly the San Carlos Apache Reservation) 7%. Approximately 12% of all owl sites documented for the United States are found within this EMU. Of the 161 owl sites in this EMU, most occur on USFS lands (96.3%), and the majority of these sites occur in the Coronado National Forest. The other six owl sites occur on DoD (Fort Huachuca) lands (Table B.2 in Appendix B). Also an unknown number occur on Tribal lands.

Recreation dominates land use within the BRW EMU. Activities such as hiking, bird-watching, camping, off-road driving, and hunting are particularly popular. Livestock grazing is widespread, but it is most intensive at low and middle elevations. Urban and rural development and mining activities occur in portions of the EMU. Timber harvest occurs mainly on the San Carlos Apache Indian Reservation. The Coronado, Prescott, and Tonto National Forests have active fuels reduction and forest management programs in place to reduce fire hazard, implement ecological restoration, and provide community protection. Military training maneuvers take place in and around Mexican spotted owl habitat on Fort Huachuca Army Base.

v. *Basin and Range-East (BRE)*

We extended the southeastern boundary of the BRE EMU to incorporate portions of West Texas. This change was based primarily on recent sightings of Mexican spotted owls in the Davis and Chisos Mountains of Texas (Bryan and Karges 2001, J. P. Ward, unpublished data). There also are unverified sightings of *Strix* owls in and near Big Bend National Park, and there may be potential owl habitat along the Rio Grande River in that area that has not been effectively surveyed for owls (Peterson and Zimmer 1998).

We delineated the BRE EMU (Figure 7) based on the Basin and Range Area Province and the Desert and Steppic Ecoregions (Bailey 1980). This EMU is characterized by numerous parallel mountain ranges separated by alluvial valleys and broad, flat basins. The climate features mild winters, as indicated by the presence of broad-leaved evergreen plants at relatively high elevations (USDA FS 1991).

Regional vegetation transitions from Chihuahuan desert scrubland and Great Basin grasslands at lower elevations, through Great Basin woodland (pinyon-juniper) at middle elevations, to petran montane coniferous forests at high elevations (Brown et al. 1980, Dick-Peddie 1993). Montane habitat includes ponderosa pine, mixed-conifer, Madrean pine-oak, and spruce-fir forests and is patchily distributed throughout the higher mountain ranges. Cottonwood bosques as well as other riparian vegetation exist along the Rio Grande corridor. Montane and especially riparian plant communities have been altered considerably by human activities.

Mexican spotted owls occur in the isolated mountain ranges and in deep reticulated canyons scattered across this EMU. They are most common in mixed-conifer forest but are also found in ponderosa pine and Madrean pine-oak forests, riparian habitats, and pinyon-juniper woodland (Skaggs and Raitt 1988, Ward et al. 1995, Bryan and Karges 2001, Mullet 2008). The owl has been found within mixed-conifer and deep rocky canyon habitat in the Guadalupe Mountains National Park (McDonald et al. 1991, Mullett 2008).

Of the BRE EMU land area, Federal lands comprise 35%, private lands 38%, State lands 13%, and Tribal lands 4% (Table 5 and Figure 7). Approximately 14% of all owl sites reported for U.S. lands occur in the BRE EMU (Table B.2 in Appendix B). Of the 188 sites recorded for this EMU, most occur on USFS lands (82.4%) and are primarily concentrated in the Sacramento Mountains of New Mexico in the Lincoln National Forest. Another 17% of these sites are on NPS lands (Table B.2 in Appendix B). Five sites are on private lands, primarily The Nature Conservancy lands, and an unknown number occur on Tribal lands.

Dominant land uses within the BRE EMU include forest management and livestock grazing. Recreational activities such as off-road driving, skiing, hiking, camping, and hunting also are locally common within this EMU.

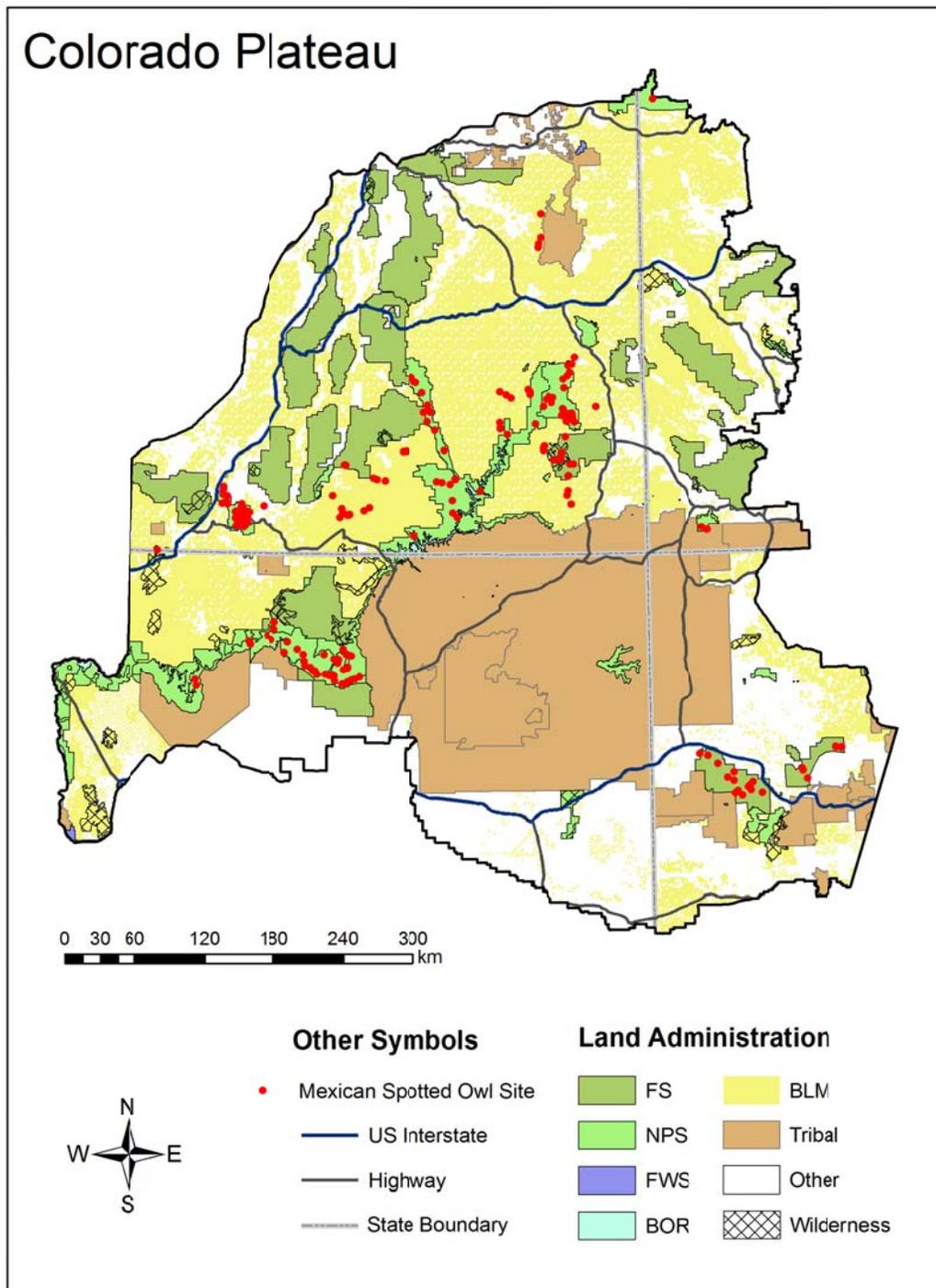


Figure 3. Colorado Plateau Ecological Management Unit

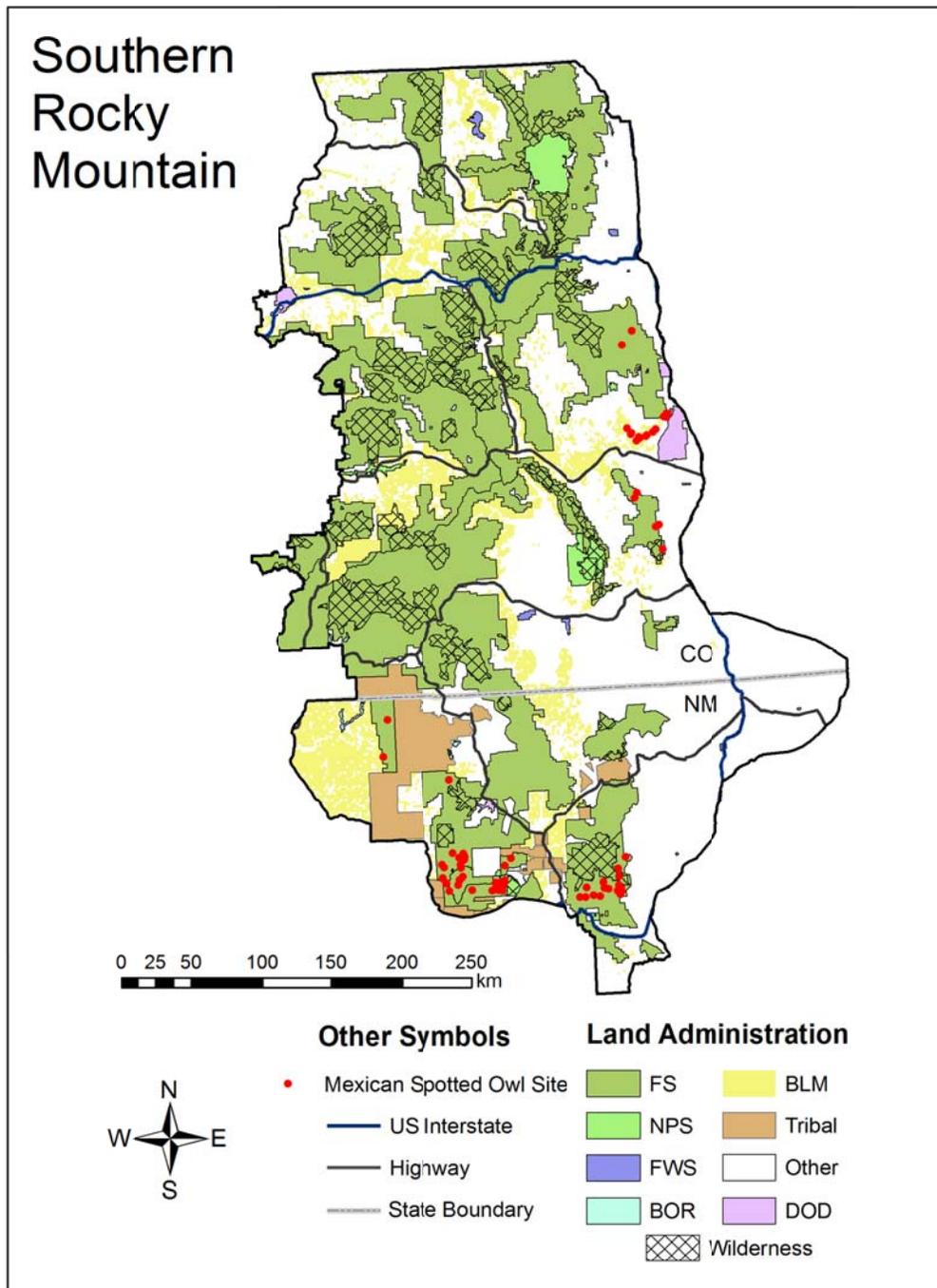


Figure 4. Southern Rocky Mountains Ecological Management Unit

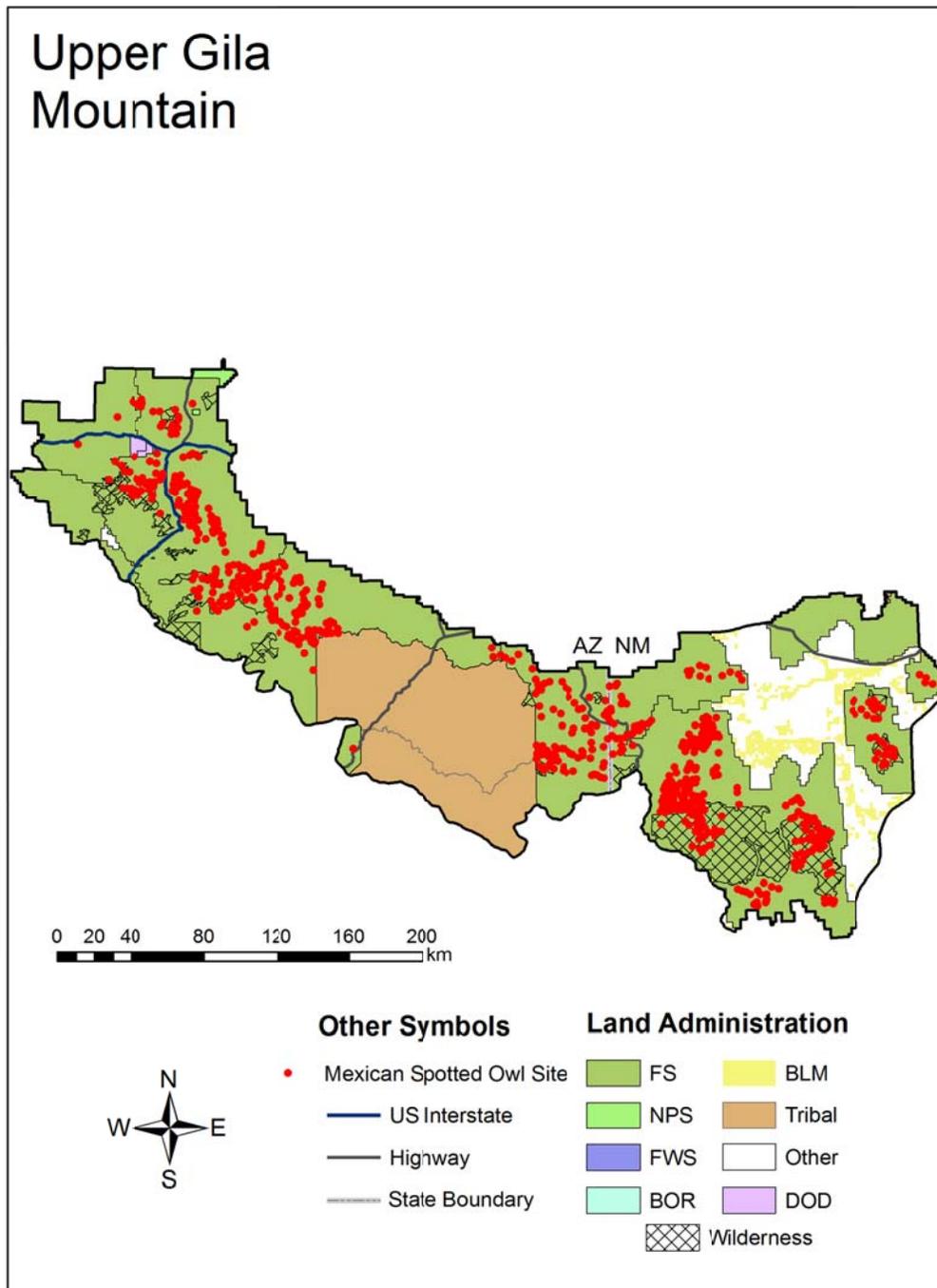


Figure 5. Upper Gila Mountains Ecological Management Unit

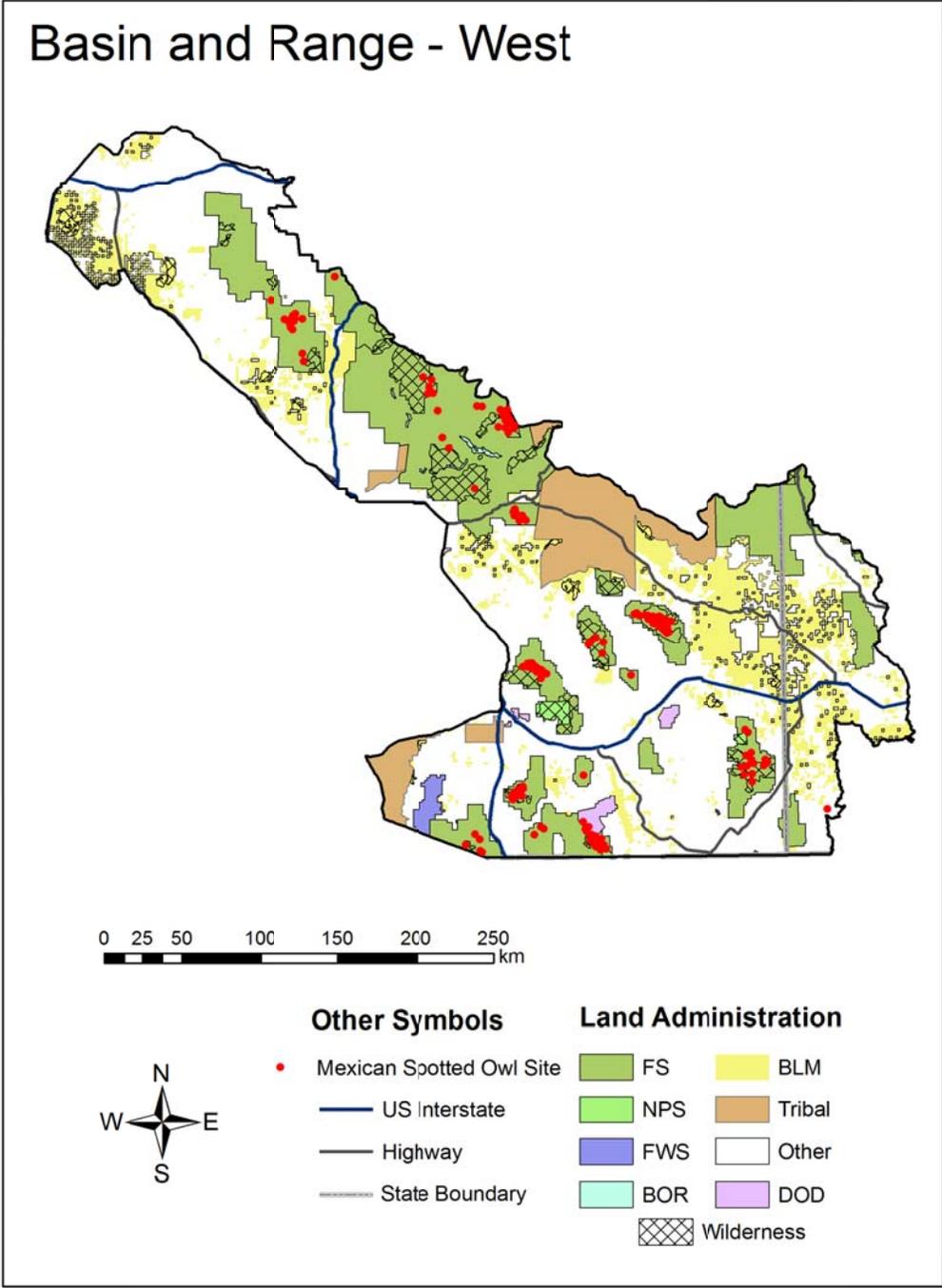


Figure 6. Basin and Range-West Ecological Management Unit

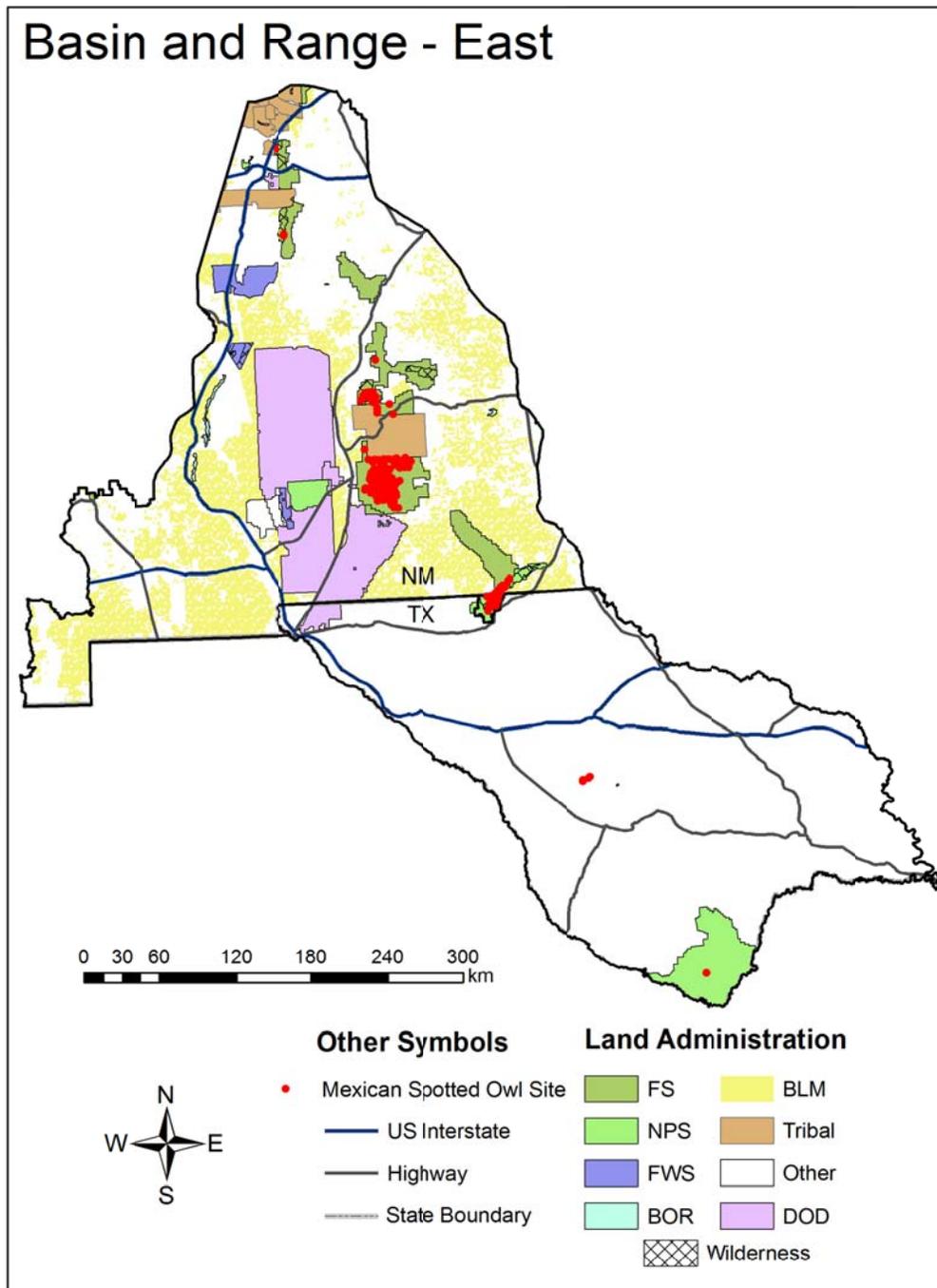


Figure 7. Basin and Range-East Ecological Management Unit

b. MEXICO – Ecological Management Units

The five EMUs in Mexico include: Sierra Madre Occidental – Norte; Sierra Madre Oriental – Norte; Sierra Madre Occidental – Sur; Sierra Madre Oriental – Sur; and Eje Neovolcanico (Figure 8). We used three major physiographic provinces in the delineation: Sierra Madre Occidental, Sierra Madre Oriental, and Sistema Volcanico Transversal (Cuanalo et al. 1989). Criteria we used to delineate EMUs in Mexico were similar to those used in the United States. These criteria, listed in order of importance, were:

- (1) distribution of the spotted owl,
- (2) local vegetation,
- (3) physiographic features,
- (4) administrative boundaries, and
- (5) potential threats to the conservation of the owl and its habitat.

Mexican spotted owl distribution is disjunct across Mexico. Williams and Skaggs (1993) report spotted owls at 53 locations in 11 mainland Mexican States. These were partitioned by Ward et al. (1995) into 35 historical (pre-1989) and 18 current (since 1989) sites (see Young 1996 for additional sites discovered in the Mexican State of Chihuahua). Although vegetation types differ throughout each EMU, oak and pine-oak forest types appeared to be commonly associated with owl habitat in most or all EMUs. These oak species included *Quercus resinosa*, *Q. gentryi*, *Q. eduardii*, *Q. grisea*, *Q. chihuahuensis*, *Q. potosina/Q. laeta*, and *Q. coccolobifolia*. *Pinus teocote* was the most common pine species occurring on upper mesas and occasionally on north-facing slopes in some areas where owls were found. Land uses within all EMUs include timber cutting, cattle and sheep grazing, fuelwood gathering, and clearing forested areas for agriculture. Although these land uses are practiced in different amounts throughout each EMU, the majority occur within ejidos (communally-operated land).

Several Natural Protected Areas (Áreas Naturales Protegidas) in Mexico have records of this species (Table 6) and others have potential habitat but no records of spotted owls (Table 7). The Zona Sujeta a Conservación Ecológica “Sierra Fría” in Aguascalientes is a state protected area where pairs of owls have been documented in six different localities: Barranca El Tiznado, Cueva Prieta, El Carrizal, El Pinal, El Tejamanil, and La Angostura. Since nests have not been found, it is unclear if the species nests in the area (Márquez-Olivas et al. 2002).

There are also records of the Mexican spotted owl in the Reserva de la Biosfera de la Michilía, a Federal protected area in southeastern Durango. According to Garza-Herrera (1999), the species distribution in this Reserve is above 2,330 m (1.46 mi) in conifer and pine-oak forest. He also mentions a crude density of 0.054 owls/km² (0.021 owls/mi²), which is lower than previously reported elsewhere in its range (0.105 to 0.273 owls/km², or 0.041 to 0.105 owls/mi²; Garza-Herrera 1999).

The following narratives describe dominant physical and biotic attributes, distribution of owls, and land administration and ownership of each unit. Where available, we provide a brief description of potential threats to the owl.

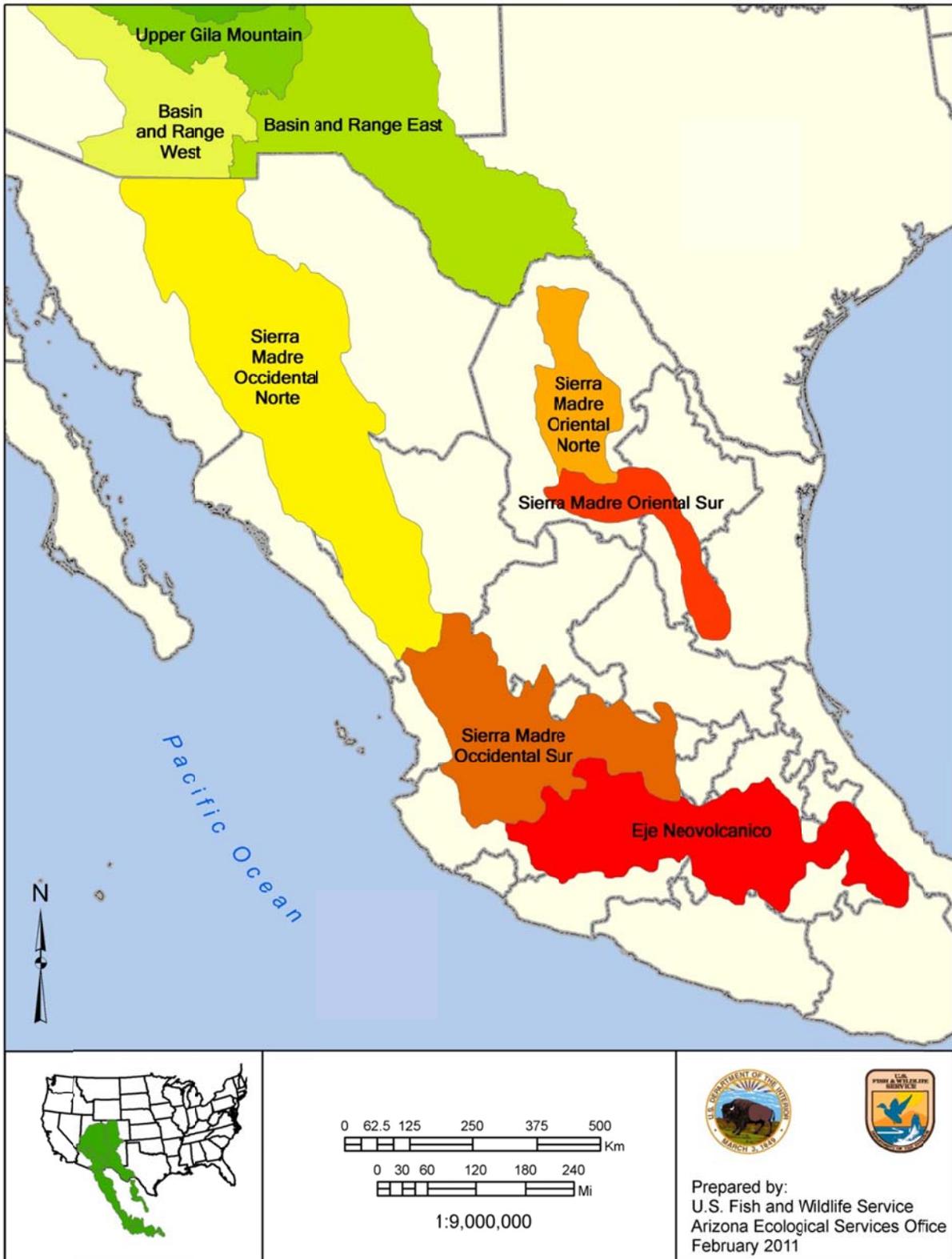


Figure 8. Ecological Management Units in Mexico

i. Sierra Madre Occidental-Norte

Covering an enormous area, the Sierra Madre Occidental - Norte includes parts of the States of Chihuahua, Sinaloa, Durango, and Sonora. In general, this area is characterized by isolated mountain ranges surrounded by both narrow and wide valleys. Vegetation communities consist of pine-oak forest, tropical deciduous forest, oak forest, microphyll shrub, and grassland.

Mexican spotted owls have been reported in the northern and western portions of this EMU. A recent study in Sonora found 12 sites in isolated mountain ranges (Cirett-Galan and Diaz 1993). The owls occupied canyons and slopes with various exposures, and most were found in pine-oak forest. In portions of Chihuahua, 25 owls were located at 13 different localities in several mountain ranges (Tarango et al. 1997). Most owls were found in small, isolated patches of pine-oak forest in canyons. Records for the State of Sinaloa are limited. There are at least two records from the high Rancho Liebre Barranca, near the Sinaloa-Durango State line (Williams and Skaggs 1993). These sites were described as deep canyons containing pine-oak and subtropical vegetation (Alden 1969).

A study by CONANP (National Commission on Natural Protected Areas) and PRONATURA-SUR in 2008 concluded that large-scale logging operations in the Sierra Madre Occidental have destroyed large areas of tree coverage to supply paper and to clear forests in order to prevent wildfires and the spread of pests (CONANP-Pronatura sur 2008).

ii. Sierra Madre Oriental-Norte

The Sierra Madre Oriental-Norte includes the central portion of the State of Coahuila. This area is characterized by broad mountain ranges surrounded by valleys. Vegetation consists of grasslands, mesquite woodland, dwarf oak groves, submontane shrubland, desert shrubland, crasicaule shrub, and pine-oak and oak forests.

Two owl records are reported for this EMU. At one of these sites an owl was observed roosting in a canyon bottom under a dense canopy of maples and oaks. Vegetation in the other canyon was described as “garden-like,” containing pines, oaks, and madrones (Williams and Skaggs 1993).

iii. Sierra Madre Occidental-Sur

The Sierra Madre Occidental-Sur EMU includes parts of the States of Durango, Zacatecas, San Luis Potosi, Aguascalientes, Jalisco, Nayarit, Queretaro, and Guanajuato. In general, this area is characterized by isolated mountains, valleys, and severely dissected canyons and gorges. Vegetation includes mesquite woodland, submontane shrub, grasslands, pine-oak forest, crasicaule shrub, low tropical deciduous forest, and desert shrubland.

Records exist for Mexican spotted owls in La Michilia Biosphere Reserve. In addition, Mexican spotted owls have been found in Aguascalientes near the border of Zacatecas, in the Sierra Fria (Williams and Skaggs 1993, Marquez-Olivas et al. 2003), and in Zacatecas state near Valparaiso (Bravo-Vinaja et al. 2005). Owl records also exist within Guanajuato State.

Logging is prohibited in Sierra Fría and security guards inspect every vehicle driving through the area to stop illegal timber harvest as part of the protected area management (Tarango et al. 2001).

iv. *Sierra Madre Oriental-Sur*

The Sierra Madre Oriental - Sur includes parts of the States of Coahuila, Nuevo Leon, and Tamaulipas. This EMU is characterized by long ridges with sharp pinnacles, narrow valleys, and a few plateaus. Vegetation consists of pine forest, submontane shrublands, dwarf oak, and desert roseto shrublands.

Mexican spotted owls have been found in the southern portions of Coahuila (Williams and Skaggs 1993) and in Tamaulipas (Ward et al. 1995). The owls were found in oak, pine, juniper, and mixed-conifer forests. They were reported to use cliff sites for nesting and roosting. Five locations have been reported in Nuevo Leon. These sites were described as pine-oak and mixed-conifer forests with large cliffs having northeast exposures.

In the Sierra Madre Oriental devastating wildfires scorched large areas of old-growth forests. Two hundred hectares (ha) (494 acres [ac]) of mature forest were lost in El Taray in 2006, and 400 ha (988 ac) were burned in the Municipio de Santiago Nuevo León in 2008 (CONANP-Pronatura Noreste 2008). In some areas like the Parque Nacional Sierra de San Pedro Mártir, another threat to forest habitat of the spotted owl is the spread of bark beetles during the dry season. Since these insects are part of the ecology of the area, the full scope of this problem should be studied (CONANP 2006).

v. *Eje Neovolcanico*

The Eje Neovolcanico EMU covers portions of the States of Jalisco, Michoacan, Guanajuato, Queretaro, Hidalgo, Guerrero, Puebla, Morelaos, Tlaxcala Veracruz, Oaxaca, and Mexico City. This EMU is characterized by volcanic cones severely dissected by ravines. The area also includes rounded hills, slopes, and plateaus. Vegetation communities include pine-oak forest, grassland, low tropical deciduous forest, crasicaule shrub, oak forest, juniper forest, pine forest, mesquite woodlands, and desert shrublands.

Mexican spotted owls have been reported in Jalisco on the volcano of Cerro Nevado de Colima (Voacan de Nieve). Vegetation in this area consists of pine-oak forest. One Mexican spotted owl was collected near the city of Uruapan in the State of Michoacan at Cerro de Tancitaro. However, this area is now developed and no longer contains owl habitat. Although other states in this EMU appear to contain suitable owl habitat, Jalisco is the only state known to have recent records of spotted owls.

In this EMU, increased habitat modifications in proximity to urban areas pose threats to the owl (Navarro-Sigüenza et al. 2007). Human overpopulation and associated activities such as agriculture, cattle raising, and other land-uses threaten various organisms (Navarro-Sigüenza et al. 2007). This area also faces deforestation, illegal extraction of soil and volcanic rocks, illegal hunting and poaching, burning of natural vegetation to increase cattle forage, and wildfires by arson, all of which increase threats to the spotted owl (Navarro-Sigüenza et al. 2007).

4. Definitions of Forest Types and Canyon Habitat

In this Recovery Plan we propose specific guidelines for several forest cover types based on: (1) considerable evidence that these cover types provide habitat for nesting, roosting, and foraging activities by Mexican spotted owls (Ganey and Dick 1995); and (2) our desire to target guidelines for the most appropriate habitats. In addition to a discussion on forest cover types referenced in this plan, we revised this section from the 1995 Recovery Plan to include a discussion on canyon cover type.

A. Forest Types

Numerous treatments deal with the concepts of classifying vegetation to cover or habitat types (e.g., Daubenmire 1952, 1968; Pfister 1989). We will not review these concepts in any depth here. In general, we accept the view that the basic unit of classification of climax vegetation is the plant association (Küchler 1964, Daubenmire 1968, Pfister 1989). These associations are defined using information on present species composition and successional pathways. However, under natural disturbance regimes, many southwestern forests may not attain climax conditions, so application of plan guidelines to plant associations may not be appropriate. For example, in an analysis of Mexican spotted owl habitat on the Alpine Ranger District, Apache-Sitgreaves National Forest, we determined that habitat classifications based on current and climax vegetation gave very different results. Based on current vegetation, important roosting and nesting habitat was classified as mixed-conifer forest. The same forests would be classified as spruce-fir based on potential natural vegetation. This demonstrates the need for clear operational definitions of forest types to be used when applying guidelines under this plan.

In this section, we provide operational definitions for forest types referred to in the plan, and a simple key to these types. This key will allow land managers to classify lands in a manner compatible with the recommendations we provide in this plan. A review of literature on classification of forest types in southwestern forests was provided in the 1995 Recovery Plan and is not repeated here.

B. Plan Definitions for Forest Types

This classification scheme is primarily concerned with a subset of the available forest types in the southwestern U.S. We are interested in both potential and existing vegetation. Consequently, this scheme is a hybrid of classification schemes based on potential vegetation (series, association, and habitat type) and forest cover types based on existing vegetation.

Three terms used in these definitions require clarification: pure, majority, and plurality. Various definitions describe a pure stand. Daniels et al. (1979) described pure stands as those where $\geq 90\%$ of the dominant or co-dominant trees are of a single species. Dominant trees are those whose crown extends above the general level of the main canopy (Helms 1998). The crowns of co-dominant trees help to form the main canopy in even-aged stands. In uneven-aged stands, crowns of co-dominant trees are above the crowns of the tree's immediate neighbors and receive full light from above and partial light from the sides (Helms 1998). Under this definition, a stand may have an understory of other species without changing the pure designation. The key to this

concept is the distinction between the dominant and co-dominant species and the understory component.

In contrast, Eyre (1980) defined a pure stand as one where $\geq 80\%$ of the stocking is by one species. For purposes of this plan, we use the term pure to refer to any stand where a single species contributes $\geq 80\%$ of the basal area of dominant and co-dominant trees. We use the term majority to refer to the situation where a single species contributes $\geq 50\%$ of the basal area (Eyre 1980). We use the term plurality to refer to the situation where a species (or group of species of interest) comprises the largest proportion, but not a majority, of a mixed-species stand (Eyre 1980). With these definitions and concepts in mind, we provide definitions for specific forest types below.

a. Ponderosa Pine (*Pinus ponderosa*) Forest Type

The ponderosa pine forest type occurs in what Moir (1993) described as the Lower Montane Coniferous Forest. Forests in this zone are dominated by pines, sometimes co-occurring with junipers and oaks. The climate is sometimes not conducive for forests, with moisture becoming limiting in the upper portions of the soil profile during part of the long growing season. We define the ponderosa pine forest type as:

- (1) Any forested stand of the *Pinus ponderosa* series not included in the Pine-oak Forest Type (see below), or;
- (2) Any stands that qualify as pure (Eyre 1980) ponderosa pine, regardless of the series or habitat type.

b. Pine-oak Forest Type

A number of habitat types exist in the southwestern United States that could be described as pine-oak forests. Most of the stands relevant to the recovery of the Mexican spotted owl fall within two series, the *Pinus ponderosa* series and the Chihuahua pine (*Pinus leiophylla*) series. Present evidence, however, suggests that the former series includes many areas that could never attain the type of forest structure sought by spotted owls for roosting and nesting. Therefore, we use the following operational definition for pine-oak forest under this plan:

- (1) Any stand within the *Pinus leiophylla* series.
- (2) Any stand within the *Pinus ponderosa* series that meets the following criteria simultaneously:
 - a. Habitat types that reflect Gambel oak (*Quercus gambelii*) or a *Quercus gambelii* phase of the habitat type.
 - b. The stand is located in the UGM EMU, the BRW EMU, or the Zuni Mountains or Mount Taylor regions of the CP EMU.
 - c. $\geq 10\%$ of the stand basal area or $4.6 \text{ m}^2/\text{ha}$ ($20 \text{ ft}^2/\text{ac}$) of basal area consists of Gambel oak $\geq 13 \text{ cm}$ (5 inches) diameter at root collar.
- (3) Any stand within the BRW EMU of any other series that meets the following criteria simultaneously:
 - a. A plurality (Eyre 1980) of the basal area exists in yellow pines: ponderosa pine, Arizona pine (*Pinus arizonica*), Apache pine (*Pinus engelmannii*), or Chihuahua pine.

- b. $\geq 10\%$ of the stand basal area or $4.6 \text{ m}^2/\text{ha}$ ($20 \text{ ft}^2/\text{ac}$) of basal area consists of any oaks $\geq 13 \text{ cm}$ (5 inches) diameter at root collar.

c. Mixed-conifer Forest Type

Natural variability is high within this forest type and has been increased by natural and human-caused disturbances. This variability is the result of mixed-conifer forest occupying a continuum of sites situated between drier and warmer ponderosa pine forests and wetter and cooler spruce-fir forests. Despite this variability, an extant classification scheme based on series and habitat types (Layser and Schubert 1979, Hanks et al. 1983, Alexander et al. 1984a, b; Youngblood and Mauk 1985, DeVelice et al. 1986, Alexander and Ronco 1987, Fitzhugh et al. 1987) is available. This classification system is in widespread use and has multiple agency support. Given that background, we propose using that system as a starting point in defining mixed-conifer forest, with some added refinements. Specifically, we propose that the definition of mixed-conifer forest generally be confined to the following series (Layser and Schubert 1979) and associated habitat types: white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), or blue spruce (*Picea pungens*). Within this framework, we provide the following exceptions to the general guideline listed above:

- (1) Any stand within the bristlecone pine (*Pinus aristata*), Engelmann spruce (*Picea engelmannii*), or corkbark fir (*Abies lasiocarpa*) series not having a majority (Eyre 1980) of basal area in bristlecone pine, Engelmann spruce, corkbark fir, or ponderosa pine, singly or in combination also should be classified as mixed-conifer.
- (2) Stands that can be described as pure (Eyre 1980) for coniferous species other than Douglas-fir, white fir, southwestern white pine (*Pinus strobiformis*), limber pine, or blue spruce should be excluded from the broad category of mixed conifer for the purposes of plan implementation regardless of the series or habitat type.
- (3) Stands of mixed species with $>50\%$ of the basal area consisting of quaking aspen should be defined as quaking aspen for the purposes of Plan implementation regardless of the series or habitat type.

d. High-elevation Forest Type

We define high-elevation forest as any stand of the *Pinus aristata*, *Picea engelmannii*, or *Abies lasiocarpa* series that meets the following criteria:

- (1) The majority (Eyre 1980) of stand basal area consists of any of the three species listed above either singly or in combination, or
- (2) Any stands that qualify as a pure stand (Eyre 1980) of any of these species, regardless of the series or habitat type.

e. Quaking Aspen (*Populus tremuloides*) Forest Type

We define as quaking aspen forest type any stands with $>50\%$ of the total basal area consisting of quaking aspen.

f. Riparian Forest Type

Riparian forest consists of plant assemblages associated with the increased availability of moisture and micro-climatic conditions created by the presence of nearby surface or subsurface water. Within the range of the owl, these forests are highly variable but typically have vegetative assemblages that differ in species and/or form from surrounding areas due to the more mesic conditions. Although small in extent relative to surrounding vegetative communities, riparian areas in the southwestern United States are among the most productive and diverse communities, with a biological importance much greater than suggested by their area (Minckley and Brown 1982, Naiman and Décamps 1997). Riparian forests can provide nesting, roosting, and foraging habitat for owls and may be important dispersal corridors (e.g., Ganey and Dick 1995, Stacey and Hodgson 1999).

Defining and delineating riparian zones is problematic because they exist as an ecotone from wet to upland areas and are generally more heterogeneous spatially due to increased disturbance and differing life-history strategies of their constituent organisms (Naiman and Décamps 1997).

However, within the range of the owl, riparian forests generally are characterized by:

- (1) Presence of riparian species, such as cottonwoods (*Populus* spp.), maples (*Acer* spp.), box elder (*Acer negundo*), alders (*Alnus* spp.), and willows (*Salix* spp.) (Minckley and Brown 1982).
- (2) Presence of species found in adjacent upland community. Prominence of these species is more extensive within higher elevation riparian forests in this area (Minckley and Brown 1982).
- (3) Generally higher basal area, stem densities, and above-ground biomass than adjacent upland communities (Naiman and Décamps 1997).

C. Key to Forest Types Referenced in the Recovery Plan

Note: Bold-faced names on the right side of the key are identified forest cover types. Numbers on the right side refer the user to the corresponding number on the left side of the key.

- | | | |
|-----|---|-------------------------------------|
| 1. | Trees deciduous and broadleaved, often confined to floodplain, drainage, or canyon bottom (Layser and Schubert 1979) | Riparian Forest |
| 1. | Dominant trees evergreen and/or needle-leaved | 2 |
| 2a. | Series = <i>Pseudotsuga menziesii</i> , <i>Abies concolor</i> , <i>Pinus flexilis</i> , or <i>Picea pungens</i> | 3 |
| 2b. | Series not as above | 5 |
| 3a. | >80% of dominant and codominant trees are species other than <i>Pseudotsuga menziesii</i> , <i>Abies concolor</i> , <i>Pinus strobiformis</i> , <i>Pinus flexilis</i> , or <i>Picea pungens</i> | Classify by Dominant Species |
| 3b. | Stand not as above | 4 |

4a.	<i>Populus tremuloides</i> contributes >50% of stand basal area	Quaking Aspen Forest
4b.	Not as above	Mixed- Conifer Forest
5a.	Series = <i>Pinus leiophylla</i>	Pine-oak Forest
5b.	Series not as above	6
6a.	Series = <i>Pinus ponderosa</i>	7
6b.	Series not as above	10
7a.	Habitat type or phase includes <i>Quercus gambelii</i>	8
7b.	Not as above	Ponderosa Pine Forest
8a.	Area is located within UGM EMU, BRW EMU, or the southeastern portion of the CP EMU (Zuni Mtns., Mt. Taylor)	9
8b.	Area not located as above	Ponderosa Pine Forest
9a.	>10% of stand basal area or 4.6 m ² /ha (20 ft ² /ac) consists of <i>Quercus gambelii</i> >13 cm (5 inches) diameter at root collar	Pine-oak Forest
9b.	Not as above	Ponderosa Pine Forest
10a.	Series = <i>Pinus aristata</i> , <i>Picea engelmannii</i> , or <i>Abies lasiocarpa</i>	11
10b.	Series not as above	13
11a.	Stand can be defined as pure for <i>Pinus aristata</i> , <i>Picea engelmannii</i> , or <i>Abies lasiocarpa</i>	Spruce-fir Forest
11b.	Stand not as above	12
12a.	<i>Pinus aristata</i> , <i>Picea engelmannii</i> , or <i>Abies lasiocarpa</i> contribute >50% of the stand basal area, either singly or in combination	Spruce-fir Forest
12b.	Stand not as above	Mixed-conifer Forest
13a.	Stand located in BRW EMU	14
13b.	Stand not located as above	Other

14a.	A plurality of stand basal area is contributed by <i>Pinus ponderosa</i> , <i>Pinus engelmannii</i> , or <i>Pinus leiophylla</i> , either singly or in combination	15
14b.	Stand not as above	Other
15a.	>10% of stand basal area or 4.6 m ² /ha (20 ft ² ac) consists of any oak >13 cm (5 inches) diameter at root collar	Pine-oak Forest
15b.	Stand not as above	Other

D. Rocky-Canyon Habitat

Mexican spotted owls occupy rocky-canyon habitats that differ in many ways from forest habitats. Although rocky-canyon habitat is primarily located within the CP EMU, structurally similar canyon habitats also occur within other EMUs. Review of available studies suggests several habitat characteristics are closely associated with owl sites in rocky-canyon environments, especially steep canyon walls with isolated pinnacles and rims with large vertical cliffs. Cliff faces contain numerous caves and ledges that create protected microsites for nesting and roosting, and canyon walls are typically dissected by narrow, tributary canyons that provide relatively cool and humid roost and nest sites. In essence, rocky cliffs and slot canyons provide complex nesting and roosting habitat structure similar to that typically associated with late-seral forest (Rinkevich and Gutiérrez 1996, Willey 1998a, Johnson 1997).

E. Definition for the Rocky-Canyon Habitat

Rocky-canyon environments that provide nest, roost, and foraging habitats for Mexican spotted owls are diverse but also possess common emergent properties. These rocky-canyon habitats are associated with complex vertical and horizontal landscape structure, complex geomorphology, and canyon-forming geologic substrates. Rocky-canyon habitat is defined by:

- (1) Canyon walls comprised of steep cliffs (>90 degree slopes) that extend for at least 1 km (0.6 mi) along parallel sides of the canyon reach (Willey et al. 2007).
- (2) Canyon widths are typically relatively narrow (<1 km rim to rim) (Willey 1998b).
- (3) Presence of large cliff faces (typically >15 m [16.25 yd] tall and ≥ 90 deg slopes) with numerous ledges and caves that provide locations with cool and shaded microclimates (D. Willey, Montana State University, pers. comm.).
- (4) Rocky-canyon habitat occurs in key geologic layers that form steep, narrow entrenched canyons and cliffs with extensive ledge structures. On the CP these formations are generally hard sandstones or limestone, but other forms of bedrock can create these conditions within the range of the owl.
- (5) Forest vegetation, when present, includes riparian, mixed-conifer, pine-oak, and pinyon-juniper woodland. Late seral conditions including large trees and multi-storied canopies typically dominate within forest stands present in rocky-canyon habitat.

Willey and Spotskey (2000) and Willey et al. (2007) developed Geographic Information Systems (GIS)-based regression models that predicted the potential distribution of nest and roost habitat in Utah. Those models were parameterized using variables that represented the habitat

characteristics outlined above. GIS maps produced by these models provided an approximation of the distribution and extent of habitats that meet characteristics defining the rocky-canyon habitat (Figure 9). Similar GIS models are available for managers working in other areas where owls are using rocky-canyon habitat (Johnson 2003, Mullet 2008).



Figure 9. Photograph illustrating Mexican spotted owl sites within the rocky-canyon habitat.

5. Habitat Use

Although Mexican spotted owls have been observed to nest, roost, forage, and disperse among a diverse array of biotic communities, the owl is typically considered a “habitat specialist” in that roost and nest habitats classically occur in late seral forests or rocky canyon habitats. Some spotted owls undergo altitudinal migrations during winter where habitat structure and composition differ from that used during breeding (refer to Appendix B - 5 for a more comprehensive discussion).

A. Nesting and Roosting Habitat

In areas within Arizona and New Mexico, owls occur in both forested and rocky-canyon habitats. Forests used for roosting and nesting often contain mature or old-growth stands with complex structure (USDI FWS 1995:26). Forests used by spotted owls are typically uneven-aged, are multistoried, and have high canopy cover (USDI FWS 1995:27). In these areas, nest trees are typically large (average diameter of nest trees is 61 cm [24 inches]), although owls roost in both

large and small trees (Ganey 1988, Seamans and Gutiérrez 1995, Willey 1998b, Ganey et al. 2000, May and Gutiérrez 2002, May et al. 2004). Tree species used for nesting vary somewhat among areas and cover types, but Douglas-fir is the most common nest tree in many areas (SWCA, Inc. 1992, Willey 1998b).

In parts of its range, the Mexican spotted owl occupies a variety of steep, rocky-canyon habitats (Ganey and Balda 1989a, Rinkevich and Gutiérrez 1996, Willey 1998a, Willey and Van Riper 2007). Most notably, the rocky-canyon habitats of Utah typically include landscapes with complex tributary canyons, a variety of desert scrub and riparian vegetation communities (Brown et al. 1980), and prominent vertical-walled cliffs (Rinkevich and Gutiérrez 1996, Willey 1998a, Willey et al. 2007, Mullet 2008). Within these canyons, owls nest and roost on cliff faces using protected caves and rocky ledges (Willey 1998a).

In northern New Mexico, the volcanic-tuff canyons of Bandelier National Monument also provide many pot-holes, ledges, and small caves for owls to use as daytime roosts and nests (Johnson and Johnson 1985). Mexican spotted owls also occur within the complex canyon networks of the Guadalupe Mountains in southern New Mexico and west Texas. Mullet and Ward (2010) quantified 21 microhabitat features surrounding known nest and roost sites to characterize conditions within canyon habitats in the Guadalupe Mountains. Mexican spotted owl nest and roost sites were associated with steep and relatively narrow canyons, high canopy cover, saplings in the understory, and rocky outcrops.

B. Foraging Habitat

Mexican spotted owls appear to use a wider variety of cover types for foraging than for roosting or nesting (Ganey and Balda 1994, Ganey et al. 2003). Radio-marked owls in Arizona foraged more than expected in unlogged forest (Ganey and Balda 1994), and Ward (2001) found that woodrats (an important prey item for Mexican spotted owls) were more abundant in late-seral mixed-conifer forests. However, owls forage in a variety of habitats: managed and unmanaged forests, pinyon-juniper woodlands, mixed-conifer and ponderosa pine forests, on cliff faces and terraces between cliffs, and along riparian zones (Ganey and Balda 1994, Willey 1998a,b; Ganey et al. 2003, Willey and Van Riper 2007).

C. Home Range and Territoriality

Spotted owls are territorial in the sense that mated pairs defend a breeding territory within a larger home range (or use area). Fidelity to these territories is relatively high in Mexican spotted owls, with most owls remaining on the same territory year after year (Ganey 1988, Gutiérrez et al. 1995). Investigators have studied home-range size of Mexican spotted owls by monitoring movements of radio-marked owls in a number of different geographic areas and habitats. Mexican spotted owls use relatively large home ranges, and home-range size appears to vary among geographic areas and habitats (Ganey and Balda 1989a, Zwank et al. 1994, Willey 1998b, Ganey et al. 2005, Willey and Van Riper 2007, Bowden 2008). Some of this variation may be due to differences in methodology among studies, but we assume that some of the observed variation is real rather than an artifact of methodology. Information on area requirements can inform conservation decisions. At this time, the relative influences of biogeographic regions versus local differences in habitat quality on home-range size of Mexican spotted owls remain

unclear, although limited information suggests that such local differences can be important (Ganey et al. 2005, see also Carey et al. 1992, Zabel et al. 1995).

In all study areas, smaller areas of concentrated use (activity centers) occurred within owl home ranges. The size of Protected Activity Centers (PACs) as defined both here and in the 1995 Recovery Plan (Ganey and Dick 1995:84-89) is based on the size of these activity centers (i.e., 75% adaptive kernel isopleths), not home ranges, in an attempt to focus management on central areas within the home range most important to the owls (See Appendix C). Although the minimum PAC area is 243 ha (600 ac), there is no upper limit for PAC sizes. PACs are defined as the area of concentrated use by a single owl or pair of owls and provides a location for specific management actions. In addition, core areas (40 ha [100 ac]) within PACs also receive concentrated use during the breeding season and include the most immediate area surrounding frequently used roosting sites and nest locations. Habitat used for nesting and roosting within PACs is emphasized because the owls are most selective for such habitat (Ganey and Dick 1995, Appendix B) and these forest conditions are most limited across the landscape. These areas also provide resources to meet other life-history needs of the owl. Thus, core areas are smaller and nested within PACs, which generally are smaller than owl home ranges (see Appendix B - 5.b).

D. Juvenile Dispersal

Spotted owls appear to be obligate dispersers, with all juveniles dispersing from natal areas. Most radio-marked juvenile spotted owls were observed to disperse in September and October, with the majority dispersing during September (Arsenault et al. 1997, Ganey et al. 1998, Willey and Van Riper 2000). Like the other spotted owl subspecies, juvenile Mexican spotted owls are capable of moving long distances (Ganey et al. 1998, Willey and Van Riper 2000). However, based primarily on work on Northern spotted owls (Forsman et al. 2002), we believe that most successfully dispersing juveniles occupy territories near their natal territory. For example, distance from the natal site to the last observed location for radio-marked juveniles observed by Ganey et al. (1998) ranged from <1 to >92 km (<0.6 to 57 mi). Juvenile Mexican spotted owls move through a wide variety of habitats during the dispersal period, and many of these habitats differ greatly from typical breeding habitat and have no formal protective measures under the 1995 Recovery Plan (i.e., they fall under the category of other forest and woodland types; Ganey and Block 2005a).

E. Migration and Wintering Areas

Although most radio-marked Mexican spotted owls remained on or near their breeding territory throughout the year, some owls migrated during winter. This migration generally entailed a change in elevation as Mexican spotted owls moved down slope (Willey 1998a, Ganey and Block 2005b). Migrating radio-marked owls typically left study areas in November or December and returned from January to April. Distances moved typically ranged from 5-50 km (3-31 mi), although Gutiérrez et al. (1996) recorded a color-banded adult moving >160 km (>99 mi) south of its breeding territory. At present, there is little information on specific habitat features that migratory spotted owls use in wintering areas. Further, owls use stopover areas at a time of year when they are unlikely to vocalize (Ganey 1990), thus reducing detection. Low winter detection rates make it difficult to locate migratory stopover areas through calling surveys, thus we are left

with no objective means to identify and protect such areas (Ganey and Block 2005a). The types of lowland areas in which wintering owls have been observed cover vast areas, and we presently have no evidence that suitable wintering areas are limiting. Nevertheless, this is an area where further research would be valuable.

F. Key Habitat Variables

Throughout its lifetime, a Mexican spotted owl will use a variety of habitats for different needs. To maintain a diversity of habitat types for the various activities of the owl, key habitat variables are required. These include nesting, roosting, and foraging habitat patches with structural, compositional, and successional diversity, as well as connectivity among suitable patches. Specifics regarding these are found in Table 1 below describing desired future conditions.

Table 1. Generalized description of key habitat variables forming Desired Future Conditions (DFCs) in forest and woodland cover types typically used by Mexican spotted owls for nesting and roosting. DFCs should guide management within PACs and recovery habitats. The ecological relevance of each DFC to this owl subspecies and examples of variables useful for quantifying desired conditions are also shown.

Desired Future Condition	Relevance to Owl	Potential Variables
Nest/roost habitat: forest and woodland patches >1 ha (2.5 acre) patch size.	These habitat patches are most limiting to the owl.	Size, cumulative acreage, density of patches, % of landscape, amount of edge habitat, average patch canopy cover, average age of dominant overstory component of patch.
Horizontal and vertical habitat heterogeneity, including physiognomy and species composition. Patches of all ages and unevenly spaced trees with interlocking crowns and high canopy cover.	Provides roosting options, thermal and hiding cover for the owl, and habitat for a variety of prey species.	Patch size and configuration (shape), juxtaposition (topology of patches), interspersions, edge length; canopy cover by height strata; number of vegetation strata present (herbaceous, shrub, sapling, pole, mature trees); uneven tree spacing and clumpiness.
Tree species diversity, especially with a mixture of hardwoods and shade-tolerant species.	Provides habitat and food sources for a diversity of prey, roosting options, and perches for young owls during early development of flapping flight. Diversity increases probability of some tree species setting seed in a given year.	Species occurrence (presence), Hill Diversity Index (including richness and equitability), basal area by species, density/species.
Diverse composition of vigorous native herbaceous species; healthy levels of residual biomass, seed head production. Shrub species diversity, physiognomy.	Provides sustainable habitat for a variety of prey; fine fuels to carry surface fire.	Cover/plant group; plant height; vertical density profile; diversity measure (richness and equitability); Robel Pole (vertical distribution); maximum height.
Range of patch sizes > 1 ha (2.5 acres).	Enhances spatial heterogeneity; roosting options, thermoregulation habitat options, creates edges for prey species (e.g., <i>Neotoma</i>).	Frequency distribution of patches by size class, total edge, core to edge distance, fractal index of patch (area to edge ratios).
Opening sizes between 0.04-1 ha (1-2 acres).	Openings provide habitat for a variety of prey and can slow or reduce fire severity by breaking the continuity of dense tree canopies and ladder fuels.	Frequency distribution of openings by size class, % of landscape in openings. Grass and herbaceous cover in openings (Daubenmire plots for coverage percent).
5 snags >46 cm dbh/ha (2 snags >18 inches dbh/acre) in pine-oak forest; 12.5 snags >46 cm dbh/ha (5 snags >18 inches dbh/acre) in mixed conifer forest, on average across large landscapes.	Snags provide nests, foraging, and calling perches for spotted owls, while also providing habitat for a variety of prey species.	Frequency distribution of snags by size class. Type of snag (size, type, condition).
Dead and down logs. Emphasize large logs > 30 cm (12 inches) midpoint diameter;	Provides habitat for a variety of prey; moisture retention at site, which may reduce fire ignition or reduce fire severity in roosting-nesting areas.	Frequency distribution of logs by size class and decomposition stage.
Average canopy cover of 60%	Roosting; nesting; prey needs, thermal environment.	Canopy cover (remote sensing; ocular estimation, Canfield Line Intercept).
Diversity of seral stages dominated by large trees >46 cm (18 inches) dbh.	All life history needs; nesting, roosting, foraging.	Patch size/seral stage; vegetation strata; tree species richness and evenness.

6. Life History

A. Prey

Mexican spotted owls consume a variety of prey throughout their range. They commonly eat small- and medium-sized rodents such as woodrats, mice, and voles, but they also consume bats, birds, reptiles, and arthropods (Ward and Block 1995). Their diet varies by geographic location (Ward and Block 1995:Fig.II.A.4). For example, spotted owls dwelling in canyons of the Colorado Plateau take more woodrats and fewer birds than do spotted owls from other areas (Ward and Block 1995:Fig.II.A.4). In contrast, spotted owls occupying montane forests with forest-meadow interfaces, as found within the Basin and Range-East Recovery Unit, consume more voles (Ward and Block 1995:Fig.II.A.4). Regional differences in the owl's diet likely reflect geographic variation in population densities and habitats of the prey and the owl. Forsman et al. (2001) also documented spatial variation in a regional analysis of diets of northern spotted owls. For additional information on food habits and prey selection see Appendix B – 5. Prey Ecology.

B. Reproductive History

Mexican spotted owls nest on cliff ledges and caves, in stick nests built by other birds, on debris platforms in trees, and in tree cavities (Johnson 1985, Ganey 1988, Gutiérrez et al. 1995, Seamans and Gutiérrez 1995, Johnson 1997, Willey 1998a). They do not build nests, so they rely on existing structures. Spotted owls exhibit one of the lowest clutch sizes among North American owls (Johnsgard 1988, Gutiérrez et al. 1995). Females normally lay one to three eggs, two being most common, and four observed rarely (LaHaye 1997, Gutiérrez et al. 2003). Re-nesting following nest failure is uncommon but has been observed in Mexican spotted owls (Kroel and Zwank 1992, Gutiérrez et al. 1995).

Knowledge of the annual reproductive cycle of the Mexican spotted owl is important both in an ecological context and for placing seasonal restrictions on management or on other activities that may occur within areas occupied by nesting spotted owls. Mexican spotted owls have distinct annual breeding periods, with timing that may vary slightly throughout their range but is generally consistent overall. In Arizona, courtship begins in March with pairs roosting together during the day and calling to each other at dusk (Ganey 1988). Eggs are laid in late March or, more typically, early April. Incubation begins shortly after the first egg is laid, is performed entirely by the female, and lasts approximately 30 days. During incubation and the first half of the brooding period, the female leaves the nest only to defecate, regurgitate pellets, or to receive prey delivered by the male, who does most or all of the foraging (Forsman et al. 1984, Ganey 1988). Eggs usually hatch in early May (Ganey 1988). Females brood their young almost constantly for the first few weeks after the eggs hatch but then begin to spend time hunting at night, leaving chicks unattended for up to several hours (Forsman et al. 1984, Delaney et al. 1999b). Nestling owls (owlets) generally fledge in early- to mid-June, four to five weeks after hatching (Ganey 1988). Owlets usually leave the nest before they can fly, jumping from the nest to surrounding tree branches or the ground (Forsman et al. 1984, Ganey 1988). Fledglings depend on their parents for food during the early portion of the fledgling period. Hungry fledglings give a persistent, raspy “begging call,” especially when adults appear with food or call

nearby (Forsman et al. 1984, Ganey 1988). Begging behavior declines in late August, but it may continue at low levels until dispersal occurs, usually from mid September to early October (Arsenault et al. 1997, Ganey et al. 1998, Willey and Van Riper 2000).

Mexican spotted owls are sporadic breeders. In good years, most of the population nests successfully, whereas in poor years only a small proportion of pairs will nest successfully (Fletcher and Hollis 1994; Gutiérrez et al. 1995, 2003). This life history strategy allows owls to reproduce when conditions are favorable and survive unfavorable periods with little or no reproduction.

C. Mortality Factors

Several mortality factors have been identified as potentially important to the Mexican spotted owl, including predation, starvation, accidents, disease, and parasites. Although some owl carcasses have been recovered following mortality and examined by field biologists and laboratory personnel, most owls that die are not collected for sampling purposes. Even when dead owls are recovered, cause of death is often difficult or impossible to determine because carcasses are often too decomposed to determine cause of death. Consequently, we know little about the extent or relative importance of these mortality factors.

Predation. Predation may be a common mortality factor for spotted owls, however. Potential avian predators of Mexican spotted owls include great horned owls, northern goshawks, red-tailed hawks, and golden eagles. Some of these predators occupy the same general habitats as the spotted owl, but there is little direct evidence that they prey on spotted owls (Gutiérrez et al. 1995). Ganey (1988) reported one instance of apparent great horned owl predation on an adult spotted owl, but Ganey et al. (1997) did not document predation on spotted owls in a study involving radio-marked, sympatric spotted and great horned owls. Richard Reynolds (USDA FS, Fort Collins, Colorado, pers.comm.) reported a golden eagle preying on a spotted owl.

Starvation. Starvation is another source of mortality. When starvation occurs in resident adults, it is likely due to synchronous declines in prey populations; this form of mortality can influence a number of owls at one time. When low survival is combined with lack of reproduction, population decrease can be rapid. There is evidence that this occurs in some Mexican spotted owl populations (Seamans et al. 1999, Ward 2001, Gutiérrez et al. 2003).

Accidents. Accidents are another known mortality factor. For example, instances of spotted owls being hit by cars have been documented (R. Skaggs, Glenwood, New Mexico, pers.comm.; R. Duncan, Southwestern Field Biologists, Tucson, Arizona, pers. comm.; J. L. Ganey, Rocky Mountain Research Station, unpublished data). Roads involved in these accidents ranged from unpaved forest roads to paved highways. Owls flying at night also might collide with power lines, tree branches, or other obstacles. This might be particularly true for birds migrating or dispersing through unfamiliar terrain (Martin 1986). Little information is available on how frequently this might occur or when it occurs. Starvation or hunger could predispose owls to accidents or predation if it drives them to hunt along roadsides or in other unfamiliar areas or in weakened condition.

Research. Owl mortalities also can occur when capturing and handling owls for research purposes. Given the limited extent of research studies on Mexican spotted owls, such impacts are likely localized. Similarly, widespread inventory and monitoring surveys may impact spotted owl behavior to some unknown extent.

West Nile virus. Little is known about how disease and parasites contribute to mortality of spotted owls. One disease of particular concern is West Nile virus (WNV). This virus was first isolated in Africa, and it first appeared in the United States in 1999, in New York (see review in Blakesley et al. 2004). It spread rapidly across the country, and it has now reached the range of the Mexican spotted owl. Millions of birds have died from WNV since its arrival in 1999, and as a rule, owls appear to be susceptible (Fitzgerald et al. 2003). The impact of WNV on Mexican spotted owls is difficult to ascertain. The WNV is an arbovirus that is transmitted primarily by mosquito vectors. In general, we know little about the abundance and behavior of the relevant vectors in areas occupied by spotted owls. Thus, it is difficult to predict infection rates. We also do not know how many of the owls infected by WNV will die or suffer reduced viability, or whether or not owls will develop some level of immunity to the disease following initial exposure. Recent surveillance in the Sierra Nevada of California failed to detect antibodies to WNV in California spotted owls (Hull et al. 2010). However, this could indicate lack of exposure, sampling error, or high mortality rates of infected individuals, leaving no survivors. Thus, all we can say with certainty at this time is that WNV has arrived, and it has the potential to impact population viability of Mexican spotted owls.

Competition. Several other species of owls occur within the range of the Mexican spotted owl. In general, we know little about potential competitive relationships between these owl species. Logically, the two species most likely to compete directly with Mexican spotted owls are the great horned owl and the barred owl, based on their relative size, natural history, and, in the case of the barred owl, genetic similarity. Throughout much of the range of the Mexican spotted owl, the most likely competitor is the great horned owl (Forsman et al. 1984, USDI FWS 1995). This owl is larger than the spotted owl, is sympatric with spotted owls throughout their range, and both owls are active at night, suggesting that they could compete for nocturnally active prey (Gutiérrez et al. 1995, Houston et al. 1998, Ganey and Block 2005b).

7. Population Trends

From a recovery standpoint, the actual number of spotted owls and temporal trend of those numbers are important. Since the owl was listed in 1993, the documented range of the U.S. owl population has increased in size as new areas have been surveyed for owls. Within the documented species' range there is little evidence of populations disappearing, though individual territories may have been vacated (but see Stacey and Peery 2002). Also, the total documented population size has increased with the additional surveys throughout the range (i.e., populations on NPS lands, and others). However, the population trend remains unclear.

Population estimates recorded 758 owl sites from 1990 to 1993, and 1,222 owl sites from 1990 to 2004. For this revision, the Recovery Team compiled 1,301 owl sites known today in the U.S. portion of the owl's range (Table 2 below; Table B.2 in Appendix B). This increase is mainly a product of new surveys being completed within previously unsurveyed areas (e.g., several National Parks within southern Utah, Grand Canyon in Arizona, Guadalupe National Park and

Guadalupe Mountains in southeastern New Mexico and West Texas, Dinosaur National Monument in Colorado, Cibola National Forest in New Mexico), with only a few additions to numbers of sites recorded for previously well-surveyed National Forests. Thus, an increase in the species' abundance cannot be inferred from these data.

In terms of Ecological Management Units (Table 2), the Colorado Plateau (CP) EMU contains 197 sites, representing 15% of the total Mexican spotted owl population in the U.S. since 1989. The Southern Rocky Mountain (SRM) EMU supports 71 owls, covering 6% of the total known population. Hosting the largest number of all known sites, the Upper Gila Mountains (UGM) EMU holds 684 owls or 63% of the sites in the U.S. The Basin and Range – West (BRW) EMU contains 161 sites (12%), while the Basin and Range – East (BRE) EMU has 188 recorded owl sites (14%). In Mexico, the Sierra Madre Occidental – Norte has recorded 12 owls in Sonora, 25 owls at 13 sites in Chihuahua, and 2 sites at the Sinoloa-Durango state line. The Sierra Madre Oriental - Norte has documented two owl localities in Coahuila. The Sierra Madre Occidental - Sur contains records in La Michilla Biosphere Reserve, as well as observations in the states of Aguascalientes, Zacatecas, and Guanajuato. The Sierra Madre Oriental - Sur has recorded five locations in Sierra Leon, while the Eje Neovolvanico has reported owls in the state of Jalisco, and one owl was collected in Michoacan.

Table 2. Mexican Spotted Owl Known Populations in the United States and in Mexico

Ecological Management Area	Number of Sites or Owls	Percent of Total
<i>United States</i>		
Colorado Plateau (CP)	197 sites	15
Southern Rocky Mountains (SRM)	71 sites	6
Upper Gila Mountains (UGM)	684 sites	63
Basin and Range – West (BRW)	161 sites	12
Basin and Range – East (BRE)	188 sites	14
<i>Mexico</i>		
Sierra Madre Occidental - Norte	27 sites	-
Sierra Madre Oriental - Norte	2 sites	-
Sierra Madre Occidental - Sur	extant	-
Sierra Madre Oriental - Sur	5 sites	-
Eje Neovolvanico	extant	-
Total	1301 sites in the U.S.	-
	34+ sites in Mexico	Incomplete surveys

A Mexican spotted owl population for a specific area and time can be modeled using the combined effect of births, deaths, immigration, and emigration, which influences the viability of the population and its long-term persistence. Because these owls are long-lived, population trend

studies must be long-term (i.e., > 10 years). Data on trends in populations or occupancy rates are sparse, and methods and sample sizes differ among studies, making comparisons difficult. In general, however, results suggest that most populations studied either have declined in the recent past or may still be declining (Seamans et al. 1999, Stacey and Peery 2002, Gutiérrez et al. 2003).

Environmental conditions greatly affect reproduction and/or survival of spotted owls, and environmental variability across space and time is pronounced within the range of the Mexican spotted owl (Gutiérrez et al. 2003). Consequently, understanding how spotted owls respond to environmental variation is critical to recovering the owl. Despite concerted efforts to understand the influence of environmental variation on owl vital rates, considerable uncertainty remains. In general, temporal variation in owl vital rates appears to be influenced by climatic factors, especially precipitation. Because estimated vital rates appear responsive to precipitation several months prior to the estimation period, Gutiérrez et al. (2003) suggested that precipitation influences vital rates through an indirect mechanism. They further proposed that this mechanism might involve precipitation influencing primary productivity, prey population dynamics, and ultimately, owl vital rates. A greater understanding of these interactions will be required to project the effects of climate change on Mexican spotted owls. For detailed information regarding specific studies of population trends and factors affecting Mexican spotted owl populations, see Appendix B - 6.E.

We have learned a great deal about the Mexican spotted owl in the last decade, but significant information gaps remain. Most studies of the owl have been descriptive rather than experimental. Although we have identified patterns with respect to some aspects of the owl's ecology (e.g., habitat use), cause and effect relationships have not been documented. Much more information is needed on how specific factors alone and in combination affect change in Mexican spotted owl abundance. These considerations suggest that additional research would contribute greatly to our understanding of the owl, and that management recommendations in the near-term must deal with high levels of uncertainty (see Part V.6. - Research Needs).

8. Critical Habitat

On 31 August 2004, the FWS designated approximately 3.5 million ha (8.6 million ac) of critical habitat for the Mexican spotted owl on Federal lands in Arizona, Colorado, New Mexico, and Utah (69 FR 53181). Within the critical habitat boundaries, critical habitat only includes protected and restricted habitats as defined in the original Recovery Plan (USDI FWS 1995). Similarly, the primary constituent elements of critical habitat were listed as those habitat features recognized in the Recovery Plan as associated with spotted owl occupancy, as follows:

A. Primary Constituent Elements Related to Forest Structure:

- A range of tree species, including mixed-conifer, pine-oak, and riparian forest types, composed of different tree sizes reflecting different ages of trees, 30-45% of which are large trees with a trunk diameter of ≥ 0.3 m (12 inches) when measured at 1.4 m (4.5 ft) from the ground;
- A shaded canopy created by the tree branches and foliage covering $\geq 40\%$ of the ground; and

- Large, dead trees (i.e., snags) with a trunk diameter of at least 0.3 m (12 inches) when measured at 1.4 m (4.5 ft) from the ground.

B. Primary Constituent Elements Related to Maintenance of Adequate Prey Species:

- High volumes of fallen trees and other woody debris;
- A wide range of tree and plant species, including hardwoods; and
- Adequate levels of residual plant cover to maintain fruits, seeds, and allow plant regeneration.

C. Primary Constituent Elements Related to Canyon Habitat:

Include one or more of the following:

- Presence of water (often providing cooler air temperature and often higher humidity than the surrounding areas);
- Clumps or stringers of mixed-conifer, pine-oak, pinyon-juniper, and/or riparian vegetation;
- Canyon walls containing crevices, ledges, or caves; and
- High percent of ground litter and woody debris.

9. Threats and Threats Assessment

A. Reasons for Listing

The Mexican spotted owl, listed as a threatened species under the ESA in 1993 (58 FR 14248), is one of three subspecies of spotted owl. Under Section 3 of the ESA, the term species includes “...any subspecies of fish or wildlife...” Although the Mexican spotted owl is a subspecies, it is sometimes referred to as a species in the Recovery Plan when discussed in the context of the ESA or other laws and regulations. An endangered species is defined under the ESA as “...any species which is in danger of becoming extinct throughout all or a significant portion of its range...” A threatened species is one “...which is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range.” Section 4(A)(1) of the ESA lists five factors that can, either singly or collectively, result in listing a species as endangered or threatened provided their effects are significant enough that the species meets one of the above definitions. We summarize those five factors below, as they were discussed in the 1993 final listing rule (58 FR 14248). Our assessment of the current situation with regard to the subspecies’ status and threats is reflected in Part 8.B, below.

a. Present or Threatened Destruction, Modification, or Curtailment of the Mexican Spotted Owl’s Habitat or Range (Factor A)

Current and future timber-harvest practices in the Southwestern Region (Region 3) of the U.S. Department of Agriculture (USDA) Forest Service (FS) were cited as the primary factors threatening the continued existence of the owl. The final rule stated that the Southwestern Region of the USFS managed timber primarily under a shelterwood harvest regime. This harvest method produces even-aged stands rather than the uneven-aged, multi-layered stands that are most often used by owls for nesting and roosting. In addition, the shelterwood silvicultural system calls for even-aged conditions in perpetuity. Thus, stands already changed from

“suitable” (i.e., presently supporting spotted owls) to “capable” (i.e., not currently supporting spotted owls but with the potential to support them in the future) would not be allowed to return to a suitable condition. Acreage slated for future harvest would be similarly rendered perpetually unsuitable for owl nesting and roosting.

The final listing rule stated that “...significant portions of spotted owl habitat have been lost or modified,” and it cited Fletcher (1990) in estimating that 420,000 ha (1,037,000 ac) of habitat in the U.S. were converted from suitable to capable. Of this, about 78.7%, or 330,000 ha (816,000 ac), was a result of human activities, whereas the remainder was converted primarily by wildfire. We are not aware of similar data for Mexico, so cannot provide information about habitat change in Mexico at this time. According to the final rule, forest plans in USFS Region 3 allowed up to 95% of commercial forest (59% of suitable spotted owl habitat) to be managed under a shelterwood system. The final rule also cited the loss of lower- and middle-elevation riparian habitat plus habitat lost to recreation developments as factors in habitat loss.

b. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes (Factor B)

The final listing rule stated that scientific research has the greatest potential for overutilization of the Mexican spotted owl, whereas birding and educational field trips are likely to increase as the owl becomes better known. The effects of these activities, either chronically or acutely, were unknown.

c. Disease or Predation (Factor C)

The final listing rule stated that great horned owls (*Bubo virginianus*) and other raptors are predators of Mexican spotted owls. The rule implied that forest management created transition habitats (i.e., ecotones) favored by great horned owls, thus creating an increased likelihood of contact between the two species.

d. Inadequacy of Existing Regulatory Mechanisms (Factor D)

The final listing rule discussed various Federal and state laws and agency management policies, concluding that existing regulatory mechanisms were inadequate to protect the owl. Specifically cited was the conflict between attaining assigned timber-volume targets and management of occupied and unoccupied spotted owl habitat.

e. Other Natural or Manmade Factors Affecting the Mexican Spotted Owl’s Continued Existence (Factor E)

The final listing rule cited wildfires as a threat to owl habitat. The potential for increasing malicious and accidental anthropogenic harm to the species was also cited as a possible threat. In addition, the final listing rule recognized the potential for the barred owl (*Strix varia*) to expand its range into that of the Mexican spotted owl, resulting in possible competition and/or hybridization. It was speculated that habitat fragmentation may encourage and hasten this expansion.

B. Current Threats

We summarize the current status of the species (i.e., abundance, distribution, and population information) in Part II.3 - 6, and we discuss it in detail in Appendix B – Ecology of the Mexican spotted owl. In this Revised Recovery Plan, we discuss the Federal actions that have affected the owl since its listing in 1993, and we analyze factors currently influencing the species. The activities we discuss below may not necessarily be threats per se, depending on their level of intensity, duration, or geographic extent. The activities and situations we discuss are potential influencing factors on the owl and/or its habitat, and we evaluate their impacts herein.

C. Federal Actions Affecting the Mexican Spotted Owl

Since the Mexican spotted owl was listed as threatened, the FWS has completed numerous formal consultations on actions affecting this subspecies. These formal consultations have reviewed Federal agency actions affecting over 400 Protected Activity Centers (PACs; USDI FWS 1995). Agencies initiating consultation have included the USFS, Bureau of Indian Affairs (BIA), Department of Defense (DOD; including Air Force, Army, and Navy), Department of Energy (DOE), National Park Service (NPS), Bureau of Land Management (BLM), and Federal Highway Administration (FHWA). Proposed projects have included timber sales, road construction, fuels treatments, fire/ecosystem management projects (including prescribed natural and management-ignited fires), livestock grazing, recreation activities, utility corridors, military and sightseeing overflights, oil and gas exploration and extraction, and other activities. Only two projects resulted in biological opinions that the proposed action would likely jeopardize the continued existence of the Mexican spotted owl: (1) implementation of the Region 3 Forest Plans without adopting the Recovery Plan (an action that was never implemented), and (2) the release of site-specific owl location information (that information was ultimately released under the Freedom of Information Act but is not known to have resulted in adverse effects to the owl).

D. Factors Affecting the Mexican Spotted Owl in the United States

Section 4 of the ESA requires consideration of five factors when determining whether a species should be listed, delisted, or reclassified under the ESA (five-factor analysis). Thus, in this revised Recovery Plan, we included an up-to-date five-factor analysis to ensure that recommended recovery actions (as provided in Parts II.8 and II.9; Table 3: Crosswalk Between Threats and Management Recommendations; and Appendix D) address the factors responsible for the species' threatened status.

a. Present or Threatened Destruction, Modification, or Curtailment of the Mexican Spotted Owl's Habitat or Range (Factor A)

Human-managed alteration of forests in the southwestern U.S. has resulted in extensive areas of spotted owl habitat that are now more vulnerable to the effects of stand-replacing wildfires. A plethora of ecological and historical research has documented intensified land-use in southwestern U.S. forests beginning in the 1880s with European-American settlement (Weaver 1951, Cooper 1960, Bahre 1991, 1995; Swetnam et al. 1999). Livestock grazing and selective timber harvesting were identified as management practices that resulted in substantial changes to

forests (e.g., Fulé et al. 1997; Kaufman et al. 1998; Swetnam and Baisan 2003). Furthermore, human land-use practices resulted in fire exclusion, altering pre-settlement forest ecology throughout the southwest.

Frequent, low-intensity surface fire regimes played an important role in the evolution and ecology of pine-oak, ponderosa pine, and mixed-conifer forests prior to European-American settlement (Weaver 1951, Cooper 1960, Grissino-Mayer et al. 1995a, 1997, 2003b; Swetnam and Baisan 2003). The primary fuels for these low-intensity surface fires included conifer needles, leaf litter, grasses, and forbs. During pre-settlement, low-intensity surface fires burned regularly across southwestern forests (Swetnam 1990, Swetnam and Baisan 1996a).

Pine-oak and ponderosa pine forest fire-scarred trees have recorded mean fire intervals of every 2–14 years, while dry mixed-conifer-site intervals ranged from 9–30 years (Dieterich 1983, Kaib et al. 1996, Swetnam and Baisan 1996b, Swetnam et al. 1999, Brown et al. 2001, Grissino-Mayer et al. 1995a, 1995b, 2004; Heinlein et al. 2005, Brown and Wu 2005, Fulé et al. 2009). The more frequent fire intervals occurred in the lower elevations and on southern slope-aspects in the pine-oak, ponderosa, and dry mixed-conifer forests. In the higher elevations and on northern aspects with wetter mixed-conifer forests, mean fire intervals were longer with greater variation, and fire effects included mixed severities with surface and stand-replacing fire characteristics often discernible within existing aspen stands (e.g., Brown et al. 2001, Fulé et al. 2004, 2009; Margolis et al. 2007, Margolis and Belmat 2009). Fires were less frequent in arid and rocky-canyon habitats, where natural fire barriers and limited fuels existed (Swetnam and Baisan 1996a, 1996b; Brown et al. 2001, Swetnam et al. 2001, Fulé et al. 2003a, 2003b).

Historical descriptions of mixed-conifer forests 100 or more years before present included a variety of conditions depending on the time since and severity of the most recent fire incidents. Early accounts of mixed-conifer forest described large old Douglas-fir trees and understories composed of vigorous ponderosa pines and regeneration cohorts of Douglas-fir. Fulé et al. (2004, 2009) found that mixed-conifer forest composition and structural changes between 1880 and 2004 included >50% increases in basal area (from smaller diameter age classes), declines in ponderosa pine, increases in white fir, subalpine fir, and spruce, and a decline in early seral habitats at higher elevations. Others have noted similar changes to mixed-conifer forest in different mountain ranges of the southwest (Heinlein et al. 2005, Margolis et al. 2007, Margolis and Belmat 2009).

i. Stand-replacing Fire

Current forest conditions have the potential to sustain landscape-scale stand-replacing fires that would positively or negatively alter owl habitat over extensive landscapes in a single fire incident, depending on certain conditions discussed below. Indeed, several large fires—Cerro Grande, Rodeo-Chedeski, Hayman as examples—have burned in owl habitat since 1996. Thus, broad-scale, high-severity, stand-replacing fires have had, and will likely continue to have, long-term effects on both watershed and forest function (Fulé et al. 2004). Wildland fires can cause direct and indirect effects from combustion, charring, heating, smoke, and biophysical changes to the burned area. Dense forests with heavy fuel accumulations, like many forests in the

southwestern U.S., are at greater risk to high-severity and stand-replacing fires (Fulé et al. 2004). The potential effects of fire and related activities on owls depend upon:

- whether or not the fire and/or suppression activities are within owl habitat;
- type of habitat involved (e.g., nest/roost, foraging, dispersal habitat);
- severity and intensity of the wildfire and/or suppression activities;
- areal extent of wildfire and/or suppression activities;
- frequency and cumulative effects of the suppression activities; and
- time of year.

Direct and indirect fire effects on habitat include the alteration of vegetation structure, soil, and watershed conditions. These effects can be detrimental, beneficial, or both depending on the six factors we list above. Evaluation of effects is also dependent on temporal scale; effects that are detrimental in the near-term may have long-term beneficial effects. Conversely, fires may provide short-term benefits but result in stand degradation over time. The fire-severity class is directly related to the magnitude of these effects, and it also influences whether such effects are positive or negative on owl habitat. High-severity burns have the most negative long-term effects on spotted owl nest and roost habitats but could enhance foraging habitats used by owl prey species (e.g., woodrats [*Neotoma spp.*] or deer mice [*Peromyscus maniculatus*]) (Franklin et al. 2000, Kyle and Block 2000). Bond et al. (2002) monitored the fate of 21 color-marked owls representing all three (northern [*S. o. caurina*] California [*S. o. occidentalis*], and Mexican) subspecies. They concluded that when relatively large wildfires burned known nest and roost sites, the fires appeared to have a low short-term effect on survival, site fidelity, mate fidelity, and reproductive success when compared to estimates independent of fire effects (see also Jenness et al. 2004).

Bond et al. (2009) evaluated fire effects on seven radiomarked California spotted owls and found that owls roosting during the breeding season selected low-severity burned forest and avoided moderate- and high-severity burned areas. Bond et al. (2009) also found that most owls foraged in high-severity burned forest more than other burned-forest categories. Furthermore, within 1 km (0.6 mi) of the center of foraging areas, foraging owls selected all severities of burned forest and avoided unburned forest. Further, anecdotal evidence from Mexican spotted owl monitoring suggests that PACs burned with moderate-to-high fire severity continue to be occupied by owls. Conversely, owl surveys conducted two years post-fire in previously occupied but severely burned areas (e.g., within the Dude and Rodeo-Chedeski fires on the Mogollon Rim in Arizona) failed to locate spotted owls since the fires.

The Recovery Team examined the rate of fire burning at different severities in the owl's habitat in the U.S. during a recent (1996-2005) period and then used the rate of high-severity fire to project the potential for habitat alteration and loss by high-severity wildfire (Box B.2 in Appendix B). This analysis indicated that the effects of future fire on the owl's habitat will very likely depend on the type of environment that is occupied. Owl populations dwelling in canyon habitats may be at less risk than those dwelling in forested habitats, and those dwelling in a particular National Forests may have less habitat area altered over time. Even when doubling of

the amount of habitat area burned by high-severity fire during 1996-2005 and projecting out 95 years, with certain assumptions, a substantial portion of the owl's most-used habitat may not be impacted by high-severity wildfire. However, despite the variability of fire effects and existing gaps in knowledge regarding short- and long-term effects on habitat and owl responses to wildfire, we believe that stand-replacing crown fires pose a continuing threat to Mexican spotted owls. This is especially true when considering that 55 spotted owl PACs experienced high-severity stand-replacing fire in a single incident, including approximately 33,000 PAC acres that were reduced to an early successional stage. Furthermore, most climate-change models predict hotter and drier conditions in the southwestern U.S. in future decades, which will increase susceptibility of forests to large-scale, stand-replacing fires. This revised Recovery Plan therefore provides in Appendices C and D management recommendations to reduce fire risk to PACs and other habitat valuable to spotted owls while maintaining the integrity of core areas.

ii. Fire Suppression

Fire-suppression activities can result in habitat loss through building of fire lines, construction of support areas such as helipads and fire camps, and ignition of backfires and burnouts to reduce the amount of fuel available to the wildfire. Whether the habitat effects of fire-suppression activities cause more or less impact to habitat than the benefits gained by controlling the fire can only be determined site-specifically, and then only to the extent that with-suppression and without-suppression scenarios can be accurately evaluated. Fire-management teams typically include resource advisors whose responsibility is to assess and attempt to minimize potential effects to threatened, endangered, and sensitive species habitats. Fire-suppression activities can have significant negative effects on owl habitat, at least locally. Management recommendations are provided in Appendices C and D.

iii. Burned Area Response

Emergency stabilization (ES) and burned area rehabilitation (BAR) treatments are applied to stabilize and rehabilitate a burned area so that it can recover more rapidly. ES is performed within one year of the wildfire to stabilize and prevent unacceptable degradation to natural and cultural resources, to minimize threats to life or property resulting from the effects of a fire, or to repair/replace/construct physical improvements necessary to prevent degradation of land or resources (USDA and USDI 2006). BAR is undertaken within three years of wildfire containment to repair or improve fire-damaged lands unlikely to recover naturally to management approved conditions, or to repair or replace minor facilities damaged by fire (USDA and USDI 2006). Methods of ES and BAR include aerial mulching and seeding, tree planting, and water/soil control structures (e.g., gabions, water bars, straw bales). From a habitat standpoint, ES and BAR activities are probably beneficial in that they provide protection of soils, thereby reducing the likelihood of permanent soil loss in preparation for longer-term rehabilitation efforts. Use of non-native species, however, for post-fire seeding is often ineffective at meeting management objectives and may have long-term implications on forest ecology (Peppin et al. 2010).

ES and BAR activities probably do not constitute a significant threat to spotted owls, but treatments instituted post-fire can have an effect on stand structure well into the future. We therefore provide management recommendations for this activity in Appendix D.

iv. Wildland-urban Interface (WUI) Treatments

Guidance for Implementation of Federal Wildland Fire Management Policy (Fire Executive Council 2009) defined the WUI as the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels. These areas may include critical communications sites, municipal watersheds, high-voltage transmission lines, observatories, camps, research facilities, and other structures that, if destroyed by fire, would result in hardship to people and communities. The WUI often is defined to encompass these sites and a buffer that includes continuous slopes and fuels that lead directly to the sites, regardless of distance. The amount of area included can be substantial. For example, the WUI within the Sacramento Ranger District of the Lincoln National Forest in New Mexico encompasses over 80% of the district as defined by Otero County under the auspices of the Healthy Forests Restoration Act (HFRA; see discussion in 8.B.d, below). Although a variety of threats may affect owls within the WUI, our focus is on the effects of intensive fuels reduction treatments on the owl and its habitat. Fuels reduction treatments in the WUI typically aim to reduce tree basal area to 30 to 60 square feet per acre and change forest structure (e.g., reduce canopy cover by 35 to 75%) to significantly modify fire behavior (USDA, USDI 2001).

Of the areas identified for treatment in the WUI within the USFS Southwestern Region, 85% [or 650,000 ha (1.6 million ac) of the 730,000 ha (1.86 million ac)] occur in fire condition class two and three. In condition class two, the fire regime and vegetation structure and composition have been moderately altered; that is, ≥ 1 fire cycle has been missed, allowing for denser stocking and an increase in understory woody species. This primarily includes pinyon/juniper woodlands and mixed-conifer stands. Fire condition class three indicates that the fire regime and vegetation structure and composition are substantially altered; that is, multiple fire cycles have been missed. Forests and woodlands are now densely stocked, and there is a greater risk from uncharacteristic high-severity wildland fire effects. This typically applies to pine and pine-oak stands.

On the Lincoln National Forest in New Mexico, for example, forest personnel conducted an assessment of fuels treatments needed to ensure community protection, firefighter safety, and ecological functionality in the WUI. The Lincoln National Forest Capability Assessment evaluated several options, including intensive treatments applied across essentially the entire forest landscape, including owl nest stands. This approach could involve significant risk to the Mexican spotted owl population in the Sacramento Mountains. This population comprises the bulk of the population in the Basin and Range-East (BRE) Ecological Management Unit (EMU) (Ward et al. 1995). (See Part II.3 for a discussion of EMUs.) It appears to receive little if any immigration from other populations (Barrowclough et al. 1999), but it may serve as a source population for smaller populations within the region. Thus, implementation of this approach to fuels reduction in the WUI could seriously endanger owls within this recovery unit.

In summary, large blocks of land are scheduled to be treated to reduce fire risk and protect human communities throughout the owl's range within the United States (USDA, USDI 2001).

Prather et al. (2008) evaluated potential conflicts between fuels-reduction treatments and spotted owls in the western Mogollon Plateau and concluded that there were ample opportunities to treat forests without compromising owl habitat. In the Sacramento Mountains of New Mexico, however, intensive landscape-wide treatments aimed at ensuring community protection, firefighter safety, and ecological functionality had the potential to impact about 25% of the known PACs on southwestern National Forests. As proposed, the intensity of many of these treatments may have affected owls and owl habitat negatively. Also, note that many proposed treatments within the WUI were not consistent with guidelines in the 1995 Recovery Plan. As such, some WUI treatments may represent a threat to the owl, and we address these threats in Appendices C and D.

v. *Silvicultural Treatments*

A review of recent harvest data from the 11 National Forests in Arizona and New Mexico (i.e., Region 3 of the U.S. Forest Service) shows a shift in the type of harvest activities performed over the past few decades. Prior to the 1980s, but post World War II, harvesting throughout the southwest tended to cover large, contiguous areas. The number of trees per acre removed was highly variable and generally consisted of removing trees that were unhealthy and expected to die in the near future, old-growth trees, and/or those that overtopped vigorous regeneration. It was not uncommon to utilize the same harvest methods and systems on thousands of contiguous acres. This type of harvest activity could neither be clearly classified as even-aged or uneven-aged forest management, because there was no real area control (even-aged) or volume control (uneven-aged) associated with this harvesting approach.

By the mid 1980s, all 11 National Forests in U.S. Forest Service's Region 3 had either completed or were close to completing their individual forest plans. All of the plans at that time emphasized: (1) even-aged management; (2) discrete stand-size treatment units; and (3) short rotation ages, generally 100-140 years. This management regime called into question whether old growth could be developed and maintained in large blocks scattered over the landscape. Although even-aged management applied in stand-size areas across the landscape might provide horizontal diversity, within-stand diversity (vertical) likely could not have been maintained.

In the early 1980s, timber harvesting approached 80,000 ha/yr (200,000 ac/yr) region-wide. By the time the last forest plan was completed (Kaibab NF-1987), annual harvest rates throughout Region 3 of the U.S. Forest Service had dropped to approximately 60,000 ha/yr (150,000 ac/yr). By 1990, total harvest rates in the region dropped to approximately 40,000 ha/yr (100,000 ac/yr), or half what it was in the early 1980s. Since the early 1990s, commercial harvest rates have steadily declined to their current level of approximately 4,000 ha/yr (10,000 ac/yr).

With the incorporation of the Goshawk Management Guidelines into all 11 forest plans in 1996, management of most of the ponderosa pine type and much of the mixed conifer type outside of areas managed for spotted owls shifted to 0.04- to 1.6-ha (0.1- to 4-ac) groups consisting of 6 vegetative structural stages (Reynolds et al. 1992). In shifting from large stand-size areas to areas of smaller tree groups, both horizontal and vertical diversity were improved due to the increased edge effect and interspersed smaller tree-group areas.

Beginning in the early 2000s after the Cerro Grande, Rodeo Chedeski, and other large destructive wildfires, and after completion of the National Fire Plan, most silvicultural treatments within the region were designed to reduce basal area and the number of trees per acre by thinning forests from below (removing most smaller-diameter trees) within the WUI areas (see discussion above).

Another form of intermediate cut performed in the U.S. Forest Service's Region 3 is sanitation/salvage cutting. Sanitation/salvage has been performed since commercial logging first began prior to the 1900s. This type of an intermediate treatment declined in recent years; however, today salvage harvesting treatment is getting greater attention due to the increasing number of large, stand-replacing fires and increased insect-induced mortality in ponderosa pine and mixed conifer habitat. Those treatments are generally located in the more severely burned areas. In addition, Region 3 salvage operations generally involve no new road construction, logging only on slopes <30–40%, and removing only trees that are completely dead or determined to be dying. Forest Service Region 3 data show that between 2000 and 2009, 18,259 ha (45,100 ac) were sold as purely salvage sales.

There is considerable controversy over the effects of salvage logging following stand-replacing fire, and most salvage projects are appealed and/or litigated in the courts (Karr et al. 2004). Proponents of salvage logging believe that harvesting dead trees will reduce the need to harvest live trees and see the failure to log some of the dead trees as a waste of a valuable natural resource; many also see salvage logging as a way to help reduce future burn severity or provide biomass to the forest floor to help minimize erosion. Others think that the severe fire had already caused substantial environmental harm and that salvage logging may result in more environmental damage (e.g., Donato et al. 2006).

In summary, non-salvage even-aged timber-harvest activities that were the primary threat leading to listing of the owl as a threatened species have been greatly reduced in extent and severity since 1996 from the levels implemented at the time of listing in the U.S. Forest Service's Region 3. The majority, but not all, of selection harvesting in Region 3 is group selection where small (0.04- to 1.62-ha [0.1- to 4-ac]) openings are created to encourage natural regeneration. These group openings generally comprise 10-20% of the stand. The remaining 80-90% of the stand is either thinned to encourage more vigorous tree growth or treated to reduce stocking by use of group selection to favor more seral tree species, or to reduce existing fuel loading. We have no definitive information on harvest levels and prescriptions on non-Forest Service lands; however, based on the current situation in the U.S. Forest Service's Region 3, we do not consider even-aged timber harvest (i.e., activities designed to capture wood volume or provide for even-aged stand regeneration) at current levels to be a significant threat to the species.

vi. *Insects and Disease*

We view native forest insects and diseases as natural ecosystem processes with which the owl has evolved. The influences of these ecosystem processes on owls can be both negative and positive, depending on intensity and extent, both within and among forest-pathogen types. For example, patches of mixed conifer subjected to bark beetle outbreaks can deteriorate to the point that they are of little use to spotted owls and become vulnerable to severe wildfire. This may be

especially significant in areas, such as those described above, where significant habitat has already been lost and where remaining habitat is under environmental stress. However, scattered patches of beetle-infested forest may provide for forest heterogeneity, resulting in abundant and diverse prey. Similarly, dwarf mistletoe likely has some beneficial effect in providing nest sites for spotted owls as well as supporting the life-history requirements of spotted owl prey, while it also acts synergistically with other forest stressors to induce tree mortality (Lundquist and Ward 2005, Stubblefield et al. 2005, Hedwall and Mathiason 2006, Hedwall et al. 2006).

Native insects and disease likely are an issue for owl habitat only when they reach epidemic levels. Species of primary interest in this context in the southwestern U.S. include several species of bark beetles and defoliating insects (names given below), dwarf mistletoe (*Arceuthobium* species), and root decay fungi (USDA Forest Service 2004). An intensive and ongoing drought-induced bark beetle outbreak has caused extensive mortality in pinyon-juniper woodlands and ponderosa pine and mixed-conifer forests (Breshears et al. 2005, Ganey and Vojta 2005, Negrón et al. 2009). In some cases mortality has been nonrandom, with greater mortality rates in the larger trees favored by owls than in smaller trees (Mueller et al. 2005, J. L. Ganey, RMRS, unpublished data)

Defoliators, sapsuckers, and beetles have reached outbreak proportions in areas such as the White and Pinaleno Mountains, Arizona, and Sacramento Mountains, New Mexico. The Pinaleno outbreak included spruce aphid (*Elatobium abietinum*; Koprowski et al. 2005, Lynch 2009), Janet's looper (*Nepytia janetae*; Lynch 2007), spruce beetle (*Dendroctonus rufipennis*), and western balsam bark beetle (*Dryocoetes confuses*). The Pinaleno event covered at least 162 ha (400 ac) with an estimated mortality in affected areas of 85%; mortality rates ranged from 15-20% in the Sacramento and White Mountains, respectively (Lynch 2004, Koprowski et al. 2005, Lynch 2007). There is some evidence that outbreaks were associated with increasingly warm temperature regimes (Lynch 2003), suggesting that such outbreaks may increase if the climate becomes warmer in the southwest (e.g., Seager et al. 2007).

Dwarf mistletoe can be beneficial to owls in mixed conifer forest by providing nest-site platforms (Ganey 1988, Fletcher and Hollis 1994, Seamans and Gutiérrez 1995, May et al. 2004) and supporting important prey species (Hedwall and Mathiasen 2006, Hedwall et al. 2006). However, in many areas across the Southwest dwarf mistletoe levels likely increased over the last century due to greater tree density resulting from fire suppression and cattle grazing (Conklin and Fairweather 2010). This greater density allows for easier tree-to-tree spread of mistletoe (Mathiasen et al. 1990) and lack of surface fire allows more branches to exist in the lower crowns of trees than would be present if these forests burned frequently. These lower branches help to increase levels of dwarf mistletoe infection, and the resulting witches brooms provide fuel ladders that allow fire to move into the canopy more easily.

Decay fungi can kill trees or predispose trees to death by other agents. However, heartrot fungi, which decay the inner core of living trees, are essential in providing cavities for owl nests in both snags and living trees. Decay levels by heartrot fungi are typically proportional to tree and stand age (Lightle and Andrews 1968, Abella 2008, Worrall and Fairweather 2009), so retaining old trees on the landscape with decay is essential.

In summary, insects and diseases, while naturally occurring, can pose some risk to spotted owls when they involve exotic species or when native-species infestations are exacerbated by unnatural stand conditions, drought, climate change, or other factors. If the range of the owl becomes hotter and drier (see Part II.8.B.e.iv below), insect and disease outbreaks can be expected to increase in frequency, extent, intensity, and duration. We provide recommendations to manage this potential threat in Part II.9 and in Appendices C and D.

vii. *Grazing*

Effects on Mexican spotted owls from grazing by wild ungulates and domestic livestock are complex, and multiple factors may determine specific influences. These factors include local and regional climatic patterns, biotic community associations and ecology, soil types and conditions, and the timing, intensity, and duration of vegetation removal associated with the presence of grazing animals. Adding to the complexity are the interrelationships of grazing and other ecological processes, such as changes in herbaceous plant composition, woody vegetation structure, soil stability and ecology, and fire regimes. Although the effects of grazing on owls are complex, they generally fall into two categories: (1) those that result in relatively short-term effects requiring short recovery periods to restore suitable habitat characteristics; and (2) those that result in long-term alterations in plant-species composition and vegetation structure. For example, properly managed grazing in key owl foraging areas that consistently maintains residual herbaceous biomass of forage species, sufficient to allow for individual plants to recover and reproduce during most growing seasons, should provide cover and food sources for some prey species (especially during drought periods), and may also prove beneficial to owls over the long-term by cropping plants to a level that increases owls' access to prey species associated with herbaceous cover habitat types. In contrast, grazing that allows for moderate- to high-intensity grazing throughout several successive growing seasons may result in impaired vegetation productivity and ultimate changes in species composition, density, and vigor, which can degrade spotted owl habitat characteristics over the long-term.

Grazing can adversely affect the owl primarily through four indirect effects: (1) diminished prey availability and abundance (Ward 2004, Willey 2007, Willey and Willey 2010), (2) increased susceptibility of habitat to destructive fires, (3) degradation of riparian and meadow plant communities, and (4) impaired ability of plant communities to recover or develop into more suitable spotted owl habitat. These impacts are most likely to affect owls in certain geographic portions of the Colorado Plateau (CP), Southern Rocky Mountain (SRM), Upper Gila Mountain (UGM), and Basin and Range-East EMUs (see Part II.3), where individuals forage in or adjacent to grazed areas preferred by wild and domestic ungulates, including montane meadows, riparian corridors, or canyon bottoms (Ward and Block 1995, Willey 2007, Willey and Willey 2010).

Consistent moderate- to high-intensity grazing during the growing season reduces height and horizontal distribution of herbaceous plants that serve as protective cover and food sources for some of the owl's prey species, most notably voles (Birney et al. 1976, Getz 1985, Peles and Barrett 1996). Reduction of herbaceous plant biomass may also influence the food of other prey species (e.g., white-footed mice; *Peromyscus* spp.) by removing or reducing the availability of plant seeds. Over time, without sufficient opportunities for growing season biomass recovery and seed production within these plant communities, their ecological condition will not be

maintained or improved (Holechek et al. 2001), and some sites may fall into a degraded ecological condition (Kothmann 2009). Where limited herbaceous cover and seed production persist in preferred owl foraging areas over several breeding seasons, reduction of prey availability can limit the energy intake of those owls, particularly when other prey species are concurrently limited. These conditions can contribute to reduced reproduction and declines in some owl populations (Willey and Willey 2010).

In areas that are heavily grazed over long periods of time, reductions in herbaceous ground cover and increased density of shrubs and small trees can decrease the potential for beneficial low-intensity ground fires while increasing the potential for destructive, high-intensity crown fires (Zimmerman and Neuenschwander 1984). Low-intensity ground fires prevent fuel accumulation, stimulate nutrient cycling, promote grasses and forbs, discourage shrubs and small trees, and perpetuate the patchiness that supports small mammal diversity, all indirectly or directly beneficial to owls. High-intensity crown fires reduce or eliminate foraging, wintering, dispersal, roosting, and nesting habitat components.

Excessive grazing in riparian areas can reduce or eliminate important shrub, tree, forb, and grass cover, all of which in some capacity support the owl or its prey. Unmanaged or poorly managed grazing of riparian plant communities can also physically damage stream channels and banks (Ames 1977, Kennedy 1977, Kauffman et al. 1983, Blackburn 1984, Clary and Webster 1989, Platts 1990). Deterioration of riparian vegetation structure can allow channel widening. This event, in turn, elevates water and soil temperatures and thus evaporation and lowering of water tables, as well as significantly increasing the potential for accelerated flood damage (Platts 1990). These processes alter the microclimate and vegetative development of riparian areas, potentially impairing its use by spotted owls. Prolonged use of these key habitats by large ungulates can alter plant reproduction and recruitment (e.g., cottonwoods, oaks), along with other negative habitat impacts including alteration of stream corridor morphology and hydrology, compaction of soil, and removal of stabilizing vegetation such as willows, sedges, and other native plants (Kennedy 1977, Rickard and Cushing 1982, Kauffman and Krueger 1984, Fleischner 1994, Krueger 1996). These impacts retard development of riparian, oak, and other plant communities into habitat that can be used by owls for roosting, nesting, or dispersal. Where riparian areas act as refuges for small mammals during drought periods, the impacts of grazing also may influence future prey abundance.

Grazing by domestic livestock and wild ungulates is widespread in regions occupied by owls. Since the Mexican spotted owl was listed as a threatened species, the FWS has conducted numerous consultations on potential effects of domestic livestock grazing in areas occupied by the owl. Grazing allotment plans provide guidance for managing and monitoring public-lands range use by livestock. Excessive grazing by wild ungulates has been documented in some specific areas of northern Arizona and southern New Mexico through forage-monitoring programs (Forest Guardians, unpublished technical report, 2004). Wild ungulates, particularly elk (*Cervus canadensis*), limit aspen regeneration. Decline of aspen impacts landscape diversity and aspen can reduce the rate of fire spread in forested landscapes. Wild ungulate populations are generally managed by state wildlife agencies through hunting programs.

In summary, we view grazing by domestic and wild ungulates as a potential threat to spotted owls when managed insufficiently in terms of its effects on prey species habitat (e.g., reducing herbaceous ground cover important to prey species), nest/roost habitat (e.g., limiting regeneration of important tree species used for nesting/roosting especially in riparian areas), and the capacity for resource managers to restore and maintain conditions supporting natural fire regimes within an array of habitat types. Grazing by domestic and wild ungulates is prevalent and recurring within most Mexican spotted owl habitat types. Thus, this potential threat occurs throughout the owl's range, and often during periods of its reproductive cycle when prey availability is most critical. The magnitude of the threat is greatly dependent on the duration, timing, and intensity of grazing, and if insufficiently managed, both short-term and long-term adverse affects on the owl's habitat and that of its prey species can be expected. We provide management recommendations (Appendices C and D) because both forms of herbivory will likely continue in the owl's habitat.

viii. Energy Development

Energy development includes oil, gas, wind, and solar extraction/harvest activities, exploration, and associated infrastructure developments (e.g., construction and expansion of power lines, pipelines, and roads). These activities may affect owls through direct disturbance from human presence, noise pollution (e.g., discharge of explosives; see discussion of noise disturbance under 8.B.e below) and alteration of habitat. Habitat alteration may be caused by facility (e.g., well pads, pipelines, power lines, wind turbines) and/or road construction, as well as exploration equipment and rarely by subsidence. Construction activities often involve use of large equipment potentially directly impacting habitat through removal of large trees, dead and down materials, etc. Such activities may also increase accessibility, opening areas to increased human disturbance.

There is little information on the extent of energy development activities in spotted owl habitat; however, information on oil and gas activities and wind energy development is available for the four states that make up the majority of the Mexican spotted owl range. This information is only reported by state, and therefore includes information from outside of the owl's range (e.g., Colorado plains east of the Rocky Mountains). We include this information here as a crude (and the only available) index of current trends and relative magnitude of oil, gas, solar, and wind energy activities in those states.

In the four-corner states, the number of active oil and gas wells increased by approximately 57% between 1993 (when the owl was listed) and 2006 (the most recent year for which data are available). In 2006 there were an estimated 92,700 wells, up from 59,200 wells in 1993 (Energy Information Administration 2010). The harvest of wind energy is also growing rapidly in the western U.S.; as of September 2009, there were 794 wind turbines either built or under construction in the four-corner states (AWEA 2009). While turbines have been shown to directly impact some owl species (Erickson et al. 2005, Smallwood et al. 2007, Smallwood and Thelander 2008), we believe that the potential for negative direct impacts (turbine strikes) to Mexican spotted owls is extremely low, though potential disturbance and/or habitat loss exists. Wind turbines can be a threat to migrating owls, although we do not know the extent of this threat. Gutiérrez et al. (1996) recorded mortality in Deming, New Mexico, of a banded adult

Mexican spotted owl, presumably after a southerly migration. The prevalence of such migration and the potential for interaction with turbines during migration is unknown. We make recommendations to address these effects in Appendices C and D.

ix. Influences on Riparian Habitats

We provide activity-specific discussions on land uses influencing riparian habitat throughout Appendix C - 4.B: Riparian Recovery Habitat) of this plan and provide specific discussion of the most prominent influences of riparian habitat under various activities herein. These include water development (Part II.8.Ba.xiii), grazing (Part II.8.B.a.vii), road development (Part II.8.B.a.x), tree removal (Part II.8.B.a.v), and recreation (Part II.8.B.a.xii). We provide this riparian-specific discussion to highlight the vulnerabilities of this important habitat type.

Many riparian systems within the range of the Mexican spotted owl are extremely degraded (i.e., formerly healthy riparian systems have lost virtually all or most trees as the result of past land-use practices and natural recovery of those areas has been precluded by erosion, altered hydrology, and/or invasion of non-native vegetation) (Stacey and Hodgson 1999). Our underlying premise is that if riparian systems are restored to properly functioning conditions, the needs of the owl (and numerous other species) in that habitat type will be satisfied (see management recommendations for riparian communities in Appendix C - 4). This is particularly true in canyon-bottom situations at middle and lower elevations where little other typical nesting or roosting habitat may be available. Because canyon bottoms are used extensively by the Mexican spotted owl (Ganey and Dick 1995, Rinkevich and Gutiérrez 1996, Willey 1998b, Stacey and Hodgson 1999), it is important to preserve and increase the quality of such habitat. The PACs described in this revised Recovery Plan (see Part II.5.C; Appendix B – 4; and Appendix C - 3) include some of the best canyon riparian habitat that still exists, but increasing the quantity and distribution of properly functioning riparian habitats outside of PACs will provide the potential for increasing the amount and extent of spotted owl habitat. A definition of proper functioning condition for riparian areas is provided by BLM (1998).

x. Roads and Trails

Construction of roads and trails can indirectly affect spotted owls through loss and fragmentation of habitat (we discuss the effects of increased noise potential, human access, and direct mortality in Part II.9.D.e below). In general, habitat loss to road construction is minor on a rangewide scale when compared to more massive habitat losses observed from other causes (wild land fires, past harvest practices, etc.); however, on a local scale roads and trails through PACs may fragment habitat continuity, alter natural movement patterns, and increase disturbance to resident owls. Management recommendations regarding roads are provided in various places within Appendices C and D.

xi. Land Development

Land development is the conversion of natural land covers to non-natural surfaces for human use. This includes housing, commercial enterprises, and the associated infrastructure such as roads, trails, and utility structures. Land development occurs along a gradient from urban

development to exurban and rural development. Exurban development is defined based on either population or housing density, but it is commonly considered as low-density, large lot residential development (i.e., one house per 4–16 ha [1–4 ac]; Theobald 2004). Exurban development probably poses a greater threat to Mexican spotted owl populations than other forms of land development, particularly in forest environments where private lands are adjacent to or located within Federal lands, although the extent of this threat is unknown. In addition, several studies have suggested that housing development threatens species occurring within many “protected” areas within the U.S. (e.g., Radeloff et al. 2010, Wade and Theobald 2010). Nationally, 80% of all developed land is at exurban densities (Wade and Theobald 2010), and exurban development is increasing at a greater rate in forested lands of the western U.S. than any other form of development, or in other regions of the country (Brown et al. 2005, Theobald and Romme 2007). This rapid growth away from urban areas, termed “rural sprawl,” appears to be due to the attractions of the environmental and recreational amenities of these areas, retirement of “baby boomers,” and the increasing separation of home and work locations due to better communications networks (Hansen et al. 2002, Brown et al. 2005, Radeloff et al. 2010).

Much of this development is occurring in proximity to National Forests and other Federal lands. Housing development within 1 km of National Forests increased by an average of 20.8% per decade from 1940-2000 and has been above the national average for housing growth since the 1970s (Radeloff et al. 2010). This pattern of greater-than-average development near and within Federal lands is expected to continue within the range of the owl, with a greater than 25% increase projected for the states of Arizona, Colorado, New Mexico, and Utah from 2000 to 2030 (Wade and Theobald 2010).

Exurban development is a potential threat in all Mexican spotted owl recovery units in the U.S. In an analysis of WUI, Radeloff et al. (2005) provide county-level data on area developed at several intensities and arrangements. Based on this information, 2.6% of all land area in counties with designated PACs falls within their definition of WUI, with 64.5% of this development being low-density intermix development. The SRM and BRE EMUs have the highest proportion of land area as WUI (5% and 4%, respectively), although the BRW EMU has the largest areal extent of land affected by this form of development. By restricting analysis to counties with at least 10 designated PACs, the BRW EMU still ranks highest in amount of land impacted by WUI development, with the UGM EMU also having substantial area.

Land development adjacent to non-developable areas can influence species distribution and abundance, as well as ecological function, within those areas by a number of mechanisms, most notably by reduction in effective size of the area, alteration of ecological processes (e.g., predation, competitive interactions), loss of important habitat features or seasonally important use areas for the species, and disturbance (Hansen and DeFries 2007). Habitat loss and fragmentation due to development usually impacts species on a landscape-scale, but development also has local-scale impacts, particularly due to disturbance and vegetation change (Schlesinger et al. 2008).

No studies have evaluated the influence of land development on use of habitat by spotted owls or effects on habitat quality. Although most known owls occur on Federal lands, specific developments in Arizona and New Mexico have been suspected to impact spotted owl habitat.

In addition, the extent to which these owls forage or winter on lands subject to development is unknown, but it is likely that the development of private lands within and surrounding Federal lands directly affects habitat used by spotted owls. Further, there have been a number of land exchanges, both completed and proposed, where the primary economic driver was to acquire Federal lands for development. Working with California spotted owls, Manley et al. (2009) projected that current levels of development in the Tahoe Basin has reduced the amount of area that met “territory” criteria by 28% to 38%. The majority of this loss was the result of indirect changes to the landscape that are typical of exurban development, rather than the actual conversion of area to structures. Development leads to declines in vegetative features important to owls, especially dead woody debris (Fraterrigo and Wiens 2005, Heckmann et al. 2008). In addition, fragmentation by development may lead to owls requiring larger areas. For example, working with northern spotted owls, Carey et al. (1992) found that in areas of high fragmentation, owls utilized three times the amount of mixed-conifer forest than in areas of limited fragmentation.

Ecological processes influencing Mexican spotted owl populations might be altered by development. Forest fragmentation may lead to increases in potential predators, such as great horned owls, which increase in abundance with high levels of habitat heterogeneity caused by fragmentation (Grossman et al. 2008). Fragmentation was found to increase the spatial overlap between great horned owls and barred owls and may increase the threat of predation on barred owls by great horned owls (Laidig and Dobkin 1995). Development also alters ecological processes associated with fire regimes, by increasing the probability of fire starts and activities associated with suppression or mitigation of risk (e.g., WUI). The threats from these activities are discussed elsewhere in this five-factor analysis (e.g., see Part II.9.D.a.ii and vi).

Increasing development leads to greater impacts on species due to increased use of surrounding areas by humans (Riebsame et al. 1996). Behavioral responses to disturbance can be a more important factor in loss of species to development than habitat alteration (Schlesinger et al. 2008). The threat of recreational disturbance to Mexican spotted owls is evaluated elsewhere in this five-factor analysis (see Part II.9.D.a.xii).

A major question not answered at present is the extent and importance of wintering habitat for Mexican spotted owls, particularly in the northern periphery of their range. In Colorado, this question may have substantial bearing on whether land development is a serious threat to continued presence of the species, as land development may disproportionately affect wintering areas there. These lower-elevation areas are more likely to be privately owned and impacted by exurban development, and in these areas exurban housing densities have shown the greatest increase (Riebsame et al. 1996, Theobald 2000).

In summary, land development poses a potential threat to spotted owls primarily through habitat fragmentation, alteration of ecological processes (e.g., predators, fire regimes), and increased potential for disturbance. This threat exists in all EMUs but the magnitude is highly variable due to the variation in amount and configuration of developable land in proximity to current spotted owl habitat. Land development probably threatens foraging and wintering habitat more than nest/roost habitat, although the level of threat is unknown. We provide management recommendations (Appendices C and D) to mitigate threat of land development to the spotted owl.

xii. Recreation

Recreational activities may affect owls directly through disturbances caused by human activity (e.g., hiking, shooting, and off-highway vehicle [OHV] use at nesting, roosting, or foraging sites; see II.9.D.2.e of this analysis) or indirectly through alteration of habitats such as damage to vegetation, soil compaction, illegal trail creation, and increased risk of wildland fires. Whether managed or unmanaged (i.e., user-created), development of new recreational facilities (e.g., trailheads, OHV and mountain bike trails) and expansion of existing facilities (e.g., campgrounds and hiking trails) may alter owl habitat.

The potential for recreation-related impacts to the owl is relatively high. Visitation at the 18 national parks, monuments, and recreation areas within the owl's U.S. range has doubled from approximately 7 million to over 14 million visits from 1971 (the first year data were available for all 18 park units) to 2009 (USDI NPS 2010). The NPS lands make up approximately 2.5% of the owl's U.S. Range (USDI FWS 1995). While only a fraction of visitors are likely to recreate in PACs, the overall high level of visitation demonstrates the scale of recreation-related human activities within the owl's range.

Depending on the extent, intensity, and duration, recreational disturbance may have negative impacts on owl habitat. For example, the number of people who drive OHVs off road has increased over 109% in the United States since completing the 1995 Recovery Plan (Cordell 2004). In addition, the number of OHVs in use from 1997 to 2001 increased almost 40%, OHV drivers increased by 36%, and OHV driving hours increased by 50% (68 FR 19975; April 23, 2003). The significant increase in OHV use, OHV-associated impacts to natural resources, and a desire to provide better OHV management have precipitated development of proposed Travel Management Plans for all Federal public lands as well as implementation of a 2009 Arizona OHV Law (SB1167). These actions illustrate that both Federal and state agencies have identified this recreational activity as a major concern.

Thus, there have been significant increases in the extent and intensity of recreational activities within the owl's range since the development of the original Mexican Spotted Owl Recovery Plan (USDI FWS 1995). Impacts are most likely to occur at the level of individual owls and/or PACs and may be adverse to small, isolated populations depending on the extent, intensity, and duration of the activity. Since the owl's listing in 1993, the canyonlands in southern Utah have experienced a steady increase in visitation, and as a result, a significant increase in canyoneering, a sport which encompasses boulder scrambling and rock-climbing to descend through canyons, including those where spotted owls are known to nest (USDI FWS 1995, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001). For example, human recreational-use levels were measured for canyons by the NPS in Zion National Park using use permits. Canyoneering permits for popular canyons occupied by the owl increased by 1714% between 1998 and 2002 (Zion National Park, unpublished backcountry use records). Recreational use of canyons has continued to rise in the last five years, and the number of permits issued for narrow slot canyon day use has increased 42% since 2003, and overnight permits increased 26%. Currently, however, recreational disturbances such as these are not known to affect regional or range-wide owl populations. Management recommendations to address the threat posed by recreation are provided in Appendix D - 7 and 8.

xiii. Water Development

Water development includes dams, permanent flooding of riparian habitats, bed degradation below dams, stream dewatering, diversions, altered-flow regimes, and artificial watering ponds (e.g., stock tanks). Effects of development on owls vary but can be loss or degradation of habitat, habitat fragmentation, disruption of migration corridors, inhibited gene flow, and altered grazing patterns by wild and domestic ungulates.

Previously occupied riparian communities in the southwestern U.S. and southern Mexico have undergone significant habitat alteration since the historical sightings (USDI FWS 1993). For example, in southern Utah and northern Arizona, inundation of Glen Canyon by Lake Powell in 1963 created a 299 km (187 mi) long and 40 km (25 mi) wide reservoir that may restrict juvenile dispersal (Willey and Van Riper 2000) and flooded a potentially large subpopulation (MacDonald et al. 1991, Willey and Spotskey 2000). Lake Powell may represent a landscape barrier isolating subpopulations in Utah from subpopulations in Arizona (Barrowclough et al. 1999).

In addition to inundating habitat and creating dispersal barriers, dams can alter hydrologic conditions below the dam and strongly influence the structure and function of riparian ecosystems (Poff et al. 1997). Dams often regulate the timing, magnitude, and duration of floods which are the primary natural disturbances in riparian ecosystems (Poff et al. 1997). Natural floods deposit sediment on flood plains that create seed beds for riparian plants, and they flush salts and redistribute nutrients. Regulation of floods below dams can reduce or eliminate these critical processes. Salinity increases can be biologically significant. Most native willows and cottonwoods are relatively intolerant of salt (Jackson et al. 1990, Shafroth et al. 1995), whereas tamarisk germination increases with salinity (Busch and Smith 1995, Smith et al. 1998). Thus, it has a competitive advantage over cottonwoods and willows on regulated rivers. Increase in tamarisk and decline in native vegetation may have implications for owl habitat quality.

Stock tanks are artificial watering holes established primarily for domestic livestock. In addition to domestic livestock, they are used by wild ungulates such as deer and elk. Effectively, these tanks have allowed both domestic and wild ungulates to expand their geographic range, thereby allowing them to graze over a wider area than they might have with limited water. Depending on the intensity, seasonality, and location of where these animals graze, potential exists for them to affect habitat for owls and their prey (see II.9.D.2.a.vii).

In summary, effects of water development can range from site-specific habitat loss or degradation to habitat fragmentation, disruption of migration corridors, and inhibited gene flow across larger landscapes. Much of our knowledge concerning effects is indirect and inferential given that no studies have specifically addressed these threats. For example, studies in the Grand Canyon by Willey and his associates have recorded a number of owl sites and have resulted in predictions of potential owl habitat. Many of the canyons inundated by Lake Powell likely possessed similar characteristics as those occupied by owls in Grand Canyon, thus it is conceivable that some would have been occupied. Not only was there probable habitat loss but given the size of the lake, movements of birds between Grand Canyon and other parts of the Colorado Plateau Ecological Management Unit may have been disrupted. Effects of dams on

downstream habitat have not been investigated, but the replacement of native cottonwood forests with non-native tamarisk stands may effectively represent a loss of owl habitat. The extent and severity of this threat warrant additional study. We provide management recommendations specific to this threat in Appendix D.

b. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes (Factor B)

i. *Commercial Exploitation*

We are unaware of any commercial exploitation of Mexican spotted owls.

ii. *Recreational Exploitation*

The southwestern U.S., particularly southeastern Arizona, is one of the premier destinations in the U.S. for birdwatching. Unfortunately, the high visitation level of birdwatchers has begun to result in recreational exploitation of Mexican spotted owls as birders attempt to “collect” sightings and/or pictures of rare species for their life lists. Recreational birders have been observed regularly visiting several owl territories in the Huachuca and Chiricahua Mountains of southern Arizona. The FWS frequently receives reports of people continuously playing audio recordings of spotted owls to elicit responses, shining lights repeatedly at owls to take pictures, and other acts of harassment. Though it is unlikely that these actions are impacting large numbers of owls, it is a threat at the site-specific level and is usually illegal absent appropriate Federal and state or Tribal permits issued for research or inventory purposes. We therefore provide management recommendations in Appendix D, Sections 7 and 8, that address management, education, and enforcement actions to minimize effects of recreational exploitation.

iii. *Scientific Exploitation*

The information obtained through scientific studies is instrumental in devising appropriate recovery strategies for threatened and endangered species, as well as in monitoring progress toward recovery goals. In the case of the Mexican spotted owl, obtaining the types of ecological information required sometimes involves trapping, handling, and marking owls either with color bands or radio transmitters. These activities have been conducted for many years on all three subspecies of spotted owls. Many hundreds of owls have been trapped and handled, with a limited number of injuries or mortalities resulting from these activities. Therefore, we generally consider these activities to be acceptable for the study of owls and do not consider research and monitoring activities to pose a significant threat to population persistence. Nevertheless, trapping and handling wildlife has certain inherent risks that can never be eliminated entirely, and efforts should be undertaken to minimize any potential impacts to the owl. To aid in this process, we provide management recommendations in Appendix D - 9. These recommendations address permitting and reporting requirements, as well as essential safeguards to minimize potential impacts of the research activities.

iv. *Educational Exploitation*

We are unaware of any exploitation of Mexican spotted owls for educational purposes.

c. Disease or Predation (Factor C)

i. *West Nile Virus*

Mexican spotted owls are not known to have suffered population declines from disease. However, The U.S. Center for Disease Control (CDC) has identified over 300 avian species (both native and non-native, wild and captive) in which dead specimens have tested positive for infection by West Nile Virus in the U.S. (www.cdc.gov). The virus first appeared in North America in 1999, with encephalitis reported in horses and humans. It has since been documented in all U.S states except Alaska and Hawaii (www.cdc.gov).

The virus is commonly spread by transmission between mosquito vectors and bird reservoir hosts. However, birds can also become infected by means other than arthropod transmission (Marra et al. 2004). Komar et al. (2003) reported that ingestion of West Nile Virus in aqueous solution resulted in infection in several bird species, including great horned owls. It is not known whether ingestion of infected prey by raptors has resulted in bird mortality, but the risk exists (Marra et al. 2004). Finally, contact transmission has been documented in the laboratory in caged birds (McLean et al. 2001; Komar et al. 2003), perhaps from such behaviors as mutual preening and beak-to-beak contact.

Avian mortality from West Nile Virus has been extensive in North America (www.cdc.gov). Natural fatal infections were detected between 1999 and 2002 in over 28,000 bird carcasses representing 198 species, including a captive spotted owl (subspecies not identified; www.cdc.gov). However, we are unaware of any records of wild spotted owls being infected with West Nile virus. Hull et al. (2010) tested 209 California spotted owls in the Sierra Nevada of California between 2004 and 2007 and detected no antibodies in those specimens. The authors remarked that these results were “somewhat unexpected” given that the California Department of Public Health had recorded numerous infection incidences in other avian species in the region during that time. Hull et al. (2010) expressed doubt that this absence of detection was simply an inadequate sampling scheme; rather, given the large number of specimens sampled, they conclude that West Nile Virus infection is absent in the area’s spotted owls. However, they alternatively hypothesize that an absence of detections could be because spotted owls exhibit such a high mortality rate that they do not survive long enough to develop a detectable immune response.

We are unaware of any incidence of West Nile Virus in Mexican spotted owls, or of any surveillance program (systematic or otherwise) for this disease. Nonetheless, the potential impact of the disease on threatened species and those of ecological importance is of great concern (Joyner et al. 2004). Marra et al. (2004) point out that, although no regional declines of imperiled avian species have been documented, species already affected by other population stressors may be at particular risk of extinction from West Nile Virus. They further state that

determining a given species' susceptibility to West Nile Virus is critical for understanding the pathogen's ecology and protecting threatened wildlife populations.

The scientific panel that reviewed the status of and threats to the northern spotted owl was unanimous in regarding West Nile Virus as a potential future threat (Courtney et al. 2004). Their concern was based on the spread of the disease to within the range of that subspecies and the fact that the disease has been fatal to spotted owls. However, that conclusion predates the work of Hull et al. (2010) and we do not know if the panel would reach the same conclusion considering Hull et al.'s results. In addition, the final Recovery Plan for the Northern Spotted Owl (USDI FWS 2008) does not recognize West Nile Virus as a current threat and recommends only monitoring for the disease as a recovery action. We also do not consider this disease to be a significant threat to the owl at this time, but because it could be in the future we make management recommendations similar to those in the northern spotted owl plan (Appendix D).

ii. *Predation*

Predation is a common mortality factor of spotted owls, accounting for at least 5 of 11 deaths documented among radio-marked adult and subadult owls (J. Ganey, USDA FS, pers. comm.), and 14 of 29 documented mortalities of radiomarked juveniles (Ganey et al. 1998, Willey and Van Riper 2000). Predation may account for more deaths than indicated because the cause of death of recovered spotted owls is often unknown. The specific predator involved is also typically unknown. Procyonid mammals were observed attempting to raid cliff-site nests occupied by spotted owls in southern Arizona (R. Duncan, Southwestern Field Biologists, pers. comm.), suggesting that they may prey on spotted owls. However, avian predation is suspected to be the main form of predation. Potential avian predators of Mexican spotted owls include great horned owls, northern goshawks (*Accipiter gentilis*), red-tailed hawks (*Buteo jamaicensis*), golden eagles (*Aquila chryseatos*), and barred owls (where they are sympatric; Leskiw and Gutiérrez 1998). Some of these predators occupy the same general habitats as the spotted owl, but there is little direct evidence that they prey on spotted owls (Gutiérrez et al. 1995). Ganey (1988) reported one instance of apparent great horned owl predation on an adult spotted owl, but Ganey et al. (1997) did not document predation on spotted owls in a study involving sympatric spotted and great horned owls. Reynolds (USDA FS Fort Collins, Colorado, pers. comm.) reported a golden eagle preying on a spotted owl.

Results from radiomarked Mexican spotted owls indicate that all age classes are preyed upon (Ganey 1988, Ganey et al. 1998, 2005; Willey 1998b, Willey and Van Riper 2000). We suspect that predation may have localized effects on spotted owl abundance, particularly due to effects on fledging rates and post-fledging juvenile survival. While predation is a documented mortality factor, there is no evidence that current predation rates are abnormally high. In summary, we do not view predation as a significant threat and provide no threat-specific management recommendations.

d. Inadequacy of Existing Regulatory Mechanisms (Factor D)

The National Environmental Policy Act (NEPA), land-management statutes like the National Forest Management Act, and state regulations governing direct taking of species were evaluated

in the final rule listing the Mexican spotted owl. We discuss these statutes and regulations further in Appendix G of this Recovery Plan, and we incorporate them here by reference. We are unaware of any changes in these statutes and regulations other than those we specify below, and the previous conclusion that they convey little protection of habitat, in absence of ESA influence, remains valid. We also note that the discussion below merely describes the relevant laws influencing spotted owls and their habitat, and inclusion of these laws does not necessarily imply inadequacy. We discuss several recent laws, regulations, and policies potentially influencing forest management below.

i. National Fire Plan and Policy

The interagency Federal Wildland Fire Policy, adopted by the U.S. Forest Service, U.S. FWS, U.S. BLM, U.S. BIA, and U.S. NPS in 1995 states, “Fire, as a critical natural process, will be integrated into land and resource management plans and activities on a landscape scale, and across agency boundaries. Response to wildland fire is based on ecological, social, and legal consequences of fire.” The National Fire Plan was developed in August 2000 with the intent of improving active response to wildland fires and their impacts to communities through development of a 10-year strategy and goals in 5 key areas: firefighting, rehabilitation, hazardous fuels reduction, community assistance, and accountability. The plan consists of a report to the president, the subsequent comprehensive strategy plan, and congressional appropriations. The strategy is to reduce wildland fire risks to communities and the environment by correcting problems stemming from the long-term disruption of natural fire cycles.

A 2009 revision of the 2003 Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy distinguished between two kinds of wildland fire: prescribed fire (planned ignitions), and wildfire (unplanned ignitions). The revision allows fire managers to manage a wildfire for multiple objectives to increase managers’ flexibility in responding to changing incident conditions and firefighting capabilities, while strengthening strategic and tactical decision implementation to support public safety and resource management objectives. Hazardous fuels reduction treatments are designed to reduce the risks of wildland fire to firefighters, people, communities, and natural resources while restoring forest and rangeland ecosystems to their historical structure, function, diversity, and dynamics. Although the intent of the National Fire Plan and Policy is also to protect habitats for the owl and other species over the long-term by reducing habitat loss from severe fire, short-term effects to owls may occur during and following treatments, and cumulative effects may possibly occur in more intensely WUI-managed landscapes. Our fire- and fuels-management recommendations in Appendices C and D are compatible with the National Fire Plan.

ii. Healthy Forests Initiative

President George W. Bush announced the Healthy Forests Initiative in August 2002 to streamline regulatory processes for Federal agencies, to provide for more timely decisions and greater efficiency in reducing fire risk through increased fuels-reduction treatments. The initiative consists of administrative changes related to fire and fuels treatment projects, including the establishment of two new categorical exclusions from NEPA analysis, changes to administrative appeal rules, and new Council for Environmental Quality guidance for environmental

assessments. Administrative actions that may affect management and treatment of owl habitat include:

- Joint counterpart regulations were developed that no longer require consultation with and written concurrence from FWS and National Marine Fisheries Service (collectively “the Services”) for National Fire Plan projects that the action agency has determined will not adversely affect listed species. The action agencies take on the responsibilities of the Services for these projects (USDI FWS and USDC NOAA 2004).
- Guidance was developed to evaluate net benefits of hazardous fuels treatment projects. During consultations, the Services evaluate the long-term benefits of these projects, including benefits of restoring natural fire regimes and native vegetation and long-term risks of severe wildfire, against the short- or long-term adverse effects of these projects (USDI FWS and USDC NOAA 2002).

Our fire- and fuels-management recommendations in Appendix C are compatible with the Healthy Forests Initiative.

iii. Healthy Forests Restoration Act of 2003

The Healthy Forests Restoration Act of 2003 (HFRA; P.L. 108-148) applies to hazardous-fuels-reduction projects on National Forest System and BLM lands. The objectives of the HFRA are to reduce wildland fire risk to communities and municipal water supplies; authorize grant programs to improve the commercial value of forest biomass; enhance efforts to protect watersheds and address threats to forest and rangeland health; identify and address the impact of insect and disease infestations on forest and rangeland health; and protect, restore, and enhance forest ecosystem components, including promoting the recovery of threatened and endangered species (HFRA 2003). The HFRA does not authorize treatments in federally designated wilderness, wilderness study areas, or other areas where vegetation removal is prohibited through congressional or Presidential protection.

Title I requires the Secretaries of Interior and Commerce to comply with any applicable guidelines specified in any management or recovery plan for threatened and endangered species (but see discussion under II.9.D.2.a.iv above). It requires that HFRA projects maintain or contribute toward restoration of the structure and composition of old-growth stands according to pre-fire-suppression, old-growth conditions. It also requires that projects maximize retention of larger trees in areas other than old-growth stands, consistent with the objective of restoring fire-resilient stands and protecting at-risk communities. Other aspects of the HFRA provide for expedited environmental review and administrative review of proposed projects. It also requires collaboration between Federal agencies and local communities in development of Community Wildfire Protection Plans that identify and prioritize areas for hazardous-fuels-reduction treatments, recommend treatment methods, and recommend measures to reduce ignition of structures in the at-risk community.

Title III provides grant programs to states, Tribes, small communities, and individuals for projects that provide watershed restoration and conservation, wetland restoration, and establishment of riparian vegetative buffers. Title V established the Healthy Forests Reserve Program. Private landowners may enroll their lands in this program if their lands will restore,

enhance, or otherwise measurably increase the likelihood of recovery of federally listed, candidate, or state-listed species or special-concern species. Landowners who enroll may receive financial assistance to restore or enhance habitat for these species.

Fire- and fuels-management recommendations are given in Appendix C and are compatible with the Healthy Forests Restoration Act of 2003.

iv. *The Omnibus Public Land Management Act of 2009, Title IV Forest Landscape Restoration Act*

The purpose of the Forest Landscape Restoration Act (FLRA) is to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes through a process that encourages ecological, economic, and social sustainability; leverages local resources with national and private resources; facilitates the reduction of wildland-fire management costs, including through reestablishing natural fire regimes and reducing the risk of uncharacteristic wildfire; and demonstrates the degree to which various ecological restoration techniques achieve ecological and watershed health objectives. To be eligible to receive funding, a collaborative forest-landscape-restoration proposal must be based on a landscape-restoration strategy that identifies and prioritizes ecological restoration for a 10-year period on a landscape that is at least 20,243 ha (50,000 ac). The FLRA states that vegetation treatments should focus on removal of small-diameter trees, retain large trees to the extent that the trees promote fire-resilient stands, and improve fish and wildlife habitat, including for endangered, threatened, and sensitive species.

The Southwestern Region of the U.S. Forest Service is currently working to develop landscape-scale restoration projects that would qualify for FLRA funding. One example of this is the Four Forest Restoration Initiative. The Apache-Sitgreaves, Coconino, Kaibab, and Tonto National Forests are working with stakeholders to develop a collaborative restoration plan in the ponderosa pine forest type across the four forests. These four forests include a significant portion of the UGM EMU and will likely include a considerable amount of Mexican spotted owl PAC and recovery habitat. Fire- and fuels-management recommendations in Appendices C and D should facilitate implementation of such large-scale treatments as envisioned under the FLRA.

v. *Stewardship Contracting Authority*

Through the Consolidated Appropriations Resolution of 2003, Congress enacted legislation expanding stewardship contracting authority for the USFS and BLM. This authority allows these agencies to enter into long-term (up to 10 yrs) contracts with small businesses, communities, and nonprofit organizations to reduce wildland fire risk and improve forest resiliency. Stewardship contracts can be used for projects that will provide benefits to local and rural communities and meet goals such as road or trail maintenance to improve water quality; improvement of soil productivity; improvement or protection of habitat for wildlife and fisheries or other resource values; use of prescribed fire or other treatments to improve forest health or wildlife habitat and reduce fire hazards; restoration and maintenance of watersheds; and control of noxious and exotic weeds coupled with reestablishment of native plant species. This stewardship authority can be useful in implementing the management recommendations in Appendix C.

e. Other Natural or Manmade Factors Affecting the Mexican Spotted Owl's Continued Existence (Factor E)

i. *Noise and Disturbance*

Infrequent, noise-producing activities are generally assumed to have relatively little long-term impact on spotted owls. However, owls will react to noise disturbances by changing behavior and/or flushing from their perches (Delaney et al. 1999a, Swarthout and Steidl 2001, 2003). These behavioral responses may alter nesting and roosting activities, thus increasing vulnerability to predators and heat-related stress. Factors such as distance to and frequency of a noise disturbance, habitat type, topography, and sound source may influence spotted owl responses (Delaney and Grubb 2004). For example, noises close to nests are likely to be more disruptive than those far from nests (Delaney et al. 1999a).

Similarly, some types of noise may be more disturbing than others. Mexican spotted owls in forested environments reacted more to chainsaws (operated out of sight of owls) than to the sound of helicopters at the same distance (Delaney et al. 1999a). The proportion of owls flushing also was negatively related to distance and positively related to noise level. Noises ≥ 80 dBO (i.e., decibels weighted for middle sound frequencies where owl hearing is the most sensitive), had a greater than 0.60 probability of causing an owl to flush (Pater et al. 2009). This noise level (80 dBO) is roughly equivalent to 69 dBA (i.e., decibels weighted for human hearing) or approximately twice as loud as ordinary conversation. In a related study, noise disturbances close (96 m) to owl nests may have affected prey delivery rates (Delaney et al. 1999b). While little research is available comparing the relative impact of various noise disturbances, it is likely that persistent noises are more disruptive than infrequent disturbances, and intensity of disturbance is proportional to sound volume.

There is also the potential for noise pollution (i.e., consistent noise-causing activities as opposed to the sporadic noise disturbances discussed above) to impact spotted owl nocturnal breeding and foraging habits. Because owls are active at night when it is difficult or impossible to see other owls, audio communication is a critical component of the owl's social system (Frid and Dill 2002; e.g., territorial defense, pair bonding and maintenance, feeding nestlings, and post-fledging activities). Further, owls depend heavily on sound to locate and capture prey in near darkness (Payne 1971, Martin 1986, Norberg 1987).

No studies have been conducted on the influence of habitat type (canyon vs. forest) on noise disturbance to owls. While both forest- and canyon-dwelling owls respond to human presence, potentially disruptive interactions between humans and owls may be more likely in canyons because canyons can amplify noises (especially in caves) and provide limited escape routes for owls. In addition, the number of sites in canyons that afford spotted owls adequate thermal protection for nesting and roosting may be more limited than in forested environments. Finally, canyons may lack visual barriers between owls and noise sources that are common in dense forests, and this also may influence owl responses.

Noise impacts are most likely to occur at the level of individual owls and/or PACs, and they may be important to small isolated populations. We believe that disturbance should be avoided when

practicable during the nesting season (see noise disturbance recommendation in Appendix D - 10).

ii. Barred Owls

Prior to the twentieth century, the barred owl was restricted to eastern North America, from southeastern Canada, through the eastern U.S., and into eastern Mexico (Mazur and James 2000). Over the past 100 years, and particularly over the past few decades, the nominate subspecies of the barred owl (*S. v. varia*) has expanded its range westward across Canada to the Northern Rocky Mountains and the Pacific Northwest, where it has rapidly invaded the range of the northern spotted owl (Dark et al. 1999, Mazur and James 2000, Courtney et al. 2004). The barred owl was recognized as a potential threat of considerable concern in the Final Rule listing the northern spotted owl (55 FR 26114) and it was addressed as a threat in the Draft Recovery Plan for that taxon (USDI FWS 1992). More recently, the barred owl has been judged as representing an even greater threat to the northern spotted owl than earlier believed and, currently, it is negatively impacting the subspecies in some areas where the two owls overlap (Courtney et al. 2004). Compared to the spotted owl, the larger, more aggressive barred owl appears to be at a competitive advantage because it feeds on a broader range of prey, occupies a wider range of habitats, and has been recorded displacing (and even killing) northern spotted owls (Dark et al. 1999, Mazur and James 2000, Hamer et al. 2001, Courtney et al. 2004, Gutiérrez et al. 2007). In addition, interbreeding between the two has been documented (Hamer et al. 1994) and such hybridization is a further threat to the northern spotted owl.

Historically, the barred owl was unknown within the U.S. range of the Mexican spotted owl. Hence, it was not considered a threat when the taxon was listed and was not addressed in the 1995 Recovery Plan for the Mexican Spotted Owl (USDI FWS 1995). However, barred owls have been verified within three of the five states where the Mexican spotted owl occurs: Colorado, Texas, and New Mexico. In addition, there have been two unconfirmed reports of barred owls in Utah. The first verified record of a barred owl in Colorado is from 1897, when an adult and a set of two eggs were collected on the plains of northeastern Colorado in the Town of Holyoke, Phillips County (L. Semo, Chair, Colorado Bird Record Committee, pers. comm.). Another verified record was of two barred owls observed in January 2000 a few miles from the Oklahoma border along the Cimarron River in Baca County (L. Semo, pers. comm.). There are also two unconfirmed reports of barred owls from Colorado: two were reported on 21 May 1960 from Bonny Reservoir, Yuma County (near the Kansas border), and another was reported nearby on 16 May 1964 (L. Semo, pers. comm.). None of the Colorado barred owl records were within the range of the Mexican spotted owl; most spotted owl records in that state have been from the central and southern mountain ranges.

Similarly, no barred owls have been detected within the spotted owl's range in Texas, although the barred owl is common in parts of that state (C. Shackelford, pers. comm.). Spotted owls have been documented only in three mountain ranges in the Trans-Pecos region of Texas (Guadalupe, Davis, and Chisos mountains), while the barred owl is common only in the eastern half of the state and reaches its range limits well east of the Pecos River. The treeless areas east of 100°W longitude appear to be limiting the barred owl's expansion into western mountains occupied by spotted owls (C. Shackelford, pers. comm.).

Unlike in Colorado and Texas, a barred owl has been verified in proximity of occupied Mexican spotted owl habitat in New Mexico. The owl was discovered in May 2004 in cottonwood riparian habitat along Galisteo Creek at Galisteo, Santa Fe County (Williams 2004). The location is only approximately 24 km (15 mi) from the southern Sangre de Cristo Mountains and 48 km (30 mi) from the Jemez Mountains, and it is within flying distance of occupied Mexican spotted owl habitat in both mountain ranges. The barred owl, which was occasionally vocal, remained in that area at least through early October 2004. In addition, an apparent New Mexico record from 1993 resulted from a freshly dead barred owl that was hit by a truck, perhaps somewhere from Albuquerque north to Raton (Williams 1993). Examination indicated that the owl was not the nominate subspecies, but instead a geographically closer race, such as *S. v. helveda* or *S. v. georgio*, of adjacent Texas and Oklahoma.

In Mexico, the range of the Mexican subspecies of the barred owl is known to overlap the southern extremity of the Mexican spotted owl, but both owls are apparently scarce in that area. The ecological relationship between the two owls where they might overlap in Mexico has not been investigated; they might or might not occupy similar elevation and/or habitat zones.

Given that few barred owls have been detected within the range of the Mexican spotted owl, that even fewer barred owls have been verified where spotted owls are known to occur, and that there does not appear to be a trend of increasing abundance of barred owls in the southwestern U.S., we currently do not recognize an incursion of barred owls as being imminent. However, we believe the situation warrants observation, because barred owls could extend their distribution into the range of the Mexican spotted owl if there are additional increases in their required habitats, particularly in availability of forested areas (see Appendix D).

iii. Direct Mortality

Causes of direct mortality other than those we previously discussed include vehicle collisions, electrocution, and possibly direct effects associated with wildland fires. Direct mortality from collisions with vehicles has been documented (R. Skaggs, Glenwood, New Mexico, pers. comm.; R. Duncan, Southwestern Field Biologists, pers. comm.; E. Brekke, BLM Royal Gorge Field Office, pers. comm.; J. L. Ganey, U.S. Forest Service unpublished data, S. Hedwall FWS unpublished data), but the extent of mortality from this source is unknown. There is at least one record of electrocution, where a color-banded adult female owl was found electrocuted near Deming, New Mexico (Gutiérrez et al. 1996). There is also a documented mortality from an encounter with a pasture fence (S. Hedwall USDI FWS unpublished data). Mortality from wildland fires through heat and smoke exposure may include, in order of increasing vulnerability, loss of adults, fledglings, nestlings, and eggs. Direct effects and mortality at active roost sites and nests from fire suppression activities (e.g., water and retardant drops) also may have occurred (D. Salas, Lincoln National Forest, pers. comm.). In summary, direct mortality from these causes is not likely a substantial influence on Mexican spotted owl persistence.

iv. Climate Change

Strong evidence exists that global climates are changing in response to increasing emissions of greenhouse gases (IPCC 2007), and that changing climates are affecting forest ecosystems

throughout the world either directly or indirectly through altered disturbance regimes (e.g., Ayres and Lombardero 2000, Breshears et al. 2005, 2009; Bonan 2008, Hogg et al. 2008, Raffa et al. 2008, Floyd et al. 2009, Negrón et al. 2009, van Mantgem et al. 2009, Allen et al. 2010). Understanding the effects of climate change on forests is critical to informing forest management and conservation planning for the future (Allen et al. 2010). This includes recovery planning for the Mexican spotted owl, which inhabits forests throughout much of its range.

Models of projected climate change typically focus on two variables: temperature and precipitation. In general, model predictions appear to be more robust with respect to temperature than precipitation (Sheppard et al. 2002). How climate change will affect summer monsoonal precipitation in the southwestern U.S. is even less certain, because precipitation predictions are based on continental-scale general circulation models (GCMs) that do not yet account for regional phenomena such as those that control monsoonal rainfall (Weiss and Overpeck 2005:2075, Archer and Predick 2008:24).

The southwestern U.S. exhibits high climatic complexity and variability in general. This is due to both complex topography and proximity to the Pacific Ocean, the Gulf of California, and the Gulf of Mexico (Sheppard et al. 2002, Brown and Comrie 2002). Because of this complexity and steep environmental gradients, many ecosystems within the southwestern U.S. may be particularly vulnerable to climate change (Archer and Predick 2008). For example, recent temperature increase in the southwest is among the most rapid in the nation, and is significantly greater than the global average (Guido et al. 2008). Projections for the southern Colorado Plateau area describe a warmer future climate, with annual temperatures likely increasing by 1.5° to 3.6° C by mid-century (Garfin et al., in press). Predicted climate change impacts in the southwest include warmer temperatures, fewer frost days, greater water demand by plants, and an increased frequency of extreme weather events such as heat waves, droughts, and floods (Weiss and Overpeck 2005, Archer and Predick 2008). Further, warmer nights and projected declines in snow pack, coupled with earlier spring snow melt, will reduce water supply, lengthen the dry season, create conditions for drought and insect outbreaks, and increase the frequency and intensity of wildfires as well as the duration of the wildfire season (Allen et al. 2010). Areas within the southwest including Arizona are currently experiencing a severe, multiple-year drought, and current models suggest that a 10 to 20 year (or longer) drought is anticipated (Woodhouse and Overpeck 1998, McCabe et al. 2004, Seager et al. 2007). Prolonged drought, combined with warmer temperatures, may cause increases in insect outbreaks and increased wildfires in southwestern forests (Betancourt 2004, Allen et al. 2010). Severe or prolonged drought may cause mature trees to be more susceptible to insects and disease (Hanson and Wetzin 2000, Mueller et al. 2005, Floyd et al. 2009, van Mantgem et al. 2009; see also Negrón et al. 2009: fig 3, Ganey and Vojta, in review).

The effects of climate change on rare, endangered, and endemic species are highly variable (Galbraith and Price 2009) and will differ depending upon life-history characteristics (Travis 2003) and dispersal abilities. Climate change has already resulted in significant effects on species and ecosystems (Gitay et al. 2002, Hannah and Lovejoy 2003, Root et al. 2003, Harris et al. 2006, Parmesan 2006). Mawdsley et al. (2009) identified a number of effects that could impact the Mexican spotted owl. These include: (1) shifts in the distribution of the owl itself, along with major prey species and potential competitors and predators, possibly along

elevational or latitudinal gradients; (2) effects on demographic rates, such as survival and reproduction; (3) changes in coevolved interactions, such as prey-predator relationships; (4) direct loss of habitat due to increased fire frequency, bark beetle outbreaks, and direct warming of habitats; (5) increased population or range expansion of species that are direct competitors; and (6) reductions in population size. All of these effects are discussed in Appendix D.

Shifts in Distribution. Shifts in Mexican spotted owl distribution could occur in response to predicted warming in the southwestern U.S. that may cause elevation shifts in tree species distribution, with many forest and woodland types requiring less precipitation moving up in elevation in response to warmer and drier conditions. This could lead to the local loss of some tree species and/or forest types in much of the southwest, because these forest types frequently occur at the highest elevations available and thus would have no local refugia to which to migrate (DeGomez and Lenart 2006, Archer and Predick 2008). Owls occur in mixed-conifer and pine-oak forests at the tops of many of the Sky Island ranges in Arizona and New Mexico. Conifers within some of the Sky Islands may be eliminated as temperatures increase and snowpack runoff decrease (Archer and Predick 2008). Loss of these forest types would eliminate or greatly reduce habitat for owls in these ranges. This in turn could reduce connectivity and viability of Mexican spotted owl populations (e.g., Keitt et al. 1995, 1997; Barrowclough et al. 2006; see also Ganey et al. 2008).

Changes in Demographic Rates. Climate change also could affect demography of spotted owls as well as their prey, competitors, and predators. Annual weather patterns are known to affect survival and reproduction of spotted owls (Franklin et al. 2000, 2004; North et al. 2000, Seamans et al. 2002, LaHaye et al. 2004, Olson et al. 2004, Dugger et al. 2005). For example, Seamans et al. (2002) found positive relationships between precipitation (i.e., precipitation during the previous year, during the previous winter, or during the previous monsoon season) and survival and reproductive output in two populations of Mexican spotted owls.

Temperature and precipitation may influence the owl's reproductive output directly, or indirectly through effects on prey abundance. Examples of direct effects could include: (1) negative effects of increased temperature on energy and water use (e.g., Ganey et al. 1993, Weathers et al. 2001), or (2) negative effects of increased precipitation during the nesting period on survival and especially reproduction (e.g., Franklin et al. 2000, North et al. 2000, LaHaye et al. 2004; note that this has not been documented in Mexican spotted owls). Seamans et al. (2002) speculate that precipitation was probably important in providing indirect benefits to Mexican spotted owls. Specifically, germination and sprouting of annual plants during the monsoon may extend the breeding season of small mammals in the Southwest, and may increase overwinter survival and therefore abundance of prey. Principal prey species in habitats occupied by Mexican spotted owls typically exhibit high temporal variability in abundance (Ward and Block 1995, Ward 2001, Block et al. 2005), and Ward and Block (1995) noted that a year of high reproductive output by spotted owls in the Sacramento Mountains of New Mexico was accompanied by an irruption of deer mice. Interactions among temperature and moisture regimes may differ across elevational gradients, thus affecting small mammal populations differently in different areas (Seamans et al. 2002).

Changes in Co-evolved Interactions. Changing climates also could influence distribution patterns and abundance of major prey species, as well as potential competitors with and predators on spotted owls. It seems likely that prey species, which are strongly influenced by weather (Vickery and Bider 1981) and have shorter generation times than spotted owls, would respond to such changes more quickly than would the owls themselves. The magnitude and direction of such potential changes remain unknown at this time, however. Similarly, changes in forest composition could strongly influence abundance and distribution of owl competitors and predators (see below). Again, however, the magnitude and direction of such potential changes remain unknown at this time.

In rocky canyon habitats in southern Utah, Willey (2007) conducted demographic studies of potential spotted owl prey within three owl territories in the Paria River watershed. Severe drought occurred during the onset of research (2000-2003), followed by significant increases in local precipitation during 2004-2006. Prey abundance and species richness increased with increased precipitation. During the 2000-2003 dry period, spotted owl reproduction dropped, females were no longer detected, and by 2003, only males were detected at the sites. Increased precipitation during 2004-2006 resulted in recolonization of all three sites by females. Thus, precipitation appeared to exert strong effect on prey abundance, site occupancy, and reproductive rates by owls (Willey 2007).

Direct Loss of Habitat. Mexican spotted owls may experience direct loss of habitat due to increased fire frequency and extent (Westerling et al. 2006), bark beetle outbreaks, and direct warming of habitats as a result of climate change. Using tree-ring data, Swetnam and Lynch (1993) and Ryerson et al. (2003) examined the relationships between western spruce bud worm outbreaks and climate variability over multi-century periods. They found that periods of increased and decreased budworm activity coincided with wetter and drier periods, respectively. Allen et al. (2010) and Breshears et al. (2009) documented recent examples of drought- and heat-related forest stress and dieback (defined as tree mortality noticeably above usual mortality levels) from all forested continents. Drought-related mortality occurred in forest types with tree species that included *Abies*, *Populus*, *Pseudotsuga*, and *Quercus* species found within spotted owl habitat. Ganey and Vojta (in review) documented high and accelerating tree mortality in mixed-conifer and ponderosa pine forests within the range of Mexican spotted owls in northern Arizona. This drought-mediated mortality was nonrandom with respect to tree species and size classes, and is rapidly changing the composition of these forests. Increasing levels of drought, along with associated insect outbreaks and wildfires, could rapidly and dramatically affect the distribution, amount, and composition of spotted owl habitat.

Interactions with Competitors and Predators. As discussed above, northern spotted owls are being affected by a direct competitor, the barred owl, which recently expanded its range into the Pacific Northwest and California (Dark et al. 1998, Courtney et al. 2004, Monahan and Hijmans 2007, Livezey 2009a). Barred owls appear to be competitively excluding northern spotted owls from preferred habitats in parts of their range and hybridize with spotted owls, and barred owls have been identified as a serious threat to continued persistence of northern spotted owls. Reasons for the recent range expansion by barred owls are unclear. Some authors have implicated climate change as a significant factor facilitating the range expansion (Monahan and Hijmans 2007), whereas other authors dispute this conclusion, citing anthropogenic changes as

likely drivers (Livezey 2009a, b). In addition, it is possible that warmer, drier conditions might favor such potential predators as great-horned owls (see predation discussion under factor II.9.D.c.ii above).

Reduction in Population Size. At this time, little evidence exists suggesting that climate change is causing reductions in Mexican spotted owl population size. Seamans et al. (1999) estimated that two populations within the conifer forests of the Upper Gila Recovery Unit were declining at roughly 10% per year, but the causes of the declines were unknown. The owl remains well distributed in the area, suggesting that this estimated decline has not been borne out in subsequent years. As mentioned above, however, both survival and reproduction were positively correlated with precipitation in two populations studied (Seamans et al. 1999). This suggests that increasingly warmer and drier climates may not benefit spotted owls.

We explored the vulnerability of Mexican spotted owls to climate change using current knowledge of Mexican spotted owl ecology and three tools designed to allow assessment of effects of climate change on species of interest. The assessment tools used included (1) NatureServe *Climate Change Vulnerability Index* (see Young et al. 2010), (2) Environmental Protection Agency (EPA 2009) *Framework for Categorizing the Relative Vulnerability of Threatened and Endangered Species to Climate Change*, and (3) Rocky Mountain Research Station's *Species Vulnerability Assessment Method* (Bagne and Finch 2008). These tools use different approaches to evaluate vulnerability to climate change, and results varied somewhat among tools. All three tools indicated at least moderate vulnerability to climate change for the Mexican spotted owl, however, along with fairly high uncertainty in the ratings. Thus, these assessments, although crude, provide further support for the hypothesis that the owl and its habitat are vulnerable to changes caused by changing climates.

In summary, climate change will likely influence spotted owl habitat significantly, but the nature of such influence is difficult to predict. Further, addressing the causes of climate change is beyond the scope of this Recovery Plan. Therefore, our recommendations in Appendix D - 11 include mitigation strategies (i.e., actions that reduce causes of stress) and adaptation strategies (i.e., actions that help forested ecosystems accommodate change) designed to enhance forest resiliency and provide sustainable habitat so that Mexican spotted owls may better withstand the impacts of climate variability.

E. Factors Affecting the Status of the Mexican Spotted Owl in Mexico

Habitat modification is the main threat to biodiversity in Mexico and in many parts of the world. Data through 1993 show that primary vegetation has decreased 54% in the entire country, considering the original potential coverage of primary vegetation (CONABIO 2009). Based on this, habitat loss and fragmentation are the main threats to the Mexican spotted owl (Márquez-Olivas et al., 2002). Habitat modifications include land-use changes for agriculture and cattle raising, wildfires, and illegal logging, which have negative effects on its reproduction and dispersal (Márquez-Olivas et al. 2002, CONABIO 2009).

In southwestern Chihuahua and the rest of the Sierra Madre Occidental, activities by local residents are the main threats to the Mexican spotted owl; e.g., legal and illegal logging,

overgrazing, and firewood harvest (Tarango et al. 1997). A study by CONANP and PRONATURA-SUR in 2008 concluded that in the Sierra Madre Occidental, large-scale logging operations have destroyed large areas of tree coverage to supply the cellulose industry (paper production) and forest clearing has been conducted to prevent wildfires and the spread of pests (CONANP-Pronatura sur, 2008). Several researchers also had suggested that the clearing of trees on this area, especially cutting of mature forests, caused the disappearance of the imperial woodpecker (*Campephilus imperialis*) and declines in western thick-billed parrot (*Rhynchopsitta pachyrhyncha*) populations (CONANP-Pronatura Sur, 2008).

In the Sierra Madre Oriental, devastating wildfires scorched large areas of old-growth forests. Two hundred ha (494 ac) of mature forest were lost in El Taray in 2006, and 400 ha (988 ac) were burned in the Municipio de Santiago Nuevo León in 2008 (CONANP-Pronatura Noreste, 2008).

In some areas like the Parque Nacional Sierra de San Pedro Mártir, another threat to forest habitat of *Strix occidentalis lucida* is the spread of bark beetles during the dry season. Since these insects are part of the ecology of the area, the full scope of this problem should be studied (CONANP 2006).

In the area in the Transvolcanic Range where this species is reported, it faces problems related to the proximity to urban areas and increased habitat modification and decreased original tree coverage (Navarro-Sigüenza et al. 2007). Human over-population and anthropogenic activities like agriculture and cattle raising and other land-use changes are threats to the different species of birds and other organisms on this area (Navarro-Sigüenza et al. 2007). This area also faces deforestation, illegal extraction of soil and volcanic rocks, illegal hunting and poaching, burning of natural vegetation to increase cattle forage, and wildfires by arson, all of which increase damage to the region (Navarro-Sigüenza et al. 2007).

Table 3. Crosswalk Between Threats and Management Recommendations

		MANAGEMENT ACTION									
Appendix Section		C.3.C	C.3.D	C.3.E	C.4.A.c	C.4.A.d	C.4.B	C.5	D.1.A.a	D.1.A.b	D.1.A.c
Part II Section	THREAT	Within PACs, outside cores	Within PACs, within cores	Within PACs, post disturbance salvage	Recovery habitat, replacement nest-roost habitat	Recovery habitat, non replacement habitat	Riparian habitat	Other forest and woodland types	Wildfire suppression	Burned area emergency response and rehabilitation	Prescribed fire and hazardous fuels treatments
	FACTOR A										
II.8.B.a.i	Stand-replacing Fire	X	X	X	X	X		X			
II.8.B.a.ii	Fire Suppression								X		
II.8.B.a.iii	Burned Area Response			X					X	X	
II.8.B.a.iv	Wildland-urban Interface (WUI) Treatments								X		X
II.8.B.a.v	Silvicultural Treatments	X		X	X	X		X			X
II.8.B.a.vi	Forest Insects and Disease										
II.8.B.a.vii	Grazing	X					X				
II.8.B.a.viii	Energy Development										
II.8.B.a.ix	Influences on Riparian Habitats						X				
II.8.B.a.x	Roads and Trails	X					X				
II.8.B.a.xi	Land Development										
II.8.B.a.xii	Recreation	X	X				X				
	FACTOR B										
II.8.B.a.xiii	Water Development										
II.8.B.b.ii	Recreational Exploitation										
II.8.B.b.iii	Scientific Exploitation										
	FACTOR C										
II.8.B.c.i	West Nile Virus										
II.8.B.c.ii	Predation										

Table of Crosswalk Between Threats and Management Recommendations

		MANAGEMENT ACTION									
	Appendix Section	C.3.C	C.3.D	C.3.E	C.4.A.c	C.4.A.d	C.4.B	C.5	D.1.A.a	D.1.A.b	D.1.A.c
Part II Section	THREAT	Within PACs, outside cores	Within PACs, within cores	Within PACs, post disturbance salvage	Recovery habitat, replacement nest-roost habitat	Recovery habitat, non replacement habitat	Riparian habitat	Other forest and woodland types	Wildfire suppression	Burned area emergency response and rehabilitation	Prescribed fire and hazardous fuels treatments
	FACTOR D										
II.8.B.d.i	National Fire Plan and Policy					X		X			
II.8.B.d.ii	Healthy Forests Initiative	X			X			X			
II.8.B.d.iii	Healthy Forests Restoration Act of 2003	X			X			X			
II.8.B.d.iv	Omnibus Public Land Management Act of 2009, Title IV Landscape Restoration	X			X			X			
II.8.B.d.v	Stewardship Contracting Authority										
	FACTOR E										
II.8.B.e.i	Noise and Disturbance										
II.8.B.e.ii	Barred Owls										
II.8.B.e.iii	Direct Mortality										
II.8.B.e.iv	Climate Change										

Table of Crosswalk Between Threats and Management Recommendations

		MANAGEMENT ACTION										
	Appendix D Section	D.2	D.3	D.4	D.5	D.6	D.7	D.8	D.9	D.10	D.11	D.12
Part II Section	THREAT	Insects and disease	Grazing	Energy development	Land development	Water development	Recreational exploitation	Recreational disturbance	Scientific exploitation	Noise	Climate change	West Nile virus
	FACTOR A											
II.8.B.a.i	Stand-replacing Fire											
II.8.B.a.ii	Fire Suppression											
II.8.B.a.iii	Burned Area Response											
II.8.B.a.iv	Wildland-urban Interface (WUI) Treatments											
II.8.B.a.v	Silvicultural Treatments											
II.8.B.a.vi	Forest Insects and Disease	X										
II.8.B.a.vii	Grazing		X									
II.8.B.a.vii	Energy Development			X								
II.8.B.a.ix	Influences on Riparian Habitats		X			X						
II.8.B.a.x	Roads and Trails											
II.8.B.a.xi	Land Development											
II.8.B.a.xii	Recreation						X	X				
	FACTOR B											
II.8.B.a.xiii	Water Development					X						
II.8.B.b.ii	Recreational Exploitation						X					
II.8.B.b.iii	Scientific Exploitation								X			
	FACTOR C											
II.8.B.c.i	West Nile Virus											X
II.8.B.c.ii	Predation											

Table of Crosswalk Between Threats and Management Recommendations

		MANAGEMENT ACTION										
Appendix D Section		D.2	D.3	D.4	D.5	D.6	D.7	D.8	D.9	D.10	D.11	D.12
Part II Section	THREAT	Insects and disease	Grazing	Energy development	Land development	Water development	Recreational exploitation	Recreational disturbance	Scientific exploitation	Noise	Climate change	West Nile virus
	FACTOR D											
II.8.B.d.i	National Fire Plan and Policy											
II.8.B.d.ii	Healthy Forests Initiative											
II.8.B.d.iii	Healthy Forests Restoration Act of 2003											
II.8.B.d.iv	Omnibus Public Land Management Act of 2009, Title IV Landscape Restoration											
II.8.B.d.v	Stewardship Contracting Authority											
	FACTOR E											
II.8.B.e.i	Noise and Disturbance									X		
II.8.B.e.ii	Barred Owls											
II.8.B.e.iii	Direct Mortality											
II.8.B.e.iv	Climate Change											

10. Conservation Measures and Management in the United States and Mexico

Federal, State, Tribal, and Mexican agencies have participated in managing and conserving lands for the Mexican spotted owl since the species was listed (Tables 4, 5, 6, and 7 below). The U.S. Forest Service is the primary administrator of lands supporting Mexican spotted owls in the United States (Table 4). A full description of past and present activities is given in Appendix H – Conservation Measures and Management in the United States and Mexico.

The following agencies, nations, and countries have been and continue to be involved:

Federal Agencies:

- U.S. Fish and Wildlife Service (USFWS) (U.S. Department of the Interior - USDI)
- U.S. Forest Service (USFS) (U.S. Department of Agriculture - USDA)
- National Park Service (NPS) (USDI)
- Bureau of Land Management (BLM) (USDI)
- Department of Defense (DOD)
- Department of Energy (DOE)

States:

- Arizona, Colorado, New Mexico, Texas, Utah

Tribes:

- Mescalero Apache Tribe (New Mexico)
- White Mountain Apache Tribe (Arizona)
- San Carlos Apache Tribe (Arizona)
- Jicarilla Apache Tribe (New Mexico)
- Navajo Nation (Arizona, New Mexico, Utah)
- Southern Ute (Colorado)
- Northern and Southern Pueblos Agencies (New Mexico)

Mexico: (see Tables 6 and 7)

- Secretariat of Environment and Natural Resources – Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)
- National Commission of Natural Protected Areas – La Comisión Nacional de Áreas Naturales Protegidas (CONANP)

Table 4. Cumulative range-wide number of sites occupied by one or more Mexican spotted owls in the United States at least once during the breeding season since 1989 according to land ownership.

Land Owner	No. Sites	(%)
USDA Forest Service	1,077	82.8
USDI National Park Service	155	11.9
USDI Bureau of Land Management	55	4.2
Private	7	0.5
US Department of Defense	6	0.5
State Lands	1	0.1
Total:	1,301	100

Table 5. Amount of area within each Ecological Management Unit in the United States in different land jurisdictions/ownerships.

Landowner Area by Ecological Management Unit in the United States for the Mexican Spotted Owl										
	Ecological Management Unit (EMU) in the United States									
	BRE		BRW		CP		SRM		UGM	
LAND STATUS	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares
Federal Lands										
BLM	7,175,282.5	2,903,745.4	3,659,160.0	1,480,815.5	24,785,929.3	10,030,549.8	4,255,136.0	1,721,999.3	322,758.8	130,616.4
FS	1,431,950.2	579,492.0	5,580,168.5	2,258,223.1	8,213,268.5	3,323,805.1	15,366,720.6	6,218,716.1	8,699,145.4	3,520,433.3
NPS	277,713.8	112,387.2	79,014.9	31,976.3	4,462,160.5	1,805,779.5	421,809.6	170,701.0	42,427.4	17,169.8
Total Federal	8,884,946.5	3,595,624.7	9,318,343.5	3,771,014.9	37,461,358.3	15,160,134.5	20,043,666.2	8,111,416.4	9,064,331.5	3,668,219.5
State Lands										
AZ	0.0	0.0	5,241,674.7	2,121,239.0	2,407,042.0	974,099.2	0.0	0.0	47,039.7	19,036.4
CO	0.0	0.0	0.0	0.0	60,664.5	24,550.1	758,348.2	306,893.9	0.0	0.0
NM	3,239,860.6	1,311,130.3	550,383.4	222,733.1	736,495.1	298,050.2	690,189.9	279,311.1	503,160.6	203,622.7
UT	0.0	0.0	0.0	0.0	2,554,154.6	1,033,633.8	0.0	0.0	0.0	0.0
Total State	3,239,860.6	1,311,130.3	5,792,058.1	2,343,972.1	5,758,356.3	2,330,333.4	1,448,538.1	586,204.9	550,200.3	222,659.1
Tribal Lands										
Tribal Lands	995,042.8	402,681.1	1,613,903.4	653,126.2	21,620,638.1	8,749,596.8	1,404,034.5	568,194.9	2,321,911.6	939,648.0
Private Lands										
Private Lands	9,596,716.6	3,883,668.9	6,429,327.4	2,601,866.9	15,733,238.6	6,367,041.2	16,453,866.3	6,658,670.1	1,569,133.5	635,008.4
Other										
Other	2,909,784.5	1,177,552.7	239,686.5	96,998.1	336,922.0	136,348.0	552,410.7	223,553.6	29,283.8	11,850.8
TOTAL	25,626,350.9	10,370,657.8	23,393,318.9	9,466,978.1	80,910,513.4	32,743,454.0	39,902,515.9	16,148,039.9	13,534,860.7	5,477,385.7
(in thousands)	25,626.4	10,370.7	23,393.3	9,467.0	80,910.5	32,743.5	39,902.5	16,148.0	13,534.9	5,477.4

Table 6. Federal and State Protected Areas in Mexico with records of *Strix occidentalis lucida*.

Name	Area (ha)	Location	Type
Reserva Forestal Nacional y Refugio de Fauna Silvestre Sierras de Ajos Bavispe	200,000	Sonora	Federal
Reserva de la Biosfera de Janos	526,482	Chihuahua	Federal
Reserva de la Biosfera Montes Azules	331,200	Chiapas	Federal
Reserva de la Biosfera Sierra de Manantlán	139,577	Jalisco and Colima	Federal
Reserva de Biosfera “La Michilía”	9,325	Durango	Federal
Parque Nacional Cumbres de Monterrey	177,396	Nuevo León	Federal
Parque Nacional Sierra de San Pedro Mártir	72,911	Baja California	Federal
Área de Protección de Flora y Fauna Sierra de Arteaga*	120,428	Nuevo León	Federal
Área de Protección de Flora y Fauna Sierra de Álamos-Río Chucujaqui	92,890	Sonora	Federal
Área de Protección de Flora y Fauna Cerro Mohinora*	9,126	Chihuahua	Federal
Zona Sujeta a Conservación Ecológica “Cerro el Potosí”	989.38	Municipio de Galeana, Nuevo León	State
Zona Sujeta a Conservación Ecológica Sierra Fría	112,090	San José de Gracia, Rincón de Romos, Pabellón de Arteaga, Jesús María y Calvillo, Estado de Aguascalientes	State
Zona Sujeta a Conservación Ecológica “Cerro El Peñón”	103.39	Municipio de Dr. González, Nuevo León	State

* In process to become Protected Area.

Source: Gobierno del Estado de Aguascalientes, 1998; Gobierno del Estado de Nuevo León, 2000, INE-SEMARNAP, 2000; INE-SEMARNAT, 2000; CONANP, 2005; CONANP, 2006; Gobierno Federal, 2009; CONANP, 2010.

Even though there are currently no records of this species in other NPAs, it will most likely be found in several of the Federal Protected Areas listed on Table I.3 because of its wide distribution. This would increase the distribution of the species within protected areas. This is highly probable in the Transvolcanic Range area, where it would be important to verify several sightings of this species.

Table 7. Protected Areas in Mexico with potential distribution of <i>Strix occidentalis lucida</i>.			
Name	Area (ha)	Location	Type
Reserva de la Biosfera Mariposa Monarca	56,259	Michoacán and México	Federal
Parque Nacional Iztaccihuatl-Popocatepetl	90,284	México, Puebla and Morelos	Federal
Parque Nacional Nevado de Toluca	46,784	México	Federal
Parque Nacional Malinche o Matlalcueyatl	45,711	Tlaxcala and Puebla	Federal
Parque Nacional El Tepozteco	23,259	Morelos and D.F.	Federal
Parque Nacional Bosencheve	10,432	México and Michoacán	Federal
Parque Nacional Lagunas de Zempoala	4,790	Morelos and México	Federal
Parque Nacional Insurgente Maria Morelos	4,325	Michoacán	Federal
Parque Nacional Insurgente Miguel Hidalgo y Costilla	1,580	D.F.	Federal
Parque Nacional Desierto de los Leones	1,529	D.F.	Federal
Parque Nacional Cumbres del Ajusco	920	D.F.	Federal
Área de Protección de Flora y Fauna Tutuaca	444,489	Sonora and Chihuahua	Federal
Área de Protección de Flora y Fauna Papigochi	222,274	Chihuahua	Federal
Área de Protección de Flora y Fauna Campo Verde	108,069	Sonora and Chihuahua	Federal
Área de Protección de Flora y Fauna La Primavera	30,500	Jalisco	Federal
Área de Protección de Flora y Fauna Pico de Tancítaro	23,406	Michoacán	Federal
Área de Protección de los Recursos Naturales Cuenca Alimentadora del distrito de riego 043 Estado de Nayarit	2,328,975	Nayarit, Jalisco, and Zacatecas	Federal
Área de Protección de los Recursos Naturales Cuenca Alimentadora del Distrito Nacional de Riego 004 Don Martín	1,519,920	Coahuila	Federal
Área de Protección de los Recursos Naturales Cuenca Alimentadora del Distrito Nacional de Riego 001 Pabellón	97,699	Zacatecas and Aguascalientes	Federal

Source: CONANP 2010

III. RECOVERY STRATEGY, GOALS, AND OBJECTIVE AND MEASURABLE CRITERIA

1. Recovery Strategy

This Recovery Plan presents realistic and attainable goals for recovering the owl and its ultimate delisting, involving forest habitat management and vigilant monitoring. The goals are flexible in that they allow local land managers to make site-specific decisions. Although the Mexican spotted owl was originally listed due to threats from destruction and modification of habitat caused by timber harvest and fires (Listing Factor A), increased predation associated with habitat fragmentation (Listing Factor C), and lack of adequate protective regulations (Listing Factor D), the threats of timber harvest and inadequate regulations have been largely addressed since the time of listing. Currently, the Mexican spotted owl is threatened primarily by habitat degradation and loss of old growth nesting habitats through stand-replacing wildfire (Listing Factor A); with threats of predation, disease, parasites (Listing Factor C) and starvation, accidents, and potential interactions of threat factors with climate change (Listing Factor E) considered comparatively minor. To accomplish the recovery of the Mexican spotted owl, the recovery strategy has six key elements designed to conserve the Mexican spotted owl throughout its range: 1) protecting existing populations (PACs), 2) managing for replacement nest/roost habitat, 3) managing threats, 4) monitoring population trends and habitat, 5) monitoring plan implementation, and 6) building partnerships to facilitate recovery.

Success of the plan, however, hinges on the commitment and coordination among the Mexican government, United States (U.S.) Federal and State land-management organizations, sovereign Indian nations, and the private sector to ensure that the spirit and intent of the plan is executed as envisioned by the Recovery Team. Although much of the recovery strategy is focused on the U.S. range of the bird, this strategy can and should be implemented in Mexico. Under the proposed recovery criteria, the owl could be recovered within 10 years of implementing this revised Recovery Plan. Maintaining and restoring forest health to reduce the threat of stand-replacing wildfire, while creating a mosaic of suitable Mexican spotted owl habitats and protecting existing populations, will be achieved by land use management, facilitated by section 7 consultations and agreements. The recovery criteria require monitoring. Without careful and rigorous application of monitoring, there would be no objective basis for delisting the owl.

2. Recovery Goal

The ultimate goal of the Recovery Plan is to sustain owl populations to the point that the owl can be removed from the list of endangered and threatened species.

3. Recovery Objectives

Objectives are to support the population of the Mexican spotted owl in perpetuity, and to maintain habitat conditions necessary to provide roosting and nesting habitat for the Mexican spotted owl.

4. Objective and Measurable Recovery Criteria

Section 4 of the ESA requires that recovery plans “list objective, measurable criteria which, when met, would result in a determination...that the species be removed from the list.”

Ultimately, a delisting determination is based on a species no longer meeting the definition of “threatened” under the ESA. Such a determination requires the five-factor analysis we describe in Part II.9, where all threats are evaluated.

The recovery criteria in this plan are not binding, and it is important to note that meeting the recovery criteria provided below does not automatically result in delisting the species. Rather, a delisting decision is under the authority of the Director of the U.S. Fish and Wildlife Service and must undergo the rulemaking process and analyses. Both anthropogenic and non-anthropogenic threats to the Mexican spotted owl must be considered in a five-factor analysis to be sufficiently acceptable, with adequate regulatory mechanisms in place, to ensure that the species will persist into the foreseeable future. The management recommendations in this plan are believed to be necessary and advisable to achieve this goal, but the best scientific information derived from research, management experiments, and monitoring conducted at the appropriate scale and intensity should be used to test this assumption.

Two recovery criteria must be met before the Mexican spotted owl can be delisted:

- (1) *Owl occupancy rates must show a stable or increasing trend after 10 years of monitoring.* The study design to verify this criterion must have a power of 90% (Type II error rate $\beta = 0.10$) to detect a 25% decline in occupancy rate with a Type I error rate (α) of 0.10. The monitoring approach recommended in Part V.2 and in Appendix F suggests how this might be determined. (Listing Factors A, C, and E).
- (2) *Indicators of habitat conditions (key habitat variables) are stable or improving for 10 years in roosting and nesting habitat* (key habitat variables—see Table 1 or Table C.1 in Appendix C). Habitat monitoring should be conducted concurrently with owl occupancy monitoring. Trends in all key habitat variables must be shown stable or increasing with a power of 90% (Type II error rate $\beta = 0.10$) to detect a 25% decline with a Type I error rate (α) of 0.10. (Listing Factors A, C, and E).

By design, these criteria are redundant and dependent; progress on one criterion relates to progress on the other. Likewise, meeting one criterion, to some degree, requires meeting all or some portion of the other criterion. However, to be delisted, we recommend both criteria be met. In addition, anthropogenic and non-anthropogenic threats to the Mexican spotted owl must be sufficiently moderated and/or regulated for the foreseeable future, as evidenced by the best scientific information available. The best scientific information is derived from research, management experiments, and monitoring conducted at the appropriate scale and intensity. An analysis of the five ESA listing factors must be conducted to verify that threat levels are acceptable for likely persistence of owl populations into the future.

An inherent assumption in the recovery criteria is that the existing owl population is adequate in numbers and distribution to maintain the viability of the species. While we have no data

documenting the existing range-wide population size, we will collect continuous monitoring data from randomly selected quadrats and estimate population trends using occupancy modeling. There is sufficient information to allow us to start with the assumption that the population is persisting at viable numbers for the following reasons. First, since the owl was listed in 1993, the documented range of the U.S. owl population has increased in size as new areas have been surveyed for owls. Second, within the documented species' range there is little evidence of populations disappearing, though individual territories may have been vacated (but see Stacey and Peery 2002). Third, the total documented population size has increased with the additional surveys throughout the range (i.e., populations on NPS lands, and others). And finally, the tentative acceptance of this assumption of adequate population numbers will be verified after 10 years of monitoring owl occupancy rates. That evidence will indicate whether populations are viable and will persist for longer periods. In contrast, if the occupancy monitoring demonstrates a declining owl population, it will be known that the existing population is not at an adequate level to persist under the stressors the owl is undergoing on the landscape, and continued protection and/or remedial action will be needed. In summary, we assume that the existing population is adequate, but this assumption must be tested by conducting occupancy monitoring.

5. The Delisting Process

Section 4 of the ESA governs the listing, delisting, and reclassification of species, the designation of critical habitat, and recovery planning. A codification of the general and permanent regulations regarding listing, delisting, reclassification, and critical habitat designation are published in the *Code of Federal Regulations* at 50 CFR 424. The process of delisting a species or subspecies is essentially the same as that of listing: a proposed rule describing the justification for the action is published in the *Federal Register*; a public comment period is opened, including public hearings if requested; and, within one year of the proposal, either a final rule delisting the species or a notice withdrawing the proposed rule is published in the *Federal Register*.

The Mexican spotted owl is listed as a threatened species, defined in the ESA as "...likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." According to the ESA, an endangered species is one that "...is in danger of extinction throughout all or a significant portion of its range..." Thus, in order to delist the Mexican spotted owl, it must be found to be sufficiently secure into the foreseeable future so that it does not meet the definition of a threatened species. In considering whether to delist a species, the same five factors considered in the listing process are evaluated (see Part II.9). While emphasis may be given to those factors leading to the species' listing, all of the factors must be evaluated in making a delisting determination.

Another factor to consider when contemplating delisting is whether a listed entity may be delisted throughout a portion of its range while other portions remain listed. The ESA definition of "species" includes "...subspecies...and any distinct population segment of vertebrate fish or wildlife..." The term "distinct population segment" (DPS) is not defined in either the ESA or its implementing regulations, but rather is described in the Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species Act (DPS Policy; 61 FR

4722). The DPS Policy describes a series of tests for determining whether a vertebrate population qualifies as a DPS.

The Mexican spotted owl is currently listed as a threatened subspecies throughout its range, including Mexico. However, a species may be delisted throughout a part of its range if both the delisted portion and the portion remaining in listed status meet the criteria for a DPS as set forth in the DPS policy. For example, the FWS could determine that both the U.S. and Mexican populations meet the DPS criteria and delist or otherwise reclassify one or the other separately. It is beyond the purview of this Recovery Plan to address the question of whether the U.S. or Mexico populations, or any subdivisions thereof, would qualify as a DPS. Such a determination would be made by the FWS if and when appropriate. This Recovery Plan therefore provides delisting criteria only for the subspecies as a whole.

6. Post-Delisting Monitoring

Section 4(g) of the ESA directs the FWS to implement a system, in cooperation with the states, to monitor effectively for not less than five years the status of a species or subspecies that has been delisted due to recovery. The provisions of the ESA do not apply to the delisted species during this monitoring period. However, the FWS could relist a species through the standard listing process, should monitoring or other information indicate that the species has again become threatened or endangered absent the Act's protection. Once delisting occurs, managers should consider continuing the monitoring suggested in Appendix F for consistency in continuing to assess population trends. Such policy would provide additional assurance that the results of the 10-year monitoring program are reliable assessments of population and habitat trends.

IV. RECOVERY PROGRAM

1. Recovery Action Outline and Narrative

This outline contains *abbreviated* descriptions of actions necessary to implement the Mexican Spotted Owl Recovery Plan-First Revision. **Users should refer to the indicated section of Appendix C and Appendix D for detailed recommendations.** Not all recommendations are captured in this outline; actions conducted as standard operational activities, and not specifically for spotted-owl-management purposes, are not listed here. Further, specific threats with only general guidelines (see 1-5 below) are not specifically listed but are covered under the general guidelines.

1. Establish or amend, as appropriate, land-management-planning documents to adopt the Recovery Plan recommendations as agency policy.
2. Survey planned project areas for Mexican spotted owl presence following the Survey Protocol (Appendix E) before conducting activities that may affect the Mexican spotted owl. See Appendix C - 3.A for when and where surveys are recommended.

3. Maintain or enhance existing nesting/roosting habitat for Mexican spotted owls.
 - 3.1. Establish PACs at known owl sites (see definition of “site” in Part II, Box I and Appendix C - Box C.2) from 1989 through the life of the Recovery Plan, including new sites located during surveys (see Appendix C - 3.A for PAC-establishment procedures). Exceptions to PAC establishment or continuance are possible and are discussed in detail in Appendix C - 3.E and 3.F. PACs should also be established at historical sites (i.e., sites established prior to 1989) within the CP and SRM EMUs that meet the definition of an owl site (see Part II, Box 1 and Appendix C - Box C.2). PACs should be at least 243 ha (600 ac) in size.
 - 3.2. Conduct fuels-reduction treatments or other management actions to reduce the risk of compromising the ability of PACs to provide for successful owl nesting, following the procedures outlined in sections Appendix C - 3.B and 3.C. Consider treating other forest and woodland types first, followed by recovery habitat (emphasize non nest-roost replacement habitat before entering nest-roost replacement habitat), and then PACs. Much of the work needed to reduce fire risk in and to owl habitat can be achieved by treating areas around owl habitat.
 - 3.2.1. Conduct restoration/fuels treatments in up to 20% of the non-core PAC area within each EMU that exhibit high fire-risk conditions, following the guidelines in section Appendix C - 3.B.
 - 3.2.2. Conduct fuels treatments in remaining PACs as described in section Appendix C - 3.B and 3.C.
 - 3.3. Avoid conducting activities that may disturb nesting spotted owls during the breeding season unless protocol surveys (Appendix E) allow inference of non-nesting.
4. Manage for replacement nesting/roosting habitat on the landscape.
 - 4.1. Identify and map replacement nest-roost recovery habitat throughout each administrative unit (see Appendix C). Replacement nest-roost habitat should be identified so that the landscape percentages recommended in Appendix C - Table C.2 are delineated.
 - 4.1.1. Where appropriate, implement management actions necessary to drive replacement nest-roost recovery habitat toward the component values recommended in Appendix C - Table C.2. The recovery team suspects that most replacement nest-roost stands will achieve those values with minimal manipulation, but acknowledges that treatment may be desirable in some circumstances.
 - 4.1.2. Conduct fuels-reduction treatments or other management actions to reduce the risk of losing important components for future spotted owl nesting/roosting habitat. Consider treating other forest and woodland types first, followed by recovery habitat (emphasize non nest-roost replacement habitat before entering nest-roost replacement habitat), and then PACs. Much of the work needed to reduce fire risk in and to owl habitat can be achieved by treating areas around owl habitat.
5. Manage for foraging and dispersal habitat.
 - 5.1. Identify and map “other recovery” mixed-conifer and pine-oak forests (outside of PACs and nest-roost replacement habitat; see Appendix C - 4.a.iv) throughout each

administrative unit.

5.1.2. Conduct fuels-reduction treatments or other management actions to reduce the risk of losing important components of owl foraging and dispersal habitat as described in Appendix C - 4.a.iv. Consider treating other forest and woodland types first. Much of the work needed to reduce fire risk in and to owl habitat can be achieved by treating areas around owl habitat.

6. Manage specific threats as described in Appendix D – Threat-specific management recommendations.

6.1. Implement fire-management recommendations (other than those for fuels-reduction purposes).

6.1.1. Implement fire-suppression recommendations as described in section Appendix D - 1.A.a.i.

6.1.1.1. Conduct landscape-level fire behavior assessments to strategically locate and prioritize fire suppression activities/tactics to mitigate the effects of high-severity fire and suppression activities on PACs and recovery habitat.

6.1.1.2. Where possible, wildfire suppression activities should be applied that limit high-severity fire and loss of key habitat elements within PACs and recovery habitats.

6.1.1.3. Research should be conducted to evaluate the short- and long-term correlates of wildfire severities and their spatial extent on Mexican spotted owls and their habitat.

6.1.2. Implement post-fire rehabilitation recommendations as described in sections Appendix C - 3.d and Appendix D - 1.a.ii.

6.2. Implement recommendations for forest insects and diseases as described in Appendix D - 2.a.

6.2.1. When considered a threat to owl or prey habitat, various tools—prescribed fire, thinning, other silvicultural treatments—should be used to limit the spread of insects or diseases.

6.3. Manage livestock-grazing operations and wild ungulate impacts as described in Appendix D - 3.

6.3.1. As detailed in Appendix D - 3.a, conduct site-specific assessments to determine appropriate utilization and/or residual levels of forage.

6.3.2. Using the information gathered under 6.3.1. above, establish allowable-use criteria through allotment-management plans, annual operating instructions, or other appropriate mechanism, to achieve the goals described in Appendix D - 3.a.

6.3.3. Implement monitoring as described in section Appendix D - 3.a.

6.3.4. Implement management actions regarding livestock and wild ungulate grazing to promote riparian health as described in Appendix D - 3.a.

6.4. Implement the land-development recommendations as described in Appendix D - 5.a.

6.4.1. Managers are encouraged to pursue voluntary consultation on a case-by-case basis with local governments and developers to encourage development in areas least likely to directly influence habitat use of known owls. Development of positive incentive programs may be a feasible approach.

- 6.5. Implement recommendations for water development (see Appendix D - 6).
 - 6.5.1. Collect materials for genetic analyses to evaluate if large water developments are impeding movements and gene flow. If so, consider lowering water levels to reduce barriers to movement.
 - 6.5.2. Discharge water from dams in such a way to sustain and enhance native riparian vegetation.
- 6.6. Manage against recreational exploitation (see Appendix D - 7).
 - 6.6.1. Report continued issues due to recreational exploitation of owls to the appropriate FWS Law Enforcement Office.
- 6.7. Minimize recreation disturbance in PACs.
 - 6.7.1. Any construction within PACs during the non-breeding season should be considered on a case-specific basis. Modifications to existing facilities pertaining to public health, safety, and routine maintenance are excepted; however, when implementing such activities, those conducting the work should use all measures possible to avoid potential effects on owls.
 - 6.7.2. In areas of owl occupancy, assess the impacts of currently allowed (both permitted and non-permitted) recreational activities and institute limitations as described in section Appendix D - 8.a.
 - 6.7.3. Seasonal closures of specifically designated recreational activities should be considered where disturbance to breeding owls seems likely.
 - 6.7.4. Conduct education through signing, interpretation events, access permitting, or other information sources to inform the public of proper and legal behaviors when encountering owls.
- 6.8. Monitor and minimize effects of scientific exploitation as described in section Appendix D.9.a.
 - 6.8.1. Quality-assurance and quality-control procedures should be applied to all scientific studies that may directly or indirectly affect owls or owl habitat. Quality assurance requires that study plans undergo appropriate levels of review, revision, and approval.
 - 6.8.2. Contingency plans (e.g., how an injured owl will be treated or transported and where an injured owl will be taken) for dealing with injured owls should be included as part of the study proposal submitted with the permit application. In addition, many researchers must undergo approval of animal care and use by their employing institutions.
 - 6.8.3. If a particular study or a particular activity results in an undue number of mortalities, FWS should convene an independent expert panel to evaluate the situation and propose recommendations to continue, adjust, or cease the activity resulting in mortalities.
 - 6.8.4. Radio-marking spotted owls likely poses the highest risk among typical research activities. This risk may be alleviated partially by adhering to marking requirements issued by the Bird Banding Lab. We recommend that transmitter packages used on Mexican spotted owls not exceed 16 g for female owls and 14 g for male owls.
 - 6.8.5. Any attachment methods other than backpack and tail mounts should be viewed as experimental and should be tested on captive owls before deployment in the field. If this option is not available, then experimental

- attachments should be tested on a very small sample of wild spotted owls, and results should be monitored before allowing widescale use of the method.
- 6.8.6. All radios should be attached by researchers with demonstrated expertise in handling raptors and attaching transmitter packages to raptors.
 - 6.9. Implement actions to minimize noise disturbance within PACs during the breeding season (1 Mar - 31 Aug). If owls are not detected or non-breeding owls are inferred during approved-protocol surveys in a PAC during the breeding season, restrictions on noise disturbances should be relaxed depending on the nature and extent of the proposed disturbance.
 - 6.9.1. Managers should, on a case-specific basis, assess the potential for noise disturbance to nesting owls.
 - 6.9.2. Breeding-season restrictions should be considered if noise levels are estimated to exceed 69 dBA (A-weighted noise level) (~80 dBO [owl-weighted noise level, Delaney et al. 1999a]) consistently (i.e., >twice/hour) or for an extended period of time (>1 hr) within 50 m (165 ft) of nesting sites (if known) or within entire PAC if nesting sites are not known.
 - 6.10. Implement actions to detect and, if present, monitor West Nile Virus activity as described in section Appendix D.12.a.
 - 6.10.1. Carry out well-distributed demographic studies to detect significant downward population trends.
 - 6.10.2. Conduct spotted owl surveillance to detect the disappearance of birds from a given area.
 - 6.10.3. Local biologists should monitor reports of avian mortality on the Centers for Disease Control and Prevention (CDC) website (www.cdc.gov) as well as those of state and county health departments.
 - 6.10.4. If any of the above situations lead to suspicion of a West Nile virus epizootic, conduct surveillance for the disease using standard arbovirus surveillance techniques.
 - 6.10.5. Biologists who become aware of spotted owl captures for other purposes should look into asking researchers to collect saliva swabs or other minimally invasive samples. If researchers are also collecting blood or other tissue samples, testing of those for West Nile virus antibodies is advised.
 7. Monitor owl occupancy as described in Part V.2 and Appendix F – Monitoring.
 - 7.1. Coordinate among administrative units to develop occupancy-monitoring design and secure funding.
 - 7.2. Conduct a landscape analysis to define the sampling frame to include all possible owl habitat.
 - 7.3. Develop sampling strata for the allocation of samples to reduce sampling variance.
 - 7.4. Develop sampling protocols.
 - 7.5. Have monitoring design reviewed by scientific experts and revise accordingly.
 - 7.6. Implement the monitoring design.
 8. Develop and implement habitat monitoring as described in Appendix F – Monitoring.
 - 8.1. Coordinate among administrative units and FIA to develop habitat-monitoring design and secure funding.

- 8.2. Conduct a landscape analysis to define the sampling frame to include all possible owl habitat.
 - 8.3. Develop sampling strata for the allocation of samples to reduce sampling variance.
 - 8.4. Develop sampling protocols.
 - 8.5. Have monitoring design reviewed by scientific experts and revise accordingly.
 - 8.6. Implement the monitoring design.
9. Implement research to inform recovery as described in Part V.6 in the U.S. and Mexico.
- 9.1. Conduct research to answer questions related to habitat.
 - 9.1.1. Which habitat features directly influence reproduction and/or survival of Mexican spotted owls?
 - 9.1.2. Which habitat features indirectly influence reproduction and/or survival of Mexican spotted owls by enhancing prey availability?
 - 9.1.3. How should these features be arranged spatially on the landscape to optimize owl fitness and habitat quality?
 - 9.1.4. How do stochastic environmental disturbances (particularly unplanned wildland fire) alter key habitat constituents and owl demography?
 - 9.1.5. Which habitat features help buffer the influence of weather effects on reproduction and survival?
 - 9.1.6. How do various planned management activities alter key habitat constituents (including prey) and owl demography?
 - 9.1.7. What is the probability that threshold nest/roost conditions recommended in the plan will become recovery habitat for roosting and/or nesting by Mexican spotted owls?
 - 9.1.8. Which silvicultural prescriptions are best suited for creating and sustaining habitats used by Mexican spotted owls for various activities like roosting, nesting, foraging, and dispersal?
 - 9.1.9. Which types of planned burning regimes and methods will promote development of the owl's roosting, nesting, and foraging habitat?
 - 9.1.10. What proportion of Mexican spotted owl populations migrate seasonally, where are winter habitats located, what habitat features do owls use to select these areas, and how important are these areas for owl dispersal and survival?
 - 9.1.11. How will climate change alter distribution, structure, and composition of owl habitat?
 - 9.1.12. How will climate change influence owl and prey distribution and abundance?
 - 9.1.13. If livestock grazing occurs within owl nesting, roosting, and foraging habitats, what livestock grazing strategies can be implemented to best maintain suitable habitat conditions for owl prey species and alleviate grazing impacts on the development of future owl nesting/roosting habitats (e.g., oak/cottonwood/willow/alder trees)?
 - 9.1.14. What are the effects of various recreational activities (hiking, climbing, off-road vehicle use) on Mexican spotted owl behavior, habitat use and demography? How can managers mitigate potential effects in high-use areas?
 - 9.1.15. If salvage logging is needed after a disturbance event (e.g., fire, insect/disease outbreak), how can it be implemented to maintain and protect existing habitat features or accelerate the development of future owl habitat?

- 9.2. Conduct research related to biological community interactions.
 - 9.2.1. Are parasites, disease, predation, and competition limiting Mexican spotted owl populations?
 - 9.2.2. What are the effects of invasive pathogens like West Nile virus?
 - 9.2.3. What is the relative influence of other predators on common prey of the Mexican spotted owl?
 - 9.2.4. What environmental conditions will lead to increased effects of community-level interactions?
 - 9.2.5. What types of management actions are necessary to alleviate deleterious community-level interactions?
 - 9.2.6. How might climate change alter these factors and/or their impacts on Mexican spotted owls?
 - 9.2.7. How will planned habitat treatments influence different biological interactions that can limit Mexican spotted owl populations, and how do these effects vary across spatial and temporal scales?
- 9.3. Conduct research involving population structure.
 - 9.3.1. What are the relative numerical and genetic contributions of core and exterior populations?
 - 9.3.2. Are subpopulations within and between EMUs connected?
 - 9.3.3. What habitats and large-scale habitat configurations are required to maintain adequate survival rates during juvenile dispersal or adult migration?
 - 9.3.4. What is the optimal arrangement of owl numbers and genetic mix that will lead to persistent populations at various time scales?
 - 9.3.5. Which management activities help to ensure a well distributed set of functioning subpopulations? Which hinder this goal?
 - 9.3.6. What are the potential impacts of climate change on connectivity of owl populations throughout their range?
- 9.4. Conduct research involving ecosystem function.
 - 9.4.1. What are the effects of implementing this Recovery Plan on ecosystem structure and functions like soil erosion, water yield, and nutrient flow?
 - 9.4.2. What are the effects of implementing this Recovery Plan on plant community structure, composition, and sustainability?
 - 9.4.3. How has the implementation of this Recovery Plan affected long-term restoration of forested systems?
 - 9.4.4. How are other focal wildlife species responding to conservation guidelines in this Recovery Plan?
 - 9.4.5. How might this Recovery Plan be adjusted to mitigate potentially deleterious effects on other ecosystem attributes?
 - 9.4.6. What are the potential implications of climate change to resilience of the ecosystems that support Mexican spotted owls, and how can we best balance increasing resilience in those systems with maintaining owl habitat.
- 9.5. Conduct research specific to Mexico, where less research has been conducted.
 - 9.5.1. What is the range, distribution, and abundance of the Mexican spotted owl in Mexico?
 - 9.5.2. What is the population trend in Mexico?
 - 9.5.3. What factors are threatening the status of the Mexican spotted owl in Mexico?

- 9.5.4. What actions can remedy factors negatively affecting the Mexican spotted owl and encourage factors positively affecting the species?
- 9.5.5. What is the most effective approach to creating an education and outreach program about the Mexican spotted owl in Mexico?

10. Develop and conduct plan implementation oversight and coordination.

- 10.1. Ensure that Ecological Management Unit Working Teams (WTs) have primary implementation oversight.
 - 10.1.1. Review current WT membership and broaden as appropriate (see Appendix A).
 - 10.1.2. Develop charter and operating procedures.
 - 10.1.3. Meet with members of the Recovery Team to ensure consistent interpretation of the Recovery Plan.
 - 10.1.4. Conduct implementation workshops with land managers.
 - 10.1.5. Coordinate (1) landscape assessments; (2) strategic location of PAC treatments; (3) occupancy monitoring; (4) habitat monitoring.
 - 10.1.6. Provide feedback to FWS and the Recovery Team on implementation of the Recovery Plan, including impediments and recommendations.
- 10.2. Implement continuing functions of the Recovery Team.
 - 10.2.1. Coordinate regularly with WTs to receive feedback on Recovery Plan implementation.
 - 10.2.2. Meet annually or as needed to consider WT recommendations, review new research findings, and generally assess plan implementation.
 - 10.2.3. Make recommendations to FWS on plan clarifications and adjustments.
- 10.3. Establish a centralized Mexican spotted owl information repository.

V. IMPLEMENTATION AND OVERSIGHT

1. Implementation Schedule

Disclaimer: The Implementation Schedule that follows outlines actions and estimated costs for the recovery plan for the Mexican Spotted Owl, as set forth in this recovery plan. It is a guide for meeting the recovery goals outlined in this plan. This schedule indicates action priorities, action numbers, action descriptions, duration of actions, the parties responsible for actions (either funding or carrying out), and estimated costs. Parties with authority, responsibility, or expressed interest to implement a specific recovery action are identified in the Implementation Schedule. When more than one party has been identified, the proposed lead party is indicated by an (*). The listing of a party in the Implementation Schedule does not require the identified party to implement the action(s) or to secure funding for implementing the action(s). For further information on selected columns see discussion at the end of the table.

Key to the Implementation Table below by column:

Priority Number:

1. Actions necessary to prevent extinction or irreversible decline.
2. Actions necessary to prevent extinction or a significant decline in population or habitat, or other effect short of extinction.
3. All other actions necessary to provide for full recovery.

Action Number:

Refers to corresponding action number in the Recovery Action Outline and in Appendices.

Recovery Criterion Number:

Corresponds to the appropriate recovery criteria which the action will help achieve.

Action Duration:

Continual, Ongoing, Unknown, or actual number of consecutive years. If periodic, then the frequency should be noted under Comments (e.g., "every 3 years"). Numerical values are the anticipated number of years to complete the action. "Ongoing" refers to actions that are currently being implemented and are recommended to continue. "Continuous" actions are those not currently being implemented but that are recommended to be implemented over the course of Recovery Plan implementation.

Responsible Party:

All Feds = all Federal agencies, as applicable

BLM = Bureau of Land Management

BR = Bureau of Reclamation

Counties = applicable counties within the range of the Mexican spotted owl

FS = U.S. Forest Service, National Forest Systems

RMRS = Rocky Mountain Research Station, Forest Service

FWS = U.S. Fish and Wildlife Service

MX = Mexico

NPS = National Park Service

RT = Mexican Spotted Owl Recovery Team

States = States of AZ, CO, NM, TX, and UT as applicable via their agencies:

AZGFD = Arizona Game and Fish Department

CDOW = Colorado Department of Wildlife

NMDGF = New Mexico Department of Game and Fish

TXPWD = Texas Parks and Wildlife Department

UDWR = Utah Department of Wildlife and Recreation

Tr. = Native American Tribes

Univ. = Universities

USGS = U.S. Geological Survey

WTs = Ecological Management Unit Working Teams

Cost Estimate:

Figures given may vary substantially depending on scope of implementation.

When zero cost is shown it is under the assumption that the action is part of ongoing land-management activities to which owl considerations add little or no cost.

“Costs captured below” indicates that costs of an activity are broken down into the costs for the relevant subactivities.

“Costs captured above” indicates that costs for individual subactivities are aggregated into a total cost for the larger activity, since the subactivities have no independent utility apart from collectively supporting the larger effort.

Table 8. Implementation Table for the Mexican Spotted Owl Recovery Plan, First Revision

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
2	1.	Adopt recovery plan recommendations through land-management-planning documents.	1, 2	1	FS, NPS, BLM, MX, Tr.	No	1,000	1,000	0	0	0	0	
2	2.	Survey project areas for Mexican Spotted Owls.	1, 2	Ongoing	Feds, Tr., MX	No	2,500	250	250	250	250	250	
1	3.	Maintain/enhance nesting/roosting habitat.	1, 2	Ongoing		No	0	0	0	0	0	0	
1	3.1.	Establish PACs.	1, 2	Ongoing	Feds, Tr., MX	No	1,000	100	100	100	100	100	
1	3.2.	Conduct treatments to reduce fire risk.	1, 2	Ongoing	FS, NPS, Tr., MX	No	0	0	0	0	0	0	
1	3.2.1.	Treat up to 20% of high risk PAC areas.	1, 2	Continuous	FS, MX, NPS, Tr.	No	0	0	0	0	0	0	
2	3.2.2.	Treat remaining PACs.	1, 2	Continuous	FS, NPS, Tr., MX	No	0	0	0	0	0	0	
2	3.3.	Avoid disturbing nesting owls (seasonal restriction).	1	Ongoing	Feds, Tr., MX	No	1,000	100	100	100	100	100	
2	4.	Manage for replacement nesting/roosting habitat.	2	Ongoing		No							Costs captured below.
2	4.1.	Identify and map replacement nest/roost recovery habitat.	2	Ongoing	FS, NPS, Tr., MX	No	2,000	200	200	200	200	200	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
2	4.1.2.	Manage fuels in replacement habitat.	2	Ongoing	FS, NPS, Tr., MX	No	0	0	0	0	0	0	
2	5.	Manage for foraging and dispersal recovery habitat.	2	Ongoing	FS, NPS, Tr., MX	No							Costs captured below.
2	5.1.	Identify and map "other" recovery habitat.	2	Ongoing	FS, NPS, Tr., MX	No	2,000	200	200	200	200	200	
2	5.1.2.	Conduct treatments to protect foraging- and dispersal-habitat components.	1, 2	Ongoing	FS, NPS, Tr., MX	No	0	0	0	0	0	0	
2	6.	Manage specific threats.	1, 2	Ongoing									Costs captured below.
2	6.1.	Implement fire-management recommendations.	1, 2	Continuous	FS, NPS, Tr., MX	No							Costs captured below.
2	6.1.1.	Implement fire-suppression recommendations.	1, 2	Continuous	FS, NPS, Tr., MX	No							Costs captured below.
3	6.1.1.1.	Conduct landscape-level fire-behavior assessments.	1, 2	5	FS, NPS, Tr., MX	No	1,000	200	200	200	200	200	
3	6.1.1.2.	Limit suppression activities within PACs and recovery habitats.	1, 2	Ongoing	FS, NPS, Tr., MX	No	1,000	100	100	100	100	100	
3	6.1.1.3.	Conduct research to evaluate fire severities related to owl habitat.	1, 2	5	FS, NPS, Tr., MX	No	500	100	100	100	100	100	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
3	6.1.2.	Implement post-fire rehabilitation recommendations.	2	Continuous	FS, NPS, Tr., MX	No	100	10	10	10	10	10	
2	6.2.	Implement forest insects and diseases recommendations.	1, 2	Ongoing									No costs (see below)
2	6.2.1.	Implement actions to limit spread of deleterious insects and diseases.	1, 2	Ongoing	FS, NPS, Tr., MX	No	0	0	0	0	0	0	
2	6.3.	Manage livestock-grazing operations and wild ungulate impacts.	1, 2	Ongoing									Costs captured below.
2	6.3.1.	Conduct assessments to determine appropriate utilization and/or residual levels of forage.	1, 2	Ongoing	FS, BLM, Tr., MX	No	0	0	0	0	0	0	
2	6.3.2.	Establish allowable-use criteria.	1, 2	Continuous	FS, BLM, Tr., MX	No	0	0	0	0	0	0	
2	6.3.3.	Implement range monitoring.	1, 2	Ongoing	FS, BLM, Tr., MX	No	0	0	0	0	0	0	
2	6.3.4.	Implement actions to promote riparian health.	1, 2	Ongoing	Feds, States, Tr., MX	No	500	50	50	50	50	50	
2	6.4.	Implement land-development recommendations.	1, 2	Continuous									Costs captured below.
2	6.4.1.	Pursue voluntary measures to reduce development impacts.	1, 2	Continuous	States, Counties	No	200	20	20	20	20	20	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
3	6.5.	Implement recommendations for water development.	1, 2	Continuous									Costs captured below.
3	6.5.1.	Conduct studies to evaluate impediment of movement and gene flow.	1	3	USGS	No	300	100	100	100	0	0	
2	6.5.2.	Discharge water from dams to sustain/enhance native riparian vegetation.	1, 2	Continuous	BR	No	100	10	10	10	10	10	
3	6.6.	Manage against recreational exploitation.	1	Ongoing									Costs captured below.
3	6.6.1.	Report continued issues due to recreational exploitation of owls to FWS Law Enforcement Office.	1	Ongoing	Feds	Yes	10	1	1	1	1	1	
3	6.7.	Minimize recreational disturbance in PACs.	1	Ongoing									Costs captured below.
2	6.7.1.	Construction within PACs should be considered on a case-specific basis.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	100	10	10	10	10	10	
2	6.7.2.	Assess the impacts of currently allowed recreational activities and institute limitations.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	100	10	10	10	10	10	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
2	6.7.3.	Consider seasonal closures of specifically designated recreational activities.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	100	10	10	10	10	10	
3	6.7.4.	Inform the public of proper and legal behaviors when encountering owls.	1	Continuous	FWS, FS, NPS, BLM, Tr., MX	No	10	1	1	1	1	1	
2	6.8.	Monitor and minimize effects of scientific exploitation.	1	Continuous									Costs captured below.
2	6.8.1.	Apply quality-control procedures to scientific studies.	1	Continuous	FWS	Yes	10	1	1	1	1	1	
3	6.8.2.	Require contingency plans for dealing with injured owls.	1	1	FWS	Yes	20	20	0	0	0	0	
2	6.8.3.	Convene an independent expert panel to evaluate mortalities, make adjustments.	1	2	FWS	Yes	20	10	10	0	0	0	
2	6.8.4.	Ensure that radio-marking adheres to Bird Banding Lab recommendations.	1	1	FWS	Yes	5	5	0	0	0	0	
2	6.8.5.	Ensure that attachment methods other than tail and backpack mounts are tested on captive owls then a small sample of wild spotted owls.	1	2	FWS	Yes	20	10	10	0	0	0	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
2	6.8.6.	Ensure that only experienced personnel attach radios.	1	Continuous	FWS	Yes	0	0	0	0	0	0	
2	6.9.	Implement actions to minimize noise disturbance within PACs during breeding season.	1	Ongoing									Costs captured below.
2	6.9.1.	Assess potential for noise disturbance to nesting owls.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	100	10	10	10	10	10	
2	6.9.2.	Consider breeding-season restrictions.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	100	10	10	10	10	10	
3	6.10.	Implement actions to detect/monitor West Nile Virus activity.	1	Continuous									Costs captured below.
3	6.10.1.	Carry out demographic studies to detect possibility of downward population trends.	1	10	FS-RMRS, FWS	No	2,000	200	200	200	200	200	
3	6.10.2.	Conduct owl surveillance and report extirpations.	1	Ongoing	FS, NPS, BLM, Tr., MX	No	500	50	50	50	50	50	
3	6.10.3.	Monitor avian mortality on CDC, state, and county health department websites.	1	Continuous	Counties	No	10	1	1	1	1	1	
2	6.10.4.	If suspicion of West Nile Virus presence, implement arborvirus surveillance techniques.	1	Continuous	Counties	No	0	0	0	0	0	0	Likely done for human health purposes.

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
3	6.10.5.	Request collection of samples from captured owls and test for West Nile Virus antibodies.	1	Continuous	FWS	Yes	10	1	1	1	1	1	
2	7.	Monitor owl occupancy.	1	10			11,900	200	1,300	1,300	1,300	1,300	
2	7.1.	Develop occupancy-monitoring design and secure funding.	1	Continuous	FS, RMRS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	7.2.	Conduct a landscape analysis to define the sampling frame.	1	1	FS, RMRS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	7.3.	Develop sampling strata.	1	1	FS, RMRS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	7.4.	Develop sampling protocols.	1	1	FS, RMRS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	7.5.	Have monitoring design reviewed and revised accordingly.	1	1	FS, RMRS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	7.6.	Implement the monitoring design.	1	10	FS, NPS, BLM, Tr., MX, RMRS	No							Costs captured above.
2	8.	Develop and implement habitat monitoring.	2	Continuous			8,750	200	75	75	75	75	
2	8.1.	Develop FIA-based monitoring design and secure funding.	2	Continuous	FS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
2	8.2.	Conduct a landscape analysis to define the sampling frame.	2	1	FS, FWS, NPS, BLM, Tr., MX	No							Costs captured above.
2	8.3.	Develop sampling strata.	2	1	FS, NPS, BLM, Tr., MX	No							Costs captured above.
2	8.4.	Develop sampling protocols.	2	1	FS, NPS, BLM, Tr., MX	No							Costs captured above.
2	8.5.	Have monitoring design reviewed and revised accordingly.	2	1	FS, NPS, BLM, Tr., MX	No							Costs captured above.
2	8.6.	Implement the monitoring design.	2	10	FS, NPS, BLM, Tr., MX	No							Costs captured above.
3	9.	Implement research.	1, 2	Continuous									Costs captured below.
3	9.1.	Conduct research related to habitat.	2	10	FS, NPS, BLM, Univ, USGS, States, Tr., RMRS, MX	No	1,000	100	100	100	100	100	
3	9.2.	Conduct research related to biological community interactions.	1	10	FS, NPS, BLM, Univ, USGS, States, Tr., RMRS, MX	No	500	50	50	50	50	50	
3	9.3.	Conduct research involving population structure.	1	10	FS, NPS, BLM, Univ, USGS, States, Tr., RMRS, MX	No	1,500	150	150	150	150	150	
3	9.4.	Conduct research involving ecosystem function.	1, 2	10	FS, NPS, BLM, Univ, USGS, States, Tr., RMRS, MX	No	1,500	150	150	150	150	150	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
3	9.5.	Conduct research specific to Mexico.	1, 2	10	MX	No	1,000	100	100	100	100	100	
3	10.	Develop and conduct plan implementation oversight and coordination.	1,2	Ongoing									Costs captured below.
3	10.1.	Ensure that Ecological Management Unit Working Teams have primary oversight.	1,2	1	FWS	Yes	0	0	0	0	0	0	
3	10.1.1.	Review current Working Teams and broaden as appropriate.	1,2	1	FWS	Yes	2	2	0	0	0	0	
3	10.1.2.	Develop charter and operating procedures.	1,2	1	WTs	No	3	3	0	0	0	0	
3	10.1.3.	Meet with Recovery Team to ensure consistent interpretation of Recovery Plan.	1,2	Continuous	WTs	No	30	3	3	3	3	3	
3	10.1.4.	Conduct implementation workshops with land managers.	1,2	1	Feds, Tr., MX	Yes	10	10	0	0	0	0	
3	10.1.5.	Coordinate landscape assessments, strategic location of PAC treatments, occupancy monitoring, and habitat monitoring.	1,2	Continuous	WTs	No	30	3	3	3	3	3	

Priority Number	Action Number	Action Description	Recovery Criterion Number	Action Duration (Years)	Responsibility		Total Cost (\$1,000s)	Cost Estimate by FY (by \$1,000s)					Comments
					Parties	Is FWS Lead?		FY12	FY13	FY14	FY15	FY16	
3	10.1.6.	Provide feedback to Recovery Team including impediments and recommendations.	1,2	Continuous	WTs	No	20	2	2	2	2	2	
3	10.2.	Implement continuing functions of the Recovery Team.	1,2	Continuous	RT	Yes							Costs captured below.
3	10.2.1.	Coordinate regularly with Working Teams to receive feedback on Recovery Plan implementation.	1,2	Continuous	RT	Yes	10	1	1	1	1	1	
3	10.2.2.	Meet annually or as needed to consider Working Team recommendations, review new research findings, generally assess plan implementation.	1,2	Continuous	RT	Yes	50	5	5	5	5	5	
3	10.2.3.	Make recommendations to FWS on plan clarifications and adjustments.	1,2	Continuous	RT	Yes	10	1	1	1	1	1	
3	10.3.	Establish and maintain a centralized Mexican spotted owl information repository.	1,2	Continuous	FWS	Yes	28	10	2	2	2	2	

2. Monitoring Procedures

Part III of this Recovery Plan lists specific criteria that must be met before the Mexican spotted owl can be delisted. Meeting two of these criteria will require large-scale monitoring of trends in owl abundance (or a surrogate for owl abundance) and habitat quantity and distribution. Here, we provide a brief overview of one approach that might be used to implement such monitoring, with technical details provided in Appendix F. We provide this approach as an example, noting that other approaches are possible and that future advances in monitoring techniques may result in other, more efficient approaches. Ultimately, any approach that can satisfactorily address the recovery criteria should be acceptable.

In USDI FWS (1995), we advocated a population monitoring scheme based on mark-recapture sampling. That design would provide rigorous demographic data on spotted owls as well as estimates of population trend. However, a pilot study conducted to evaluate those methods identified several potential problems. These included high cost and difficulty in finding sufficient numbers of highly motivated field workers. Perhaps more importantly, the mark-recapture approach required capture and banding of large numbers of owls. Although capture techniques for spotted owls are relatively safe, they are not risk-free. Further, many captures likely would be carried out by seasonal field crews, and many of these individuals likely would be inexperienced. As a result, the risk of injury to owls was deemed unacceptable.

Fortunately, advances in monitoring techniques since 1995 provide a viable alternative to mark-recapture sampling, specifically occupancy monitoring (e.g., MacKenzie et al. 2006). Occupancy monitoring does not require capture and banding of owls but is based on mark-recapture theory and does allow for estimation of detection probability. This is a critical detail, because (1) it is likely that not all resident owls will be detected in a given year, and (2) detection probabilities may change over time. Such changes in detectability of owls could result in erroneous trend estimates and misguided conservation efforts. Consequently, we propose a monitoring program based on occupancy monitoring. Such a program will not provide the detailed demographic data that mark-recapture sampling would provide, but it should be safer and cheaper to implement while still providing valid population trend estimates.

Before describing the proposed monitoring program further, we repeat the following statements to summarize pertinent discussion from elsewhere in the Plan:

- a. While monitoring habitat is important, numerous factors other than habitat conditions can influence owl populations. Therefore, it is necessary to monitor trends in both habitat and the owl population.
- b. We are assuming that the existing owl population is adequate in numbers and distribution to maintain the viability of the species (see Part III.4. Objective and Measurable Recovery Criteria, to explain this assumption). However, we are willing to accept a stable or increasing population or site occupancy trend over a period ≥ 10 years as evidence that the owl population is sustaining itself and therefore is likely to persist. The selection of a 10 year period is explained in Part V.2.A.b. below.
- c. A number of approaches are possible for monitoring owl habitat. One possibility is to use data from the USDA Forest Inventory and Analysis (FIA; <http://fia.fs.fed.us>) program. The FIA program is attractive as an aid to monitoring trends in owl habitat because it is an

existing and well-funded program that provides repeat sampling of habitat conditions throughout the range of the owl. We explain details of the FIA sampling protocols and resulting data in Appendix F - Monitoring.

- d. However habitat data is obtained, we envision: (1) using habitat data to aid in stratifying the sample of areas where owl occupancy rates are estimated, and (2) relating habitat data to owl occupancy rates, to allow for better understanding of relationships between specific habitat features and/or landscape composition and owl population trends (see Appendix F for further details).
- e. The proposed monitoring of owl occupancy rates likely will monitor only the territorial population of owls. The non-territorial portion of the owl population likely will not be detected directly (see below for further discussion of this issue).
- f. We think the minimum trend period of 10 years is a reasonable time span for monitoring the trend in owl occupancy (see discussion below).

A. Monitoring Mexican Spotted Owl Occupancy Rates

Although we support the idea of estimating population size directly and collecting associated demographic data as described in USDI FWS (1995), we propose this alternative monitoring program based on monitoring occupancy rates as an index of population size and distribution, for reasons discussed above. We define occupancy rate for Mexican spotted owls as the proportion of sample plots occupied by the species. The sample plots will consist of square blocks of 100 ha (247 ac). We propose using existing Universal Transverse Mercator (UTM) blocks that can be easily mapped using Geographic Information Systems (GIS). Appendix F - Monitoring provides a detailed discussion of the statistical aspects of using the occupancy rate to estimate owl population trend, as well as a discussion of how the owl occupancy rate would be related to habitat conditions.

One limitation of the proposed monitoring is that owl occupancy monitoring (and all known approaches) likely will monitor primarily territorial birds. This is because non-territorial “floaters” (Franklin 1992) may not respond readily and consistently during calling surveys. The proportion of non-territorial floaters in the population of Mexican spotted owls remains unknown, but may not be large. Evidence for Mexican spotted owls suggests that: (1) the proportion of birds <2 years old (i.e., subadults) holding territories is relatively high, (2) territory vacancies typically are filled by birds 1 to 2 yrs old, and (3) density of territorial Mexican spotted owls appears to track reproduction with a short lag period (Seamans et al. 1999: Fig. 5; Gutiérrez et al. 2003, J. P. Ward and J. L. Ganey, unpublished data). All of these factors suggest that large numbers of non-territorial floaters typically are not present within the range of the Mexican spotted owl. Consequently, we do not view this limitation as fatal to the monitoring program.

a. Steps to Monitoring

We envision monitoring a random sample of blocks (see above) for the presence of owls. Non-detection of owls within a sample does not imply owls are absent because observers cannot always detect the presence of owls. This is unlikely because some owls may not vocalize or an observer may fail to hear them. Thus, probability of detecting an owl or owls must be estimated as part of the monitoring process. Recent models (MacKenzie et al. 2002, 2003, 2006) provide

viable methods to estimate detection probability and thus rigorously monitor site occupancy. We assume that occupancy rate provides a valid index of population size, although the exact relationship between abundance and occupancy rate remains unknown (Royle and Nichols 2003). Presumably, however, monitoring site-occupancy rates will allow detection of important changes in the owl population.

In Appendix F, we outline a suitable framework and statistical estimation approach for monitoring owl populations via directly estimating the site occupancy rate of territorial owls, and we discuss how FIA measurements could be incorporated into the occupancy monitoring plan so that microhabitat variables can be related to owl occupancy rates. Accurate and efficient protocols for monitoring owl occupancy will require pilot studies to estimate occupancy rates and detection probabilities and their statistical variances. These estimates then can be used to determine variables such as the number of plots required and number of call points required per plot, and to evaluate tradeoffs between greater numbers of visits per plot versus increasing spatial replication by sampling more plots fewer times. Given sample data, all of these factors can be optimized to design a monitoring program that will most efficiently satisfy the quantitative targets in the delisting criterion for population monitoring.

b. Time Period for Monitoring

Recovery criterion 1 for delisting (Part III) specifies that owl population trend should be monitored for at least 10 years. Monitoring for a longer period is desirable, given the owl's long lifespan, the fact that it frequently occurs in forested and canyon ecosystems that change slowly, and the pronounced temporal variability in climate that characterizes the American southwest. We believe that 10 years is a reasonable minimum time span for owl occupancy monitoring for the following reasons. First, given current estimates of owl survival rates, more than half of the adult population should turn over during a 10-year period. Vacancies created by deaths of territorial resident owls may be filled by unpaired, non-territorial birds or, more likely, by subadult birds recruited from the previous year or two. The extent to which new owls fill territory vacancies will provide evidence on whether or not sufficient reproduction is occurring to sustain the owl population. A 10-year period should be sufficient to test whether adequate recruitment is occurring.

Second, we expect that the owl population will be subjected to considerable environmental variation during this 10-year period, including both dry and wet years and major fire events.

Third, even if occupancy rates are stable or increasing and the species is delisted, the ESA requires a minimum additional five years of monitoring post-delisting. This time period would provide further opportunity for evaluating population trend.

Fourth, we hope that the 10-year period will appear achievable to managers and thus provide incentive to implement population monitoring and acquire the monitoring data required to evaluate the potential for proposing to delist the owl.

B. Monitoring Mexican Spotted Owl Habitat

The primary objective of habitat monitoring is to validate results of occupancy monitoring. For example, if occupancy monitoring indicates stable (or increasing) occupancy rates, habitat monitoring will provide a general measure of whether there will be sufficient nest and roost habitat for occupancy rates to remain stable. We advocate no specific method for habitat monitoring and leave it up to management agencies to determine the best method(s) to use. Again, one possible approach is to use data from the existing FIA program. We provide a brief overview of that program in Appendix F - Monitoring.

3. Ecological Management Unit Working Teams

The FWS intends to continue or reform Working Teams whose responsibility would be to oversee and guide implementation of the Recovery Plan. These Working Teams would coordinate with and report to the Recovery Team, which would consider and evaluate Working Team recommendations before passing them on to FWS. Working Teams for each EMU should be appointed by FWS as subunits under the Recovery Team umbrella. Working Teams should include as a minimum one representative from each of the following:

1. Each involved FWS Ecological Services Office
2. Each involved FS Region
3. Each involved state
4. Each involved Indian nation
5. Any other involved agency (e.g., BLM, NPS)
6. At least one researcher/scientist who can provide specialized expertise related to owl biology, forest ecology, monitoring, or other relevant topics

Working Teams should recommend to FWS the appointment of additional members as needed or desired. For example, representatives of local governments, affected industries, and conservation advocacy groups should be considered for appointment. If other interested parties express interest in participating on a Working Team, they should be allowed to do so pending FWS approval. Working Teams should strive to have a diversity of members to represent ecological, economic, social, conservation, and management interests.

Functions of Working Teams should include, but not be limited to, the following:

1. Provide technical assistance to agencies and landowners on topics related to project designs, spotted owl management, and Recovery Plan implementation. The Recovery Team encourages Working Teams to hold Recovery Plan implementation workshops to provide a common understanding of the plan to all interested parties.
2. Provide guidance and interpretation on implementation and recommendations contained within the Recovery Plan.
3. Recommend Recovery Plan revisions based on lessons learned from implementation.
4. Coordinate landscape analyses among management agencies and private landowners. The landscape analyses are required to identify areas requiring management intervention to protect and develop owl habitat.

5. Coordinate occupancy and habitat monitoring among management agencies and private landowners.
6. Promote communication among local interests and help to resolve conflicting interpretations of the Recovery Plan if they arise.
7. Track plan implementation and report success, problems, and progress to the FWS and Recovery Team periodically.

4. Continuing Duties of the Recovery Team

The FWS intends that the Recovery Team be continued throughout implementation of the Recovery Plan. Once the Recovery Plan is finalized, the Recovery Team should meet annually to review plan implementation, confer with Working Teams, and to report to FWS. If changes or adjustments to the Recovery Plan are warranted, the Recovery Team will forward recommendations for those changes to FWS for their consideration.

5. Centralized Mexican Spotted Owl Information Repository

The Recovery Team recommends development of a central repository for data related to Mexican spotted owl recovery. Historically, data have been retained in dispersed locations prohibiting meta-analyses to understand the status of the owl range-wide. Given that the owl inhabits lands under multiple jurisdictions, this central repository is critical to addressing pressing information needs about owl recovery. The primary purpose of such a facility would be to collate a spotted owl GIS database, occupancy monitoring data, habitat monitoring data, and other programs recommended in this Recovery Plan.

6. Research Needs

Despite the considerable interest in and research on the ecology of the Mexican spotted owl, much remains unknown, particularly in Mexico. Research is needed to develop long-term management strategies that assure predominant threats to the persistence of Mexican spotted owls will be alleviated. The primary focus of such research should be to elucidate factors that influence change in Mexican spotted owl distribution and abundance. Emphasis should be placed on identifying those factors that can be manipulated through social or natural resource management.

Communication and collaboration among scientists, land managers, and interested publics should play a key role in shaping future research. Managers need to understand the methods, problems, and uncertainties involved with gaining reliable knowledge from ecological research. Scientists, on the other hand, must rely on managers to identify appropriate questions and political and legal constraints, to implement experimental treatments, and to develop appropriate implementation of knowledge derived from research results in an adaptive management context. Too often scientists design and implement studies that do not directly address critical management issues. By working together, managers and scientists can bridge this gap and better focus research efforts by identifying relevant objectives and approaches. Involving and informing interested publics may facilitate implementation of important research activities without administrative or legal challenges.

Clearly, all research questions cannot be answered, given limited time and money. Similarly, we know that some population processes will vary among Recovery Units. It is therefore imperative that landscapes for research study areas be considered for particular questions to maximize gain. For example, three studies of habitat requirements conducted within mixed-conifer forest in a single EMU will likely yield less information than studies in other habitat types or regions. Here, we recommend research on questions about Mexican spotted owls that still need answers. Clearly, a large number of research questions could be developed that address all aspects of Mexican spotted owl biology for which knowledge is lacking. Others have reviewed research agendas for conservation of spotted owls or other forest wildlife (DeStefano 2002, Noon and Franklin 2002). The topics we recommend here are similar. However, we pose what we believe are the most crucial questions that need to be addressed in terms of long-term resource management and recovery of Mexican spotted owls. Studies designed to answer these questions could be descriptive, experimental, or a combination of both. We do not repeat questions that will be answered through population and habitat monitoring.

A. Habitat and Demography

Recovering the Mexican spotted owl will require detailed knowledge of the habitat constituents (including food resources) required at various scales to maintain viable populations. Past research has scratched the surface of this topic and primarily concentrated on roosting and nesting microhabitat features and, to a lesser degree, on prey requirements. In particular, habitat requirements of spotted owls that dwell in canyon-type environments are poorly known. We also recognize that spotted owl nesting habitat in forested environments is not static over time and that many currently used nesting sites eventually will be lost due to various disturbance agents. We therefore recognize a need to hone management tools that can be used to develop recovery habitat. This will necessarily entail studies of long duration, given the temporal nature of forest development, for example, or the potential for climate change to alter thermal regimes and habitat conditions in arid canyonlands. Consequently, these studies should begin as soon as possible. Important questions that remain to be answered include:

- i.* Which habitat features directly influence reproduction and/or survival of Mexican spotted owls?
- ii.* Which habitat features indirectly influence reproduction and/or survival of Mexican spotted owls by enhancing prey availability?
- iii.* How should these features be arranged spatially on the landscape to optimize owl fitness and habitat quality?
- iv.* How do stochastic environmental disturbances (particularly unplanned wildland fire) alter key habitat constituents and owl demography?
- v.* Which habitat features help buffer the influence of weather effects on reproduction and survival?
- vi.* How do various planned management activities alter key habitat constituents (including prey) and owl demography? This question is particularly important relative to landscape-scale restoration projects currently in planning, because these projects have the potential to impact vast acreages in short time frames.
- vii.* What is the probability that threshold nest/roost conditions recommended in the plan will become recovery habitat for roosting and/or nesting by Mexican spotted owls?

- viii. Which silvicultural prescriptions are best suited for creating and sustaining habitats used by Mexican spotted owls for various activities like roosting, nesting, foraging, and dispersal?
- ix. Which types of planned burning regimes and methods will promote development of the owl's roosting, nesting, and foraging habitat?
- x. What proportion of Mexican spotted owl populations migrate seasonally, where are winter habitats located, what habitat features do owls use to select these areas, and how important are these areas for owl dispersal and survival?
- xi. How will climate change alter distribution, structure, and composition of owl habitat?
- xii. How will climate change influence owl and prey distribution and abundance?
- xiii. If livestock grazing occurs within owl nesting, roosting, and foraging habitats, what livestock grazing strategies can be implemented to best maintain suitable habitat conditions for owl prey species and alleviate grazing impacts on the development of future owl nesting/roosting habitats (e.g., oak/cottonwood/willow/alder trees)?
- xiv. What are the effects of various recreational activities (hiking, climbing, off-road vehicle use) on Mexican spotted owl behavior, habitat use and demography? How can managers mitigate potential effects in high-use areas?
- xv. If salvage logging is needed after a disturbance event (e.g., fire, insect/disease outbreak), how can it be implemented to maintain and protect existing habitat features or accelerate the development of future owl habitat?

The effects of different severities of wildland fire (Question iv above) on Mexican spotted owls are still poorly understood. Stochastic disturbances and activities like wildland fire that may not be readily tested with experiments for lack of suitable control can be examined through development and analysis of simulation models and comparison with observational (retrospective) analyses. Planned management activities that should be studied for effects on owls, prey, and habitat include forest restoration, forest thinning prescriptions, and domestic livestock grazing.

B. Biological Interactions

Although Recovery Plans are mostly written for a single species, they must consider a wide array of interactions within biological communities and ecosystems. Community-level interactions that can affect Mexican spotted owl populations include parasitism, disease, predation, and competition. These factors are omnipresent in shaping population processes. However, the combined influence of these factors under particular environmental conditions can prove deleterious, resulting in significant and unrecoverable population decline. Important questions include:

- i. Are any of these factors limiting Mexican spotted owl populations?
- ii. In particular, what are the effects of invasive pathogens like West Nile virus?
- iii. What is the relative influence of other predators on common prey of the Mexican spotted owl?
- iv. What environmental conditions will lead to increased effects of community-level interactions?
- v. What types of management actions are necessary to alleviate deleterious community-level interactions?
- vi. How might climate change alter these factors and/or their impacts on Mexican spotted owls?

- vii. How will planned habitat treatments influence different biological interactions that can limit Mexican spotted owl populations, and how do these effects vary across spatial and temporal scales?

C. Population Structure

For populations to persist through time, there must be adequate numbers of individuals present within and among subpopulations. The ultimate distribution and abundance of individuals is influenced by a wide array of factors. Some of these factors can be influenced by management. For example, restoration of riparian corridors between core populations may ensure stronger connectivity and mixing of genotypes. Other factors, like the distribution of canyons on the landscape, cannot be influenced, with the possible exception of removing dams. The questions posed below relate more to longer-term, larger-scale processes than the previous questions. However, these questions will need to be addressed in a long-term management plan. Specifically, questions about metapopulation function like dispersal and connectivity must be answered, along with questions about gene flow and fitness.

- i. What are the relative numerical and genetic contributions of core and exterior populations?
- ii. Are subpopulations within and between EMUs connected?
- iii. What habitats and large-scale habitat configurations are required to maintain adequate survival rates during juvenile dispersal or adult migration?
- iv. What is the optimal arrangement of owl numbers and genetic mix that will lead to persistent populations at various time scales?
- v. Which management activities help to ensure a well distributed set of functioning subpopulations? Which hinder this goal?
- vi. What are the potential impacts of climate change on connectivity of owl populations throughout their range?

D. Ecosystem Function

Implementation of recovery measures for the Mexican spotted owl will affect numerous ecosystem attributes directly and indirectly. Research is needed to determine the extent of these effects on biotic and abiotic components, and on ecosystem processes and function. Key questions are:

- i. What are the effects of implementing this Recovery Plan on ecosystem structure and functions like soil erosion, water yield, and nutrient flow?
- ii. What are the effects of implementing this Recovery Plan on plant community structure, composition, and sustainability?
- iii. How has the implementation of this Recovery Plan affected long-term restoration of forested systems?
- iv. How are other focal wildlife species responding to conservation guidelines in this Recovery Plan?
- v. How might this Recovery Plan be adjusted to mitigate potentially deleterious effects on other ecosystem attributes?
- vi. What are the potential implications of climate change to resilience of the ecosystems that support Mexican spotted owls, and how can we best balance increasing resilience in those systems with maintaining owl habitat?

PART VI. LITERATURE CITED

- Abella, S. 2008. Managing Gambel oak in Southwestern ponderosa pine forests: the status of our knowledge. USDA Forest Service, General Technical Report, RMRS-GTR-218, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Ager, A.A., M.A. Finney, B.K. Kerns, and H. Maffei. 2007. Modeling wildfire risk to northern spotted owl (*Strix occidentalis caurina*) habitat in central Oregon. *Forest Ecology and Management* 246:45-56.
- Ager, A.A., N.M. Vaillant, and M.A. Finney. 2010. A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. *Forest Ecology and Management* 259:1556-1570.
- Alden, P. 1989. Finding the birds in western Mexico: a guide to the states of Sonora, Sinaloa, and Nayarit. University of Arizona Press, Tucson.
- Alexander, B.G., Jr., and F. Ronco, Jr. 1987. Classification of the forest vegetation on the National Forests of Arizona and New Mexico. USDA Forest Service, Research Note, RM-469, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Alexander, B.G., Jr., F. Ronco, Jr., E.L. Fitzhugh, and J.A. Ludwig. 1984a. A classification of forest habitat types of the Lincoln National Forest, New Mexico. USDA Forest Service, General Technical Report, RM-104, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Alexander, B.G., Jr., F. Ronco, Jr., A.S. White, and J.A. Ludwig. 1984b. Douglas-fir habitat types of northern Arizona. USDA Forest Service, General Technical Report, RM-108, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Allen, C.D., and M. Vennetier. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660-684.
- Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D. D. Breshears, E. H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J-H. Lim, G. Allard, S. W. Running, A. Semerci, and N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259:660-684.
- American Ornithologists Union [AOU]. 1957. Check-list of North American birds. Fifth edition. American Ornithologists Union, Baltimore, Maryland, USA.

- American Society of Mammalogists. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. *Journal of Mammalogy* 79:1416-1431.
- American Wind Energy Association [AWEA]. 2009. U.S. wind energy projects. American Wind Energy Association. Available from: <http://www.awea.org>.
- Ames, C.R. 1977. Wildlife conflicts in riparian management: grazing. Pp. 43-52 *in* Importance, preservation and management of riparian habitat. USDA Forest Service, General Technical Report, RM-43, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Anthony, R.G., E.D. Forsman, A.B. Franklin, D. R. Anderson, K. P. Burnham, G. C. White, C. J. Schwarz, J. D. Nichols, J. E. Hines, G. S. Olson, S. H. Ackers, L. S. Andrews, B. L. Biswell, P. C. Carlson, L. V. Diller, K. M. Dugger, K. E. Fehring, T. L. Fleming, R. P. Gergardt, 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.
- Archer, S.R., and K.I. Predick. 2008. Climate change and ecosystems of the Southwestern United States. *Society for Range Management* 30:23-28.
- Arsenault D.P., A. Hodgson, and P.B. Stacey. 1997. Dispersal movements of juvenile Mexican spotted owls (*Strix occidentalis lucida*) in New Mexico. Pp. 47-57 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls (eds.), *Biology and conservation of owls of the northern hemisphere*. USDA Forest Service, General Technical Report, NC-190, Southern Research Station, Asheville, North Carolina, USA.
- Ayres, M.P., and M.J. Lombardero. 2000. Assessing the consequences of global change for forest disturbances for herbivores and pathogens. *The Total Science of the Environment* 262:263-286.
- Bagne, K.E., and D.M. Finch. 2008. Developing a tool to assess wildlife species vulnerability to climate change. *in* New Mexico forestry and climate change workshop; November 20, 2008; Albuquerque, New Mexico, Forest Guild. Available from: http://www.forestguild.org/climate_change/Finch.pdf.
- Bahre, C.J. 1991. A legacy of change: historic human impact on vegetation of the Arizona borderlands. University of Arizona Press, Tucson, USA.
- Bahre, C.J. 1995. Human impacts on the grasslands of southeastern Arizona. Pp. 230-264 *in* M.P. McClaran and T.R. Van Devender (eds.), *The desert grassland*. University of Arizona Press, Tucson, USA.

- Bailey, L.L., J.A. Reid, E.D. Forsman, and J.D. Nichols. 2009. Modeling co-occurrence of northern spotted and barred owls: accounting for detection probability differences. *Biological Conservation* 142:2983-2989.
- Bailey, R.G. 1980. Descriptions of the ecoregions of the United States. USDA Forest Service, Miscellaneous Publication 1391, Intermountain Research Station, Ogden, Utah, USA.
- Barrowclough, G.F., and R.J. Gutiérrez. 1990. Genetic variation and differentiation in the spotted owl (*Strix occidentalis*). *Auk* 107:737-744.
- Barrowclough, G.F., J.G. Groth, L.A. Mertz, and R.J. Gutiérrez. 2006. Genetic structure of Mexican spotted owl populations in a fragmented landscape. *Auk* 123:1090-1102.
- Barrowclough, G.F., R.J. Gutiérrez, and J.G. Groth. 1999. Phylogeography of spotted owl (*Strix occidentalis*) populations based on mitochondrial DNA sequences: gene flow, genetic structure, and a novel biogeographic pattern. *Evolution* 53:919-931.
- Barrows, C.W. 1981. Roost selection by spotted owls: an adaptation to heat stress. *Condor* 83:302-309.
- Barrows, C.W. 1987. Diet shifts in breeding and nonbreeding spotted owls. *Journal of Raptor Research* 21:95-97.
- Betancourt, J.L. 2004. Arid lands paleobiogeography: the fossil rodent midden record in the Americas. Pp. 27-46 in M.V. Lomolino and L.R. Heaney (eds.), *Frontiers in biogeography: new directions in the geography of nature*. Sinauer Associates Inc., Sunderland, Massachusetts, USA.
- Beschta, R. L., J. J. Rhodes, J. B. Kauffman, R. E. Gresswell, G. W. Minshall, J. R. Karr, D. A. Perry, F. R. Hauer, and C. A. Frissell. 2004. Postfire management on forested public lands of the western United States. *Conservation Biology* 18:957-967.
- Bevis, K.R., G.M. King, and E.E. Hanson. 1997. Spotted owls and 1994 fires on the Yakima Indian Reservation. Pp. 117-122 in *Conference proceedings—Fire effects on rare and endangered species and habitats*. November 13-16, 1995; Coeur d'Alene, Idaho. International Association of Wildland Fire.
- Bingham, B.R., and B.R. Noon. 1992. The use of core areas in comprehensive mitigation strategies. *Conservation Biology* 12:241-243.
- BirdLife International 2008. *Strix occidentalis*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.3. On line: [www.iucnredlist.org]. Web Page visited on 28 September 2010.
- Birney, E.C., W.E. Grant, and D.D. Baird. 1976. Importance of vegetative cover to cycles of *Microtus* populations. *Ecology* 57:1043-1051.

- Blackburn, W.H. 1984. Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses. Pp. 927-983 *in* Developing strategies for rangeland management. National Research Council and National Academy of Sciences. Westview Press, Boulder, Colorado, USA.
- Blakesley, J.A., D.R. Anderson, and B.R. Noon. 2006. Breeding dispersal in the California spotted owl. *Condor* 108:71-81.
- Blakesley, J.A., B.R. Noon, and D.R. Anderson. 2005. Site occupancy, apparent survival, and reproduction of California spotted owls in relation to forest stand characteristics. *Journal of Wildlife Management* 69:1554-1564.
- Blakesley, J.A., B.R. Noon, and D.W.H. Shaw. 2001. Demography of the California spotted owl in northeastern California. *Condor* 103:667-677.
- Blakesley, J.A., W. LaHaye, J.M. Marzluff, B.R. Noon, and S.Courtney. 2004. Chapter 8: Demography. Pp. 1-46 *in* S.P. Courtney, J.A. Blakesely, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. Scientific evaluation of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon, USA.
- Block, W.M., and L.A. Brennan. 1993. The habitat concept in ornithology: theory and application. *Current ornithology* 11:35-91.
- Block, W.M., J.L. Ganey, P.E. Scott, and R. King. 2005. Prey ecology of Mexican spotted owls in pine-oak forests of northern Arizona. *Journal of Wildlife Management* 69:618-629.
- Bonan, G.B. 2008. Forests and climate change: forcings, feedbacks, and the climate benefits of forests. *Science* 320:1444-1449.
- 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.
- Bowden, D.C., G.C. White, A.B. Franklin, and J.L. Ganey. 2003. Estimating population size with correlated sampling unit estimates. *Journal of Wildlife Management* 67:1-10.
- Bowden, T.S. 2008. Mexican spotted owl reproduction, home range, and habitat associations in Grand Canyon National Park. M.S. Thesis, Montana State University, Bozeman, Montana, USA. 87 pp.

- Bowles, A.E., K.J. Plotkin, B. Ikelhaimer, and T. Lavallee. 2002. Acoustic surveys for Mexican spotted owls (*Strix occidentalis lucida*): an analysis. *Journal of the Acoustical Society of America* 111(5):2392. (Abstract)
- Boyce, M.S. 1988. Bet hedging in avian life histories. Pp. 3-18 in H.O. Ouellet, (ed.), *Acta XIX Congressus Internationalis Ornithologici*. National Museum of Natural Science, Ottawa,
- Bravo-Vinaja, M.G., L.A. Tarango-Arámbula, F. Clemente-Sánchez, G.D. Mendoza-Martínez, J. Alcántra-Carbajal, and H.V. Soro-Aquino. 2005. Mexican spotted owl's (*Strix occidentalis lucida*) diet composition and variation at Valparaíso, Zacatecas, Mexico. *Agrociencia* 39:509-515. Available from: <http://www.colpos.mx/agrocien/Bimestral/2005/sep-oct/art-4.pdf>.
- Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belknap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. *Proceedings National Academy of Sciences* 102:15144-15148.
- Breshears, D.D., O.B. Myers, C.W. Meyer, F.J. Barnes, C.B. Zou, C.D. Allen, N.G. McDowell, and W.T. Pockman. 2009. Tree die-off in response to global-change-type drought: mortality insights from a decade of plant water potential measurements. *Frontiers in Ecology and Environment* 7:185-189.
- Brown, D.E. (ed.). 1982. Biotic communities of the American southwest—United States and Mexico. *Desert Plants* 4:1-342.
- Brown, D.E., C.H. Lowe, and C.P. Pase. 1980. A digitized systematic classification for ecosystems with an illustrated summary of the natural vegetation of North America. USDA Forest Service, General Technical Report, RM-73, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Brown, D.G., K.M. Johnson, T.R. Loveland, and D.M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950-2000. *Ecological Applications* 15:1851-1863.
- Brown, D.P., and A.C. Comrie. 2002. Spatial modeling of winter temperature and precipitation in Arizona and New Mexico, USA. *Climate Research* 11:115-128.
- Brown, P.M., and R. Wu. 2005. Climate and disturbance forcing of episodic tree recruitment in a southwestern ponderosa pine landscape. *Ecology* 86:3030-3038.
- Brown, P.M., M.W. Kaye, L.S. Huckaby, and C.H. Baisan. 2001. Fire history along environmental gradients in the Sacramento Mountains, New Mexico: influences of local patterns and regional processes. *Ecoscience* 8:115-126.
- Bryan, K.B., and J.P. Karges. 2001. Recent bird records in the Davis Mountains. *Texas Birds* 3(1):40-53.

- Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. *Journal of Range Management* 35:780-785.
- Buchanan, J.B., T.L. Fleming, and L.L. Irwin. 2004. A comparison of barred and spotted owl nest-site characteristics in the Eastern Cascade Mountains, Washington. *Journal of Raptor Research* 38:231-237.
- Buchanan, J. B., R. J. Gutiérrez, R. G. Anthony, T. Cullinan, L. V. Diller, E. D. Forsman, and A. B. Franklin. 2007. A synopsis of suggested approaches to address potential competitive interactions between barred owls (*Strix varia*) and spotted owls (*S. occidentalis*). *Biological Invasions* 9:670-691.
- 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.
- Burnham, K.P., D.R. Anderson, and G.C. White. 1996. Meta-analysis of vital rates of the northern spotted owl. *Studies in Avian Biology* 17:92-101.
- Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy* 24:346-352.
- Busch, D.E., and S.D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the Southwestern U.S. *Ecological Monographs* 65:347-370.
- Camp, A., C. Oliver, P. Hessburg, and R. Everett. 1997. Predicting late-successional fire refugia pre-dating European settlement in the Wenatchee Mountains. *Forest Ecology and Management* 95:63-77.
- Carey, A.B. 1985. A summary of the scientific basis for spotted owl management. Pp. 100-114 in R.J. Gutiérrez and A.B. Carey (eds.), *Ecology and management of the spotted owl in the Pacific Northwest*. USDA Forest Service, General Technical Report, PNW-185, Pacific Northwest Research Station, Portland, Oregon, USA.
- 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.
- Cartron, J-L.E. 2010. Casual and accidental raptors. Pp. 671-681 in J-L.E. Cartron, *Raptors of New Mexico*. University of New Mexico Press, Albuquerque, USA. 710 pp.
- Chaney, E., W. Elmore, and W.S. Platts. 1990. *Livestock grazing on western riparian areas*. Environmental Protection Agency, Northwest Resource Information Center Inc., Eagle, Idaho, USA.

- Chaney, E., W. Elmore, and W.S. Platts. 1993. Managing change—livestock grazing on western riparian areas. Environmental Protection Agency, Northwest Resource Information Center Inc., Eagle, Idaho, USA.
- Cirrett-Galan, J.M., and E.E.R. Diaz. 1993. Estatus y distribución del buho manchado Mexican *Strix occidentalis lucida* en Sonora, Mexico. Reporte Técnico Parcial, Centro Ecológico de Sonora, Hermosillo, Sonora, Mexico.
- 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, USA. 202 pp.
- Clary, W.P., and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. USDA Forest Service, General Technical Report, INT-263, Intermountain Research Station, Ogden, Utah, USA. 13 pp.
- Cochran, W.G. 1977. Sampling Techniques. Third edition. John Wiley & Sons, New York, New York, USA.
- Conabio. 2009. Capital natural de México, vol. II : Estado de conservación y tendencias de cambio. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México
- CONANP. 2005. Estudio Previo Justificativo para el Establecimiento del Área Natural Protegida Área de Protección de Flora y Fauna “Cerro del Mohinora”. CONANP-SEMARNAT. México. 64 pp.
- CONANP. 2006. Programa de Conservación y Manejo. Parque Nacional Sierra de San Pedro Mártir, México. México. 174 pp.
- CONANP. 2010. Sistema de Información Geográfica (SIG). México. En línea: [<http://www.conanp.gob.mx/sig/>]. Página visitada el 29 de septiembre de 2010.
- CONANP – Pronatura Noreste. 2008. Estrategia Operativa para la Conservación de la Cotorra Serrana Oriental. Informe Final. Programa de Conservación de Especies en Riesgo. Monterrey, N.L. 30 pp.
- CONANP – Pronatura Sur. 2008. Recuperación de las Poblaciones de Cotorra Serrana Occidental y Conservación de los Bosques Antiguos. Informe Final. Programa de Conservación de Especies en Riesgo. 60 pp.
- Converse, S.J., W.M. Block, and G.C. White. 2006a. Small mammal population and habitat responses to forest thinning and prescribed fire. *Forest Ecology and Management* 228:263-273.

- Converse, S.J., G.C. White, and W.M. Block. 2006b. Small mammal responses to thinning and wildfire in ponderosa pine-dominated forests of the southwestern United States. *Journal of Wildlife Management* 70:1711-1722.
- Converse, S.J., G.C. White, K.L. Farris, and S. Zack. 2006c. Small mammals and forest fuel reduction: national-scale responses to fire and fire surrogates. *Ecological Applications* 16:1717-1729.
- Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. *Ecological Monographs* 30:129-164.
- Cordell, H. 2004. *Outdoor recreation for the 21st Century America: a report to the nation, the national survey on recreation and the environment*. Venture Publishing, State College, Pennsylvania, USA.
- Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutierrez, J.M. Marzluff, and L. Szutkowski. 2004. Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon, USA.
- Covington, W.W., and M.M. Moore. 1994. Postsettlement changes in natural fire regimes and forest structure: ecological restoration of old growth ponderosa pine forests. *Journal of Sustainable Forestry* 2:153-181.
- Crozier, M.L., M.E. Seamans, R.J. Gutiérrez, P.J. Loschl, R.B. Horn, S.G. Sovern, E.D. Forsman. 2006. Does the presence of barred owls suppress the calling behavior of spotted owls? *Condor* 108:760-769.
- Cuanalo, C. E., T. E. Ojada, O. A. Santos, and S. C. A. Ortiz. 1989. *Provincias, regiones y subregiones terrestres de Mexico*. Centro de Postgraduados. Chapingo, Mexico.
- Dark, S. J., R. J. Gutierrez, and G. I Gould. 1998. The Barred Owl (*Strix Varia*) invasion in California. *Auk* 115:50-56.
- Dahms, C.W., and B.W. Geils. 1997. *An assessment of forest ecosystem health in the Southwest*. USDA Forest Service, General Technical Report, RM-GTR-295, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Dale, V.H., L.A. Joyce, S. McNulty, R.P. Neilson, M.P. Ayres, M.D. Flannigan, P.J. Hanson, L.C. Irland, A.E. Lugo, C.J. Peterson, D. Simberloff, F.J. Swanson, B.J. Stocks, and B.M. Wotton. 2001. Climate change and forest disturbances: climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides. *BioScience* 51:723-734.

- Daniels, T.W., J.A. Helms, and F.S. Baker. 1979. Principles of Silviculture. Second edition. McGraw-Hill, New York, New York, USA.
- Danzer, S. 2005. Characterization of Mexican spotted owl (*Strix occidentalis lucida*) habitat in Madrean sky island ecosystems. Pp. 387-391 in G.J. Gottfried, B.S. Gebow, L.G. Eskew, and C.B. Edminster (compilers), Connecting mountain islands and desert seas: biodiversity and management of the Madrean Archipelago II. USDA Forest Service, Proceedings, RMRS-P-36, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Dark, S.J., R.J. Gutiérrez, and G.I. Gould. 1998. The barred owl (*Strix varia*) invasion of California. *Auk* 115:50-56.
- Daubenmire, R. 1943. Vegetation zonation in the Rocky Mountains. *Botanical Reviews* 9:325-393.
- Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. *Ecological Monographs* 22:301-330.
- Daubenmire, R. 1968. *Plant Communities: A Textbook of Plant Synecology*. Harper and Row, New York, New York, USA.
- DeGomez, T., and G. Garfin. 2006. Insects, diseases, and abiotic disorders in Southwest forests and woodlands. Arizona Cooperative Extension (AZ1418), University of Arizona, Tucson, USA.
- DeGomez, T., and M. Lenart. 2006. Management of forests and woodlands. Arizona Cooperative Extension (AZ1424), University of Arizona, Tucson, USA.
- Delaney, D.K., and T.G. Grubb. 2003. Effects of off-highway vehicle noise on northern spotted owls: 2002 results. A report to the state of California Department of Parks and Recreation, Off-Highway Motor Vehicle Recreation Division, Contract Number 43-91Z9-0-0055, Construction Engineering Research Laboratory/Rocky Mountain Research Station, Flagstaff, Arizona, USA.
- Delaney, D.K., and T.G. Grubb. 2004. Sound recordings of road and maintenance equipment on the Lincoln National Forest, New Mexico. USDA Forest Service, Research Paper, RMRS-RP-49, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Delaney, D.K., T.G. Grubb, and P. Beier. 1999a. Activity patterns of nesting Mexican spotted owls. *Condor* 101:42-49.
- Delaney, D.K., T.G. Grubb, P. Beier, L.L. Pater, and M.H. Reiser. 1999b. Effects of helicopter noise on Mexican spotted owls. *Journal of Wildlife Management* 63:60-76.

- Denes, S.L., A.E. Bowles, K. Plotkin, C. Hobbs, J. Kern, and E. Pruitt. 2006. Effective area of acoustic lure surveys for Mexican spotted owls (*Strix occidentalis lucida*). *Journal of the Acoustical Society of America* 120(5):3267. (Abstract)
- DeStefano, S. 2002. Regional and national issues for forest wildlife research and management. *Forest Science* 48:181-189.
- DeVelice, R.L., J.A. Ludwig, W.H. Moir, and F. Ronco, Jr. 1986. A classification of forest habitat types of northern New Mexico and southern Colorado. USDA Forest Service, General Technical Report, RM-131, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Dick-Peddie, W.A. 1993. *New Mexico vegetation, past, present, and future*. University of New Mexico Press, Albuquerque, USA. 244 pp.
- Dickerman, R.W. 1997. Geographic variation in southwestern U.S. and Mexican spotted owls, with the description of a new subspecies. Pp. 45-48 *in* R.W. Dickerman (compiler), *The era of Allan R. Phillips: a festschrift*. Horizon Communications, Albuquerque, New Mexico, USA.
- Dickey, D.R. 1914. The nesting of the spotted owl. *Condor* 16:193-202.
- Dieterich, John H. 1983. Fire history of southwestern mixed-conifer; a case study. *Forest Ecology and Management* 6:13-31.
- Dodson E.K., D.W. Peterson, and R.J. Harrod. 2010. Impacts of erosion control treatments on native vegetation recovery after severe wildfire in the Eastern Cascades, USA. *International Journal of Wildland Fire* 19:490-499.
- Donato, D.C., J.B. Fontaine, J.L. Campbell, W.D. Robinson, J.B. Kauffman, and B.E. Law. 2006. Post wildfire logging hinders regeneration and increases fire risk. *Science* 311:353-362.
- 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.
- Duncan, R.B., and R. Sidner. 1990. Bats in spotted owl pellets in southern Arizona. *Great Basin Naturalist* 50:197-200.
- Duncan, R.B., and S.M. Speich. 1995. Spotted owl banding in sub-Mogollon Arizona, dispersal and movement: current knowledge. *North American Bird Bander* 20(3):151. (Abstract)
- Duncan, R.B., and S.M. Speich. 2002. Inter-and intra-mountain movements of Mexican spotted owls in southeastern Arizona: results of a multi-year banding study, 1991-2001. Annual meeting, Western Bird Banding Association, Bisbee, Arizona, USA. (Abstract)

- Duncan, R.B., and J.D. Taiz. 1992. A preliminary understanding of Mexican spotted owl habitat and distribution in the Chiricahua Mountains and associated sub-Mogollon mountain ranges in southeastern Arizona. Pp. 58-61 in A.M. Barton and S.A. Sloane (eds.), Proceedings of the Chiricahua Mountains research symposium, Southwest Parks and Monuments Association, Tucson, Arizona, USA.
- Eidenshink, J., B. Schwind, K. Brewer, Z-L. Zhu, B. Quayle, and S. Howard. 2007. A project for monitoring trends in burn severity. Fire Ecology Special Issue 3:3-21.
- Elliott, B. 1985. Changes in distribution of owl species subsequent to habitat alteration by fire. Western Birds 16:25-28.
- Energy Information Administration. 2010. Crude oil and natural gas exploratory and development wells. U.S. Energy Information Administration. Available from: <http://www.eia.doe.gov>.
- Enriquez-Rocha, P., J.L. Rangel-Salazar, and D.W. Holt. 1993. Presence and distribution of Mexican owls: a review. Journal of Raptor Research 27:154-160.
- Envirological Services, Inc. 2009. Mexican Spotted Owl (*Strix occidentalis lucida*) inventory surveys on Kirtland Air Force Base. Unpublished report to Kirtland Air Force Base, New Mexico.
- Erickson, W.P., G.D. Johnson, and D.P. Young. 2005. A summary and comparison of bird mortality from anthropogenic causes with emphasis on collisions. USDA Forest Service, General Technical Report, PNW-GTR-191, Pacific Northwest Research Station, Portland, Oregon, USA.
- Everett, R., D. Schellhaas, D. Spurbeck, P. Ohlson, D. Keenum, and T. Anderson. 1997. Structure of northern spotted owl nest stands and their historical conditions on the eastern slope of the Pacific Northwest Cascades, USA. Forest Ecology and Management 94:1-14.
- Eyre, F.H. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Bethesda, Maryland, USA.
- Fettig, C.J., K.D. Klepzig, R.F. Billings, A.S. Munson, T.E. Nebeker, J.F. Negron, and J.T. Nowak. 2007. The effectiveness of vegetation management practices for prevention and control of bark beetle infestations in coniferous forests of the western and southern United States. Forest Ecology and Management 238:24-53.
- Finney, M.A., R.C. Seli, C.W. McHugh, A.A. Ager, B. Bahro, and J.K. Agee. 2007. Simulation of long-term landscape-level fuel treatment effects on large wildfires. International Journal of Wildland Fire 16:712-727.
- Fitton, S.D. 1991. Vocal learning and call structure of male northern spotted owls in northwestern California. M.S. Thesis, Humboldt State University, Arcata, California, USA.

- Fitzgerald, S.D., J.S. Patterson, M. Kiupel, H.A. Simmons, S.D. Grimes, C.F. Sarver, R.M. Fulton, B.A. Steficek, T.M. Cooley, J.P. Massey, and J.G. Sikarskie. 2003. Clinical and pathologic features of West Nile Virus infection in North American owls (Family Strigidae). *Avian Diseases* 47:602-610.
- Fitzhugh, E.L., W.H. Moir, J.A. Ludwig, and F. Ronco, Jr. 1987. Forest habitat types in the Apache, Gila, and part of the Cibola National Forests, Arizona and New Mexico. USDA Forest Service, General Technical Report, RM-145, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Fleischer, R., J. Dumbacher, C. Moritz, and W. Monahan. 2004. Chapter 3: Assessment of the subspecies and genetics. Pp. 1-31 in S.P. Courtney, J.A. Blakesely, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski, Scientific evaluation of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon, USA.
- Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8:629-644.
- Fletcher, K.W. 1990. Habitats used, abundance and distribution of the Mexican spotted owl, *Strix occidentalis lucida*, on National Forest system lands. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.
- Fletcher, K.W., and H.E. Hollis. 1994. Habitats used, abundance, and distribution of the Mexican spotted owl (*Strix occidentalis lucida*) on National Forest System lands in the Southwestern Region. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.
- Floyd, M.L., M. Clifford, N.S. Cobb, D. Hanna, R. Delph, P. Ford, and D. Turner. 2009. Relationship of stand characteristics to drought-induced mortality in three southwestern piñon-juniper woodlands. *Ecological Applications* 19:1223-1230.
- Forest Ecosystem Restoration Analysis Project [ForestERA]. 2004. ForestERA data layer overview. Northern Arizona University. Available from: http://forestera.nau.edu/data_overview.htm.
- Forest Ecosystem Restoration Analysis Project [ForestERA]. 2005. ForestERA Mexican spotted owl habitat layer—overview. Northern Arizona University. Available from: http://forestera.nau.edu/data_overview.htm.
- Forest Guardians, unpublished technical report, 2004.
- Forsman, E.D. 1976. A preliminary investigation of the spotted owl in Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon, USA.
- Forsman, E.D. 1981. Molt of the spotted owl. *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 Research Station, Portland, Oregon, USA.
- 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., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (eds.). 1996. Demography of the northern spotted owl. *Studies in Avian Biology* 17:1-122.
- 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., 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.
- Foster, C.C., E.D. Forsman, E.C. Meslow, G.S. Miller, J.A. Reid, F.F. Wagner, A.B. Carey, and J.B. Lint. 1992. Survival and reproduction of radio-marked adult spotted owls. *Journal of Wildlife Management* 56:91-95.
- Franklin, A.B.. 2001. Population regulation in northern spotted owls: theoretical implications for management. Pp. 815-827 in D.R. McCullough and R.H. Barrett (eds.), *Wildlife 2001: populations*. Elsevier Applied Science, London, United Kingdom.
- 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.
- Franklin, A.B., and R.J. Gutiérrez. 2002. Spotted owls, forest fragmentation, and forest heterogeneity. *Studies in Avian Biology* 25:203-220.
- Franklin, A.B., R.J. Gutiérrez, 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* 54:1-54.
- Franklin, A.B., J.P. Ward, Jr., R.J. Gutierrez, and G.I. Gould, Jr. 1990. Density of northern spotted owls in northwest California. *Journal of Wildlife Management* 54:1-10.

- Fraterrigo, J.M., and J.A. Wiens. 2005. Bird communities of the Colorado Rocky Mountains along a gradient of exurban development. *Landscape and Urban Planning* 71:263-275.
- Frid, A., and L.M. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6:11. Available from: <http://www.consecol.org/vol6/iss1/art11>.
- Fulé P.Z., J.E. Crouse, A.E. Cocke, M.M. Moore, and W.W. Covington. 2004. Changes in canopy fuels and potential fire behavior 1880-2040: Grand Canyon, Arizona. *Ecological Modelling* 175:231-248.
- Fulé, P.Z., J.E. Crouse, T.A. Heinlein, M.M. Moore, W.W. Covington, and G. Verkamp. 2003a. Mixed-severity fire regime in a high-elevation forest: Grand Canyon, Arizona. *Landscape Ecology* 18:465-486.
- Fulé, P.Z., T.A. Heinlein, W.W. Covington, and M.M. Moore. 2003b. Assessing fire regimes on Grand Canyon landscapes with fire scar and fire record data. *International Journal of Wildland Fire* 12:129-145.
- Fulé, P.Z., J.E. Korb, and R. Wu. 2009. Changes in forest structure of a mixed-conifer forest, southwestern Colorado, USA. *Forest Ecology and Management* 258:1200-1210.
- Fulé, P.Z., M.M. Moore, and W.W. Covington. 1997. Determining reference conditions for ecosystem management in southwestern ponderosa pine forests. *Ecological Applications* 7:895-908.
- Funk, W.C., E.D. Forsman, T.D. Mullins, and S.M. Haig. 2007. Microsatellite loci for distinguishing spotted owls (*Strix occidentalis*), barred owls (*Strix varia*), and their hybrids. *Molecular Ecology Notes* 7:284-286.
- Funk, W.C., E.D. Forsman, T.D. Mullins, and S.M. Haig. 2008. Introgression and dispersal among spotted owl (*Strix occidentalis*) subspecies. *Evolutionary Applications* 1:161-171.
- Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Pp. 123-129 in Conference proceedings—Fire effects on rare and endangered species and habitats. November 13-16, 1995; Coeur d’Alene, Idaho, USA. International Association of Wildland Fire.
- Ganey, J.L. 1988. Distribution and habitat ecology of Mexican spotted owls in Arizona. M.S. Thesis, Northern Arizona University, Flagstaff, USA.
- Ganey, J.L. 1990. Calling behavior of spotted owls in northern Arizona. *Condor* 92:485-490.
- Ganey, J.L. 1991. Developing and testing a predictive model for Mexican spotted owl habitat. Dissertation, Northern Arizona University. Flagstaff, Arizona, USA.
- Ganey, J.L. 1992. Food habits of Mexican spotted owls in Arizona. *Wilson Bulletin* 104:321-326.

- Ganey, J.L. 1998. The spotted owl. Pp. 170-174 in R.L. Glinski (ed.), *The raptors of Arizona*. University of Arizona Press, Tucson, USA.
- Ganey, J.L. 2004. Thermal regimes of Mexican spotted owl nest stands. *Southwestern Naturalist* 49:478-486.
- Ganey, J.L., M.E. Alderson, R.P. Balda, and D.R. Patton. 1990. Developing a large-scale model for Mexican spotted owl habitat. Pp. 182-190 in P.R. Krausman and N.S. Smith (eds.), *Managing wildlife in the Southwest*. Arizona Chapter, The Wildlife Society, Phoenix, Arizona, USA.
- Ganey, J.L., and R.P. Balda. 1989a. Distribution and habitat use of Mexican spotted owls in Arizona. *Condor* 91:355-361.
- Ganey, J.L., and R.P. Balda. 1989b. Home range characteristics of spotted owls in northern Arizona. *Journal of Wildlife Management* 53:1159-1165.
- Ganey, J.L., and R.P. Balda. 1994. Habitat selection by Mexican spotted owls in northern Arizona. *Auk* 111:162-169.
- Ganey, J.L., R.P. Balda, and R.M. King. 1993. Metabolic rate and evaporative water loss of Mexican spotted and great horned owls. *Wilson Bulletin* 105:645-656.
- Ganey, J.L., and M.A. Benoit. 2002. Using terrestrial ecosystem survey data to identify potential habitat for the Mexican spotted owls on National Forest System lands: a pilot study. USDA Forest Service, General Technical Report, RMRS-GTR-86, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Ganey, J.L., and W.M. Block. 2005a. Dietary overlap between sympatric Mexican spotted and great horned owls in Arizona. USDA Forest Service, General Technical Report, RMRS-RP-57-WWW, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Ganey, J.L., and W.M. Block. 2005b. Winter movements and range use of radio-marked Mexican spotted owls: are current management recommendations adequate? USDA Forest Service, General Technical Report, RMRS-GTR-148-WWW, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Ganey, J.L., W.M. Block, and S.H. Ackers. 2003. Structural characteristics of forest stands within home ranges of Mexican spotted owls in Arizona and New Mexico. *Western Journal of Applied Forestry* 18:189-198.
- Ganey, J.L., W.M. Block, J.K. Dwyer, B.E. Strohmeier, and J.S. Jenness. 1998. Dispersal movements and survival rates of juvenile Mexican Spotted Owls in northern Arizona. *Wilson Bulletin* 110:206-217.

- Ganey, J.L., W.M. Block, J.S. Jenness, and R.A. Wilson. 1997. Comparative habitat use of sympatric Mexican spotted and great horned owls. *Journal of Wildlife Research* 2:115-123.
- Ganey, J.L., W.M. Block, J.S. Jenness, and R.A. Wilson. 1999. Mexican spotted owl home range and habitat use in pine-oak forest: implications for forest management. *Forest Science* 45:127-135.
- Ganey, J.L., W.M. Block, and R.M. King. 2000. Roost sites of radio-marked Mexican spotted owls in Arizona and New Mexico: sources of variability and descriptive characteristics. *Journal of Raptor Research* 34:270-278.
- Ganey, J.L., W.M. Block, J.P. Ward, Jr., and B.E. Strohmeier. 2005. Home range, habitat use, and vital rates of Mexican spotted owls in two different environments. *Southwestern Naturalist* 50:323-333.
- Ganey, J.L., and J.A. Dick. 1995. Chapter 4: Habitat relationships of Mexican spotted owls: current knowledge. Pp. 1-42 *in* Recovery plan for the Mexican spotted owl (*Strix occidentalis lucida*), Volume II. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA. Available from: <http://mso.fws.gov/recovery-plan.htm>.
- Ganey, J.L., R.B. Duncan, and W.M. Block. 1992. Use of oak and associated woodlands by Mexican spotted owls in Arizona. Pp. 1-25 *in* P.F. Ffoliott, G.J. Gottfried, D.A. Bennett, V.M. Hernandez, C.A. Ortega-Rubio, and R.H. Hamre (eds.), Ecology and management of oak and associated woodlands. USDA Forest Service, General Technical Report, RM-218, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Ganey, J.L., A. Telles, and M.A. Ramsey. 2008. Status and ecology of Mexican spotted owls in the Gila Region. *in* Natural history of the Gila, a symposium. *New Mexico Journal of Botany*, Special Issue 1:34-48.
- Ganey, J.L., and S.C. Vojta. 2005. Changes in snag populations in northern Arizona mixed-conifer and ponderosa pine forests, 1997-2002. *Forest Science* 51:396-405.
- Ganey, J.L., and S.C. Vojta. Tree mortality in drought-stressed mixed-conifer and ponderosa pine forests, Arizona. *Forest Ecology and Management* 261:162-168.
- Ganey, J.L., G.C. White, D.C. Bowden, and A.B. Franklin. 2004. Evaluating methods for monitoring populations of Mexican spotted owls: a case study. Pp. 337-385 *in* W.L. Thompson (ed.), Sampling rare and elusive species: concepts, designs, and techniques for estimating population parameters. Island Press, Washington, DC, USA.
- Galbraith, H., and J. Price. 2009. A framework for categorizing the relative vulnerability of threatened and endangered species to climate change (external review draft). U.S. Environmental Protection Agency, EPA/600/R-09/011, February 2009, Washington, DC.

- Garfin, G.M., J.K. Eischeid, M. Lenart, K.L. Cole., K. Ironside, and N. Cobb. 2010. Downscaling climate projections in topographically diverse landscapes of the Colorado Plateau in the arid Southwestern United States. Pp, 21-44 *in* C. Van Riper III, B. F. Wakeling and T.D. Sisk (eds.), *The Colorado Plateau IV: Proceedings of the 9th Biennial Conference on Colorado Plateau Research*, University of Arizona Press.
- Getz, L.L. 1985. *Microtus* habitats. Pp. 286-309 *in* R.H. Tamarin (ed.), *Biology of Microtus*. American Society of Mammology, Special Publication No. 8.
- Gitay, H., A. Suárez, and R.T. Watson. 2002. *Climate change and biodiversity*. Intergovernmental Panel on Climate Change, Geneva. United Nations Convention on Biological Diversity.
- Gobierno del Estado de Aguascalientes. 1998. Declaratoria del Área Natural Protegida Sierra Fría de Jurisdicción Estatal. [On-line]: <<http://www.aguascalientes.gob.mx/imaec/recursos/bioticos/danpsf.aspx>>. Página visitada el 8 de octubre de 2010.
- Gobierno del Estado de Nuevo León. 2000. Declaratoria de 23 Áreas Naturales Protegidas con el carácter de Zonas Sujetas a Conservación Ecológica del Estado de Nuevo León. Periódico Oficial. 21 de noviembre del 2000. Monterrey, Nuevo León, México.
- Gobierno Federal. 2009. Decreto por el que se declara como área natural protegida, con el carácter de reserva de la biósfera, la zona conocida como Janos localizada en el Municipio de Janos, en el Estado de Chihuahua. Diario Oficial de la Federación. Martes 8 de diciembre de 2009. México. Págs, 9 – 19.
- Gotelli, N.J., and G.L. Entsminger. 2001. *EcoSim: null models software for ecology*. Version 7.0. Acquired Intelligence Inc. & Kesey-Bear. Available from: <http://homepages.together.net/~gentsmi/ecosim.htm>.
- Grissino-Mayer, H.D., C.H. Baisan, and T.W. Swetnam. 1995a. Fire history and stand age structure analyses of the mixed-conifer and spruce-fir forests of the Pinaleno Mountains, southeastern Arizona. Final Report, USDA Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Grissino-Mayer, H.D., C.H. Baisan, and T.W. Swetnam. 1995b. Fire history in the Pinaleno Mountains of southeastern Arizona: effects of human-related disturbances. Pp. 399-407 *in* DeBano, L.H., P.H. Ffolliott, A. Ortega-Rubio, G.J. Gottfried, R.H. Hamre, and C.B. Edminster (technical coordinators), *Biodiversity and management of the Madrean archipelago: the sky islands of southwestern United States and northwestern Mexico*. September 19-23, 1994; Tucson, Arizona. USDA Forest Service, General Technical Report, RM-GTR-264, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Grissino-Mayer, H.D., W.H. Romme, M.L. Floyd, D. Hanna. 2004. Climatic and human influences on fire regimes in the southern San Juan Mountains, Colorado, USA. *Ecology* 85: 1708-1724.

- Grossman, S.R., S.J. Hannon, and A. Sánchez-Azofeifa. 2008. Responses of great horned owls (*Bubo virginianus*), barred owls (*Strix varia*), and northern saw-whet owls (*Aegolius acadicus*) to forest cover and configuration in an agricultural landscape in Alberta, Canada. *Canadian Journal of Zoology* 86:1165-1172.
- Grubb, T.G., J.L. Ganey, and S.R. Masek. 1997. Canopy closure around nest sites of Mexican spotted owls in northcentral Arizona. *Journal of Wildlife Management* 61:336-342.
- Guido, Z., D. Ferguson, and G. Garfin. 2008. Putting knowledge into action: tapping the institutional knowledge of U.S. Fish and Wildlife Service Region 2 and 8 to address climate change. CLIMAS, University of Arizona, Tucson, USA.
- Gutiérrez, R.J. 1985. An overview of recent research on the spotted owl. Pp. 39-49 in R.J. Gutiérrez and A.B. Carey (technical editors), *Ecology and management of the spotted owl in the Pacific Northwest*. USDA Forest Service, General Technical Report, PNW-GTR-185, Pacific Northwest Research Station, Portland, Oregon, USA.
- Gutiérrez, R.J. 1989. Hematazoa from the spotted owl. *Journal of Wildlife Diseases* 24:614-618.
- Gutiérrez, R.J., M. Cody, S. Courtney, and A.B. Franklin. 2007. The invasion of barred owls and its potential effect on the spotted owl: a conservation conundrum. *Biological Invasions* 9:181-196.
- Gutiérrez, R., M. Cody, S. Courtney, and D. Kennedy. 2004. Assessment of the potential threat of the northern barred owl. Chapter 7. Pp. 1-51 in S.P. Courtney, J.A. Blakesely, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski, *Scientific evaluation of the northern spotted owl*. Sustainable Ecosystems Institute, Portland, Oregon, USA.
- Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted owl (*Strix occidentalis*). *The birds of North America*, number 179. The Academy of Natural Sciences Philadelphia and the American Ornithologists Union, Washington, DC, USA.
- Gutiérrez, R.J., A.B. Franklin, W. LaHaye, V.J. Meretsky, and J.P. Ward. 1985. Juvenile spotted owl dispersal in northwestern California: preliminary results. Pp. 39-49 in R.J. Gutiérrez and A.B. Carey (eds.), *Ecology and management of spotted owls in the Pacific Northwest*. USDA Forest Service, General Technical Report, PNW-185, Pacific Northwest Research Station, Portland, Oregon, USA.
- Gutiérrez, R.J., and S. Harrison. 1996. Applying metapopulation theory to spotted owl management: a history and critique. Pp. 167-185 in D.R. McCullough (ed.), *Metapopulations and wildlife conservation*. Island Press, Washington, DC, USA. 429 pp.
- Gutiérrez, R.J., C.A. May, M.L. Petersburg, and M.E. Seamans. 2003. Temporal and spatial variation in the demographic rates of two Mexican spotted owl populations. Final report. USDA Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona, USA.

- Gutiérrez, R.J., M.E. Seamans, and M.Z. Peery. 1996. Intermountain movement by Mexican spotted owls (*Strix occidentalis lucida*). *Great Basin Naturalist* 56:87-89.
- Gutiérrez, R.J., J. Verner, K.S. McKelvey, B.R. Noon, G.N. Steger, D.R. Call, W.S. LaHaye, B.B. Bingham, and J.S. Senser. 1992. Habitat relations of the California spotted owl. Pp. 79-98 in J. Verner, K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould, Jr., and T.W. Beck, *The California spotted owl: a technical assessment of its current status*. USDA Forest Service, General Technical Report, PSW-GTR-133, Pacific Northwest Research Station, Portland, Oregon, USA.
- Haig, S.M., T.D. Mullins, and E.D. Forsman. 2004a. Subspecific relationships and genetic structure in the spotted owl. *Conservation Genetics* 5:683-705.
- Haig, S. M., T. D. Mullins, E. D. Forsman, P. W. Trail, and L. Wennerberg. 2004b. Genetic identification of spotted owls, barred owls, and their hybrids: legal implications of hybrid identity. *Conservation Biology* 18:1347-1357.
- Haig, S.M., R.S. Wagner, E.D. Forsman, and T.D. Mullins. 2001. Geographic variation and genetic structure in spotted owls. *Conservation Genetics* 2:25-40.
- Hall, L.S., P.R. Krausman, and M.L. Morrison. 1997. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin* 25:173-182.
- Hamer, T.E., E.D. Forsman, A.D. Fuchs, and M.L. Walters. 1994. Hybridization between barred and spotted owls. *Auk* 111:487-492.
- 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. *Condor* 109:750-768.
- 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.
- Hane, M., J. Mowdy, and R. Smith. 2007. Cliff nesting by northern spotted owls (*Strix occidentalis caurina*) in Oregon. *Journal of Raptor Research* 41:66-68.
- Hanks, J.P., E.L. Fitzhugh, and S.R. Hanks. 1983. A habitat type classification system for ponderosa pine forests of northern Arizona. USDA Forest Service, General Technical Report, RM-97, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Hannah, L., and T.E. Lovejoy. 2003. Climate change and biodiversity: synergistic impacts. *Advances in Applied Biodiversity Science* 4:1-123.
- Hansen, A.J., R. Rasker, B. Maxwell, J.J. Rotella, J.D. Johnson, A.W. Parmenter, U. Langner, W.B. Cohen, R.L. Lawrence, and M.P.V. Kraska. 2002. Ecological causes and consequences of demographic change in the New West. *BioScience* 52(2):151-162.

- Hansen, A.J., and R. DeFries. 2007. Ecological mechanisms linking protected areas to surrounding lands. *Ecological Applications* 17:974-988.
- Hanski, I. 1994. A practical model of metapopulation dynamics. *Journal of Animal Ecology* 63:151-162.
- Hanski, I. 1998. Metapopulation dynamics. *Nature* 396:41-49.
- Hanson, P.J., and J.F. Weltzin. 2000. Drought disturbance from climate change: response of United States forests. *The Science of the Total Environment* 262:205-220.
- Harris, J.A., R.J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. *Restoration Ecology* 14:170-176.
- Hathcock, C.D., and T.K. Haarmann. 2008. Development of a predictive model for habitat of the Mexican spotted owl in northern New Mexico. *Southwestern Naturalist* 53:34-38.
- Healthy Forests Restoration Act of 2003 [HFRA]. 2003. House of Representatives 1904:1-29.
- Heckmann, K.E., P.N. Manley, and M.D. Schlesinger. 2008. Ecological integrity of remnant montane forests along an urban gradient in the Sierra Nevada. *Forest Ecology and Management* 255:2453-2466.
- Hedwall, S.J., C.L. Chambers, and S.S. Rosenstock. 2006. Red squirrel use of dwarf mistletoe-induced witches' brooms in Douglas-fir. *Journal of Wildlife Management* 70:1142-1147.
- Hedwall, S.J., and R.L. Mathiasen. 2006. Wildlife use of Douglas-fir dwarf mistletoe witches' brooms in the Southwest. *Western North American Naturalist* 66:450-455.
- Heinlein, T.A., M.M. Moore, P.Z. Fule', W.W. Covington. 2005. Fire history of two ponderosa pine-mixed conifer sites: San Francisco Peaks, Arizona, USA. *International Journal of Wildland Fire* 14:307-320.
- Helms, J.A. (ed.). 1998. *The Dictionary of Forestry*. Society of American Foresters, Bethesda, Maryland, USA.
- Herter, D.R., and L.L. Hicks. 2000. Barred owl and spotted owl populations in central Washington. *Journal of Raptor Research* 34:279-286.
- Hirons, G.M. 1985. The importance of body reserves for successful reproduction in the tawny owl (*Strix aluco*). *Journal of Zoology* 1:1-20.
- Hobbs, R.J., S. Arico, J. Aronson, J.S. Baron, P. Bridgewater, V.A. Cramer, P.R. Epstein, J.J. Ewel, C.A. Klink, and A.E. Lugo. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15:1-7.
- Hodgson, A. 1996. Dispersal and habitat use of Mexican spotted owls in New Mexico. M.S. Thesis, University of Nevada, Reno, USA.

- Hogg, E.H., J.P. Brandt, and M. Michaellian. 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. *Canadian Journal of Forest Research* 38:1373-1384.
- Holechek, J.L., R.D. Pieper, C.H. Herbel. 2001. *Range Management Principles and Practices*. Fourth edition. Prentice Hall, New Jersey, USA.
- Holling, C.S., and G.K. Meffe. 1996. Command and control and the pathology of natural resource management. *Conservation Biology* 10:328-337.
- Holt, D.W., R. Berkley, C. Deppe, P.L. Enríquez Rocha, P.D. Olsen, J.L. Petersen, J.L. Rangel Salazar, K.P. Segars, and K.L. Wood. 1999. Species accounts: family Strigidae. Pp. 152-242 in J. del Hoyo, A. Elliott, and J. Sargatal (eds.), *Handbook of the birds of the world*. Volume 5, barn-owls to hummingbirds. Lynx Edicions, Barcelona, Spain.
- Houston, C.S., D.G Smith, and C. Rohner. 1998. Great horned owls (*Bubo virginianus*). The birds of North America, number 372. The Academy of Natural Sciences Philadelphia and The American Ornithologists Union, Washington, DC, USA.
- Howe, R.W., G.J. Davis., and V. Mosca. 1991. The demographic significance of “sink” populations. *Biological Conservation* 57:239-255.
- Howell, S.N.G., and S. Webb. 1995. *A Guide to the Birds of Mexico and Northern Central America*. Oxford University Press, New York, USA.
- Hull, J.M., J.J. Keane, L. Tell, H.B. Ernest. 2010. West Nile antibody surveillance in three Sierra Nevada raptors of conservation concern. *Condor* 112:168-172.
- Hunter, J.E., R.J. Gutiérrez, A.B. Franklin, and D. Olson. 1994. Ectoparasites of the spotted owl. *Journal of Raptor Research* 28:232-235.
- INE-SEMARNAP. 2000. Programa de Manejo. Reserva de la Biósfera Montes Azules, México. México. 255 pp.
- INE-SEMARNAT. 2000. Programa de Manejo. Reserva de la Biósfera Sierra de Manantlán, México. México. 203 pp.
- IPCC 2007. Fourth Assessment Report of the Intergovernmental Panel on Climate Change. November 17, 2007.
- Irwin, L., and J.W. Thomas. 2002. Policy conflicts relative to managing fire-adapted forests on Federal lands: the case of the northern spotted owl. Pp. 96-107 in S.A. Fitzgerald (ed.), *Fire in Oregon’s forests: risks, effects, and treatment actions*. Oregon Forest Resource Institute. Salem, Oregon, USA.

- Irwin, L.L., T.L. Fleming, and J. Beebe. 2004. Are spotted owl populations sustainable in fire-prone forests? *Journal of Sustainable Forestry* 18:1-28.
- Ishak, H.D., J.P. Dumbacher, N.L. Anderson, J.J. Keane, G. Valkiunas, S.M. Haig, L.A. Tell, and R.N.M. Seghal. 2008. [Online.] Blood parasites in owls with conservation implications for the spotted owl (*Strix occidentalis*). *PLOS ONE* 3(5):e2304. doi:10.1371/journal/pone.0002304.
- Jackson, J., J.T. Ball, and M.R. Rose. 1990. Assessment of the salinity tolerance of eight Sonoran Desert riparian trees and shrubs. Desert Research Institute, Reno, Nevada, USA.
- James, M.A. 2005. Integrating forest restoration treatments with Mexican spotted owl habitat needs. Working Papers in Southwestern Ponderosa Pine Forest Restoration 14. Ecological Restoration Institute, Northern Arizona University. Flagstaff, USA. 9 pp.
- Jenness, J.S. 2000. The effects of fire on Mexican spotted owls in Arizona and New Mexico. M.S. Thesis, Northern Arizona University, Flagstaff, USA. Available from: <http://www.jennessent.com/Literature/Thesis/>.
- Jenness, J.S., P. Beier, and J.L. Ganey. 2004. Associations between forest fire and Mexican spotted owls. *Forest Science*. 50:765-772.
- Johnsgard, P.A. 1988. North American owls: biology and natural history. Smithsonian Institution Press, Washington, DC, USA.
- Johnson, C.L. 1997. Distribution, habitat, and ecology of the Mexican spotted owl in Colorado. M.S. Thesis, University of Northern Colorado, Greeley, USA.
- Johnson, C.L., and R.T. Reynolds. 2002. Responses of Mexican spotted owls to low-flying military jet aircraft. USDA Forest Service, Research Note, RMRS-RN-12, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Johnson, J.A., and T.H. Johnson. 1985. The status of the spotted owl in northern New Mexico. Unpublished Report, New Mexico Department of Game and Fish, Santa Fe, USA. 39 pp.
- Johnson, J.A., and T.H. Johnson. 1988. Timber type model of spotted owl habitat in northern New Mexico. Unpublished Report, New Mexico Department of Game and Fish, Contract 516.6-75-18, Santa Fe, USA. 23 pp.
- Johnson, T.H. 1990. Revised timber type model of spotted owl habitat in northern New Mexico. Unpublished Report, Santa Fe National Forest, PO 43-8379-9-0664, New Mexico, USA. 10 pp.
- Johnson, T.H. 1993. Topographic model of potential spotted owl habitat in New Mexico. Unpublished Report, New Mexico Department of Game and Fish, Contract 80-516.6-56, Santa Fe, USA. 18 pp.

- Johnson, T.H. 1995. Fire management in spotted owl habitat in Bandelier National Monument. Unpublished Report, Bandelier National Monument, PO 1443PX712094121, . 8 pp.
- Johnson, T.H. 1996. Topographic model of potential spotted owl habitat in northern New Mexico. Unpublished Report, USDA Forest Service and Los Alamos National Laboratory, 10 pp.
- Johnson, T.H. 1998. Topographic-Landsat model of suitable spotted owl habitat around Los Alamos National Laboratory. Unpublished Report, Los Alamos National Laboratory, Agreement C-6832, 10 pp.
- Johnson, T.H. 2000. Status of the spotted owl in the Jemez Mountains, New Mexico. Unpublished Report, U.S. Geological Survey, PO 00CRSA0719. 7 pp.
- Johnson, T.H. 2001. Test of the low resolution New Mexico topographic spotted owl habitat model in the southwestern US. Unpublished Report, USDI Fish and Wildlife Service, PO 22420-9-0245. 6 pp.
- Johnson, T.H. 2003. Geophysical spotted owl habitat model for the southwestern US. Unpublished Report, U.S. Geological Survey, PO 00CRSA0718. 15 pp.
- Joyce, L., J. Aber, S. McNulty, V. Dale, A. Hansen, L. Irland, R. Neilson, and K. Skog. 2001. Potential consequences of climate variability and change for the forests of the United States. Pp. 489-522 *in* National Assessment Synthesis Team, Climate Change Impacts on the United States: the potential consequences of climate variability and change, report for the U.S. Global Change Research Program. Cambridge University Press. Cambridge, United Kingdom.
- Joyner, P.H., S. Kelly, A.A. Shreve, S.E. Snead, J.M. Sleeman, and D.A. Petit. 2006. West Nile virus in raptors from Virginia during 2003: clinical diagnosis and epidemiologic findings. *Journal of Wildlife Disease* 42:335-344.
- Kaib, J.M., C.H. Baisan, H. Grissino-Mayer, and T.W. Swetnam. 1996. Fire history in the pine-oak forests and adjacent grasslands of the Chiricahua Mountains of Arizona. Pp. 253-264 *in* P.F. Ffolliott, L.F. DeBano, M.B. Baker, Jr., G.J. Gottfried, G. Solis-Garza, C.B. Edminster, D.G. Neary, L.S. Allen, and R.H. Hamre (technical coordinators), Proceedings of the symposium on effects of fire on Madrean province ecosystems; March 11-14, 1996; Tucson, Arizona; USDA Forest Service, General Technical Report, RM-289, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Karr, J.R., J.J. Rhodes, G.W. Minshall, F.R. Hauer, R.L. Bechta, C.A. Frissell, and D.A. Perry. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American West. *BioScience* 2004 54:1029-1033.

- Kauffman, J.B., and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. *Journal of Range Management* 37:430-438.
- Kauffman, J.B. W.C. Krueger, and M. Vavra. 1983. Effects of late season cattle grazing on riparian plant communities. *Journal of Range Management* 36:685-691.
- Kaufmann, M.R., R.T. Graham, D.A. Boyce, W.H. Moir, L. Perry, R.T. Reynolds, R.L. Bassett, P. Mehlhop, C.B. Edminster, W.M. Block, and P.S. Corn. 1994. An ecological basis for ecosystem management. USDA Forest Service, General Technical Report, RM-246, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Kaufmann, M.R., L.S. Huckaby, C.M. Regan, and J. Popp. 1998. Forest reference conditions for ecosystem management in the Sacramento Mountains, New Mexico. USDA Forest Service, General Technical Report, RMRS-GTR-19, Rocky Mountain Research Station, Fort Collins, Colorado, USA.
- Keitt, T.H., A.B. Franklin, and D.L. Urban. 1995. Landscape analysis and metapopulation structure. Chapter 3. Pp. 1-16 in W.M. Block, F. Clemente, J.F. Cully, J.L. Dick, Jr., A.B. Franklin, J.L. Ganey, F.P. Howe, W.H. Moir, S.L. Spangle, S.E. Rinkevich, D.L. Urban, R. Vahle, J.P. Ward, Jr., and G.C. White, Recovery plan for the Mexican Spotted Owl (*Strix occidentalis lucida*), vol. II—technical supporting information. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA. Available from: <http://mso.fws.gov/recovery-plan.htm>.
- Keitt, T., D.L. Urban, and B.T. Milne. 1997. Detecting critical scales in fragmented landscapes. *Conservation Ecology* (online) 1(1):4. Available from: <http://www.consecol.org/vol1/iss1/art4/>.
- Kelly, E.G. 2001. The range expansion of the northern barred owl: an evaluation of the impact on spotted owls. M.S. Thesis, Oregon State University, Corvallis, USA.
- Kelly, E.G., and E.D. Forsman. 2004. Recent records of hybridization between barred (*Strix varia*) and northern spotted owls (*S. o. caurina*). *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.
- Kennedy, C.E. 1977. Wildlife conflicts in riparian management: water. Pp. 52-58 in R.R. Johnson and D.A. Jones (eds.), Importance, preservation and management of riparian habitat: a symposium. USDA Forest Service, General Technical Report, RM-43, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Kernohan, B.J., R.A. Gitzen, and J.J. Millspaugh. 2001. Analysis of animal space use and movements. Pp. 126-166 in J.J. Millspaugh and J.M. Marzluff (eds.), Radio tracking and animal populations. Academic Press, San Diego, California, USA.

- Kertell, K. 1977. The spotted owl at Zion National Park, Utah. *Western Birds* 8:147-150.
- Knight, R.L., and K.J. Gutzwiller (eds.). 1995. *Wildlife and Recreationists: Coexistence through Management and Research*. Island Press, Washington, DC, USA.
- Komar, N., R. Lanciotti, R. Bowen, S. Langevin, and M. Bunning. 2002. Detection of West Nile Virus in oral and cloacal swabs collected from bird carcasses. *Emerging Infectious Diseases* 8:741-742.
- Komar, N., S. Langevin, S. Hinten, N. Nemeth, W. Edwards, D. Hettler, B. Davis, R. Bowen, and M. Binning. 2003. Experimental infection of North American birds with the New York 1990 strain of West Nile virus. *Emerging Infectious Diseases* 9:311-322.
- Koprowski, J.L., M.A. Alanen, and A.M. Lynch. 2005. Nowhere to run and nowhere to hide: response of endemic Mt. Graham red squirrels to catastrophic forest damage. *Biological Conservation* 126:491-498.
- Kothmann, M. 2009. Grazing methods: a viewpoint. *Rangelands* 31(5):5-10.
- Krausmann, W.J., T.C. Mellin, K.B. Clark, and C.F. Enquist. Undated. Assessing gross changes within vegetation types associated with Mexican spotted owl habitat in New Mexico and Arizona. Unpublished Report, USDA Forest Service, Southwestern Region. 24 pp.
- Kroel, K.W., and P.J. Zwank. 1992. Renesting of Mexican spotted owl in southern New Mexico. *Journal of Raptor Research* 26:267-268.
- Kroll, A.J., T.L. Fleming, and L.L. Irwin. 2010. Site occupancy dynamics of northern spotted owls in the eastern Cascades, Washington, USA, 1990-2003. *Journal of Wildlife Management* 74:1264-1274.
- Krueger, W.C. 1995. Managing ungulates to allow recovery of riparian vegetation. Pp. 160-165 in W.D. Edge and S.L. Olson-Edge (eds.), *Proceedings—Sustaining rangeland ecosystem symposium*. Oregon State University, Corvallis, USA.
- Krueper, D.J. 1996. Effects of livestock management on Southwestern riparian ecosystems. Pp. 281-301 in D.W. Shaw and D.M. Finch (eds.), *Desired future conditions for southwestern riparian ecosystems: bringing interests and concerns together*. USDA Forest Service, General Technical Report, RM-272, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Küchler, A.W. 1964. *The potential natural vegetation of the conterminous United States*. American Geographic Society Special Publication 361.
- Kuntz, W.A. 1998. *Vocal variation in the Mexican spotted owl (Strix occidentalis lucida)*. M.S. Thesis, University of Nevada, Reno, USA.

- Kuntz, W.A., and P.B. Stacey. 1997. Preliminary investigation of vocal variation in the Mexican spotted owl (*Strix occidentalis lucida*): would vocal analysis of the four-note location call be a useful field tool for individual identification? Pp. 562-568 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls (eds.), *Biology and conservation of owls of the northern hemisphere*. USDA Forest Service, General Technical Report, GTR-NC-190, North Central Forest Experiment Station, St. Paul, Minnesota, USA.
- Kyle, S.C., and W.M. Block. 2000. Effects of wildfire severity on small mammals in northern Arizona ponderosa pine forests. Pp. 163-168 in W.K. Moser and C.F. Moser (eds.), *Fire and forest ecology: innovative silviculture and vegetation management*. Tall Timbers fire ecology conference proceedings 21. Tall Timbers Research Station, Tallahassee, Florida, USA.
- LaHaye, W.S. 1997. Four young fledged by a pair of California spotted owls. *Western Birds* 28:108-109.
- LaHaye, W.S., R.J. Gutiérrez, and H.R. Akçakaya. 1994. Spotted owl metapopulation dynamics in southern California. *Journal of Animal Ecology* 63:775-785.
- LaHaye, W.S., R.J. Gutiérrez, and J.R. Dunk. 2001. Natal dispersal of the spotted owl in southern California: dispersal profile of an insular population. *Condor* 103:691-700.
- LaHaye, W.S., G.S. Zimmerman, and R.J. Gutiérrez. 2004. Temporal variation in the vital rates of an insular population of spotted owls (*Strix occidentalis occidentalis*): contrasting effects of weather. *Auk* 121:1056-1069.
- Laidig, K.J., and D.S. Dobkin. 1995. Spatial overlap and habitat associations of barred owls and great horned owls in southern New Jersey. *Journal of Raptor Research* 29(3):151-157.
- Lamberson, R.H., R. McKelvey, B.R. Noon, and C. Voss. 1992. A dynamic analysis of northern spotted owl viability in a fragmented landscape. *Conservation Biology* 6:505-512.
- Lande, R. 1987. Extinction thresholds in demographic models of territorial populations. *American Naturalist* 130:624-635.
- Lande, R. 1988. Demographic models of the northern spotted owl (*Strix occidentalis caurina*). *Oecologia* 75:601-607.
- Lavier, R.A. 2006. Effects of weather and habitat on site occupancy of Mexican spotted owls in the Sacramento Mountains, New Mexico. M.S. Thesis, Colorado State University, Fort Collins, USA.
- Laymon, S.A. 1988. The ecology of the spotted owl in the central Sierra Nevada, California. Dissertation, University of California, Berkeley, USA.

- Laymon, S.A. 1989. Altitudinal migration movements of spotted owls in the Sierra Nevada, California. *Condor* 91:837-841.
- Laymon, S.A. 1991. Diurnal foraging by spotted owls. *Wilson Bulletin* 103:138-140.
- Layser, E.F., and G.H. Schubert. 1979. Preliminary classification for the coniferous forest and woodland series of Arizona and New Mexico. USDA Forest Service, Research Paper, RM-208, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Lee, D.C., and L.L. Irwin. 2005. Assessing risks to spotted owls from forest thinning in fire-adapted forests of the western United States. *Forest Ecology and Management* 211:191-209.
- Leonard, S., G. Kinch, V. Elsbernd, M. Boreman, S. Swanson. 1997. Riparian area management: grazing management for riparian-wetland areas. USDI Bureau of Land Management, Technical Reference 1737-14, Bureau of Land Management National Applied Science Center, Denver, Colorado, USA.
- Leskiw, T., and R.J. Gutiérrez. 1998. Possible predation of a spotted owl by a barred owl. *Western Birds* 29:225-226.
- Levins, R. 1970. Extinction. Pp. 77-107 in M. Gerstenhaber (ed.), *Some mathematical questions in biology*. American Mathematical Society. Providence, Rhode Island, USA.
- Levy, S. 2004. Native incursions: avian range expansions imperil threatened species. *BioScience* 54: 94-98.
- Lightle, P.C., S.R. Andrews. 1968. Red rot in residual ponderosa pine stands on the Navajo Indian Reservation. USDA Forest Service, Research Paper, RM-37, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Ligon, J.S. 1926. Habits of the spotted owl (*Syrnium occidentale*). *Auk* 43:421-429.
- 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. *The American Midland Naturalist* 161:323-349.
- Livezey, K.B., and T.L. Fleming. 2007. Effects of barred owl on spotted owls: the need for more than incidental detections and correlational analysis. *Journal of Raptor Research* 41:319-325.
- Lovejoy, T.E., and L. Hannah. 2005. *Climate Change and Biodiversity*. Yale University Press, New Haven, Connecticut, USA.

- Lundquist, J.E., and Ward, J.P., Jr. 2005. Impacts of diseases and other disturbances on non-timber forest resources: A case study involving small mammals. pp. 105-112 in: Lundquist, J.E., Hamelin, R.C, eds. Forest Pathology: From Genes to Landscapes. American Phytopathological Society Press, St. Paul, MN, USA.
- Lynch A.M. 2004. Fate and characteristics of *Picea* damaged by *Elatobium abietinum* (Walker) (Homoptera: Aphididae) in the White Mountains of Arizona. Western North American Naturalist 64: 7-17.
- Lynch A.M. 2007. *Nepytia janetae* damage in the Sacramento Mountains, New Mexico. U.S. Forest Service, Rocky Mountain Research Station, Progress Report No. 1. 4 pp.
- Lynch, Ann M. 2009. Spruce aphid, *Elatobium abietinum* (Walker): Life history and damage to Engelmann spruce in the Pinaleno Mountains, Arizona. In: Sanderson, H. Reed; Koprowski, John L., editors. The last refuge of the Mt. Graham red squirrel: Ecology of endangerment. Tucson, AZ: University of Arizona Press. p. 318-338.
- MacCracken, J.G., W.C. Boyd, and B.S. Rowe. 1996. Forest health and spotted owls in the eastern Cascades of Washington. Transactions North American Wildlife and Natural Resources Conference 61:519-527.
- 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, 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.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. Occupancy estimation and modeling—inferring patterns and dynamics of species occurrence. Academic Press, Burlington, Massachusetts, USA.
- Madany, M.H., and N.E. West. 1983. Livestock grazing-fire regime interactions within montane forests of Zion National Park, Utah. Ecology 64:661-667.
- Manley, P.N., S.A. Parks, L.A. Campbell, and M.D. Schlesinger. 2009. Modeling urban land development as a continuum to address fine-grained habitat heterogeneity. Landscape and Urban Planning 89(1-2):28-36.
- Margolis, E.Q., and J. Balmat. 2009. Fire history and fire-climate relationships along a fire regime gradient in the Santa Fe Municipal Watershed, NM, USA. Forest Ecology and Management 258:2416-2430.

- Margolis, E.Q., T.W. Swetnam, and C.D. Allen. 2007. A stand-replacing fire history in upper montane forests of the southern Rocky Mountains. *Canadian Journal of Forest Research* 37:2227-2241.
- Márquez-Olivas, M., L.A. Tarango-Arámbula, and G.D. Mendoza-Martínez. 2002. Habitat characteristics of Mexican spotted owl (*Strix occidentalis lucida* [X] Nelson, 1903) Sierra Fría, Aguascalientes. *Agrociencia* 36:541-546. Available from: <http://www.colpos.mx/agrocien/Bimestral/Contenido.html>.
- 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.
- Marshall, J.T., Jr. 1957. Birds of the pine-oak woodland in southern Arizona and adjacent Mexico. *Pacific Coast Avifauna* 32:1-125.
- Martin, G.R. 1986. Sensory capacities and the nocturnal habitat of owls (Stigiformes). *Ibis* 128:266-277.
- Mathiasen, R.L., F.G. Hawksworth, and C.B. Edminster 1990. Effects of dwarf mistletoe on growth and mortality of Douglas-fir in the Southwest. *Great Basin Naturalist* 50:67-71.
- Mawdsley, J.R., R. O'Malley, and D.S. Ojima. 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conservation Biology* 23:1080-1089.
- May, C.A., and R.J. Gutiérrez. 2002. Habitat associations of Mexican spotted owl nest and roost sites in central Arizona. *Wilson Bulletin* 114:457-466.
- May, C.A., M.L. Petersburg, and R.J. Gutiérrez. 2004. Mexican spotted owl nest- and roost-site habitat in northern Arizona. *Journal of Wildlife Management* 68:1054-1064.
- Mazur, K.M., P.C. James. 2000. Barred owl (*Strix varia*). *The birds of North America*, number 508. The Academy of Natural Sciences Philadelphia and The American Ornithologists Union, Washington, DC, USA.
- McCabe, G., M. Palecki, and J.L. Betancourt. 2004. Pacific and Atlantic Ocean influences on multi-decadal drought frequency in the United States. *Proceedings from the National Academy of Sciences* 101:4136-4141.
- McDonald, C.B., J. Anderson, J.C. Lewis, R. Mesta, A. Ratzlaff, T.J. Tibbitts, and S.O. Williams. 1991. Mexican spotted owl (*Strix occidentalis lucida*) status report. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA.
- McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. *Conservation Biology* 18:890-902.

- McLaughlin, S.P. 1986. Floristic analysis of the southwestern United States. *Great Basin Naturalist* 46:46-65.
- McLean, R.G., S.R. Ubico, D.E. Docherty, W.R. Hansen, L. Sileo, and T.S. McNamara. 2001. West Nile virus transmission and ecology in birds. *New York Academy of Sciences* 951:54-57.
- Mellin, T.C., W.J. Krausmann, K.B. Clark, and C.F. Enquist. 2000. Assessing gross changes within vegetation types associated with Mexican spotted owl habitat in New Mexico and Arizona. Pages unnumbered *in* J.D. Greer (ed.), Eighth biennial Forest Service remote sensing applications conference, Albuquerque, New Mexico, USA. 12 pp.
- Millar, C.I., N.L. Stephanson, and S.L. Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. *Ecological Applications* 17:2145-2151.
- Miller, G.S. 1989. Dispersal of juvenile northern spotted owls in western Oregon. M.S. Thesis, Oregon State University, Corvallis, USA.
- Minckley, W.L., and D.E. Brown. 1982. Wetlands. *Desert Plants* 4:223-287.
- Moen, C.A., A.B. Franklin, and R.J. Gutiérrez. 1991. Age determination of subadult northern spotted owls in northwest California. *Wildlife Society Bulletin* 19:489-493.
- Moeur, M. 1985. COVER: a user's guide to the CANOPY and SHRUBS extension of the stand prognosis model. USDA Forest Service, General Technical Report, INT-190, Intermountain Research Station, Ogden, Utah, USA.
- Moir, W.H. 1993. Alpine tundra and coniferous forest. Pp. 47-84 *in* W.A. Dick-Peddie (ed.), *New Mexico vegetation, past, present and future*. University of New Mexico Press, Albuquerque, USA.
- Monahan, W.B., and R.J. Hijmans. 2007. Distributional dynamics of invasion and hybridization by *Strix* spp. in western North America. *Ornithological Monographs* 63:55-66.
- Monson, G., and A.R. Phillips. 1981. Annotated checklist of the birds of Arizona. University of Arizona Press, Tucson, USA.
- Morton, E.S. 1975. Ecological sources of selection on avian sounds. *American Naturalist* 109:17-34.
- Mueller, R.C., C.M. Scudder, M.E. Porter, R T. Trotter, III, C.A. Gehring, and T.G. Whitham. 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. *Journal of Ecology* 93:1085-1093.

- Mullet, T.C. 2008. Evaluation of two GIS habitat models and initial characterization of nesting and breeding-season roosting microhabitat for Mexican spotted owls in the Guadalupe Mountains. M.S. Thesis, Sul Ross State University, Alpine, Texas, USA. 138 pp.
- Mullet, T.C., and J.P. Ward, Jr. 2010. Microhabitat features at Mexican spotted owl nest and roost sites in the Guadalupe Mountains. *Journal of Raptor Research* 44:277-285).
- Murphy, D.D., and B.R. Noon. 1991. Coping with uncertainty in wildlife biology. *Journal of Wildlife Management* 55:773-782.
- Naiman, R. J., and H, Decamps. 1997. The ecology of interfaces: riparian zones. *Annual Review of Ecology and Syetmatics* 28:621-658.
- Naiman, R.J., H. DeCamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* 3:209-12.
- National Academy of Sciences. 1996. Guide for the care and use of laboratory animals. Institute for Laboratory Animal Resources. Commission on Life Sciences, National Research Council, Washington, DC, USA.
- National Park Service [NPS]. 2010. U.S. Department of Interior, National Park Service public use statistics office. Available from: <http://www.nature.nps.gov/stats>.
- National Research Council. 1995. Science and the Endangered Species Act. Committee on scientific issues in the Endangered Species Act. The National Academies Press, Washington, DC, USA.
- Navarro-Sigüenza A.G., A. Lira-Noriega, A. T. Peterson, A. Oliveras de Ita and A. Gordillo-Martínez, 2007. Diversidad, endemismo y conservación de las aves. *In: biodiversidad de la faja volcánica transmexicana*. Luna, I., J.J.. Morrone and D. Espinosa (eds.). UNAM, México, D.F.
- Negrón, J.F., J.D. McMillin, J.A. Anhold, and D. Coulson. 2009. Bark beetle-caused mortality in a drought-affected ponderosa pine landscape in Arizona, USA. *Forest Ecology and Management* 257:1353-1362.
- Nelson, E.W. 1903. Descriptions of new birds from southern Mexico. *Proceedings Biological Society of Washington* 16:152.
- Newton. I. 1979. *Population Ecology of Raptors*. Buteo Books. Vermillion, South Dakota. 399 pp.
- Noon, B.R., and A.B. Franklin. 2002. Scientific research and the spotted owl (*Strix occidentalis*): opportunities for major contributions to avian population ecology. *Auk* 119:311-320.

- Noon, B.R., and K.S. McKelvey. 1992. Stability properties of the spotted owl metapopulation in southern California. Pp. 187-206 in J. Verner, K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould, Jr., and T.W. Beck, The California spotted owl: a technical assessment of its current status. USDA Forest Service, General Technical Report, PSW-GTR-133, Pacific Southwest Research Station, Albany, California, USA.
- Noon, B.R., and K.S. McKelvey. 1996. A common framework for conservation planning: linking individual and population models. Pp. 139-165 in D.R. McCullough (ed.), Metapopulations and wildlife conservation. Island Press, Washington, DC, USA. 429 pp.
- Noon, B.R., K.S. McKelvey, D.W. Lutz, W.S. LaHaye, R.J. Gutiérrez, and C.A. Moen. 1992. Estimates of demographic parameter and rates of population change. Pp. 175-186 in J. Verner, K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould, Jr., and T.W. Beck. The California spotted owl: a technical assessment of its current status. USDA Forest Service, General Technical Report, PSW-GTR-133, Pacific Southwest Research Station, Albany, California, USA.
- Norberg, R.A. 1987. Evolution, structure, and ecology of northern forest owls. Pp. 9-43 in R.W. Nero, C.R. Knapton, and R.J. Hamre (eds.), Biology and conservation of northern forest owls: symposium proceedings. USDA Forest Service, General Technical Report, RM-142, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- North, M., G. Steger, R. Denton, G. Eberlein, T. Munton, and K. Johnson. 2000. Association of weather and nest-site structure with reproductive success in California spotted owls. *Journal of Wildlife Management* 64:797-807.
- Oberholser, H.C. 1915. Critical notes on the subspecies of the spotted owl, *Strix occidentalis* (Xantus). *Proceedings U.S. National Museum* 49:251-257.
- 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.
- 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.
- Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* 37:637-669.
- Pater, L.L., T.G. Grubb, D.K. Delaney. 2009. Recommendation for improved assessment of noise impacts on wildlife. *Journal of Wildlife Management* 73:788-795.

- Paton, P.W.C., C.J. Zabel, D.L. Neal, G.N. Steger, N.G. Tilghman, and B.R. Noon. 1991. Effects of radio tags on spotted owls. *Journal of Wildlife Management* 55:617-622.
- Payne, R.S. 1971. Acoustic location of prey by barn owls (*Tyto alba*). *Journal of Experimental Biology* 54:535-573.
- 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* 37:265-276.
- Peery, M.Z., R.J. Gutiérrez, and M.E. Seamans. 1999. Habitat composition and configuration around Mexican spotted owl nest and roost sites in the Tularosa Mountains, New Mexico. *Journal of Wildlife Management* 63:36-43.
- Peles, J.D., and Barrett, G.W. 1996. Effects of vegetative cover on the population dynamics of meadow voles. *Journal of Mammalogy* 77:857-869.
- Peppin, D.L., P.Z. Fule, C. Hull Seig, J.L. Beyers, and M.E. Hunter. 2010. Post-wildfire seeding in forests of the western United States: an evidence-based review. *Forest Ecology and Management* 260:573-586.
- Peterson, J., and B. Zimmer. 1998. *Birds of the Trans Pecos*. University of Texas Press, Austin, USA.
- Peterson, N.A. 2003. Evaluation of Mexican spotted owl roosting habitat on Fort Carson Military Reservation using Landsat 7 ETM+ satellite imagery and GIS modeling. M.S. Thesis, Colorado State University, Fort Collins, USA.
- Peyton, L. 1910. Nesting of the spotted owl in northeastern Los Angeles County, California. *Condor* 12:122-123.
- Pfister, R.D. 1989. Basic concepts of using vegetation to build a site classification system. Pp. 22-28 in D.E. Ferguson, P. Morgan, and F.D. Johnson (compilers), *Proceedings—Land classifications based on vegetation: applications for resource management*. USDA Forest Service, General Technical Report, INT-257, Intermountain Research Station, Ogden, Utah, USA.
- Phillips, A., J.T. Marshall, Jr., and G. Monson. 1964. *The Birds of Arizona*. University of Arizona Press, Tucson, USA.
- Pianka, E.R. 1973. The structure of lizard communities. *Annual Review of Ecology and Systematics* 4:53-74.
- Platts, W.S. 1990. *Managing fisheries and wildlife on rangelands grazed by livestock: a guidance and reference document for biologists*. Nevada Division of Wildlife, Carson City, USA.

- Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegard, B.D. Richter, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. *BioScience* 47:769-784.
- Pollock, K.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. *Wildlife Monographs* 107:1-97.
- Prather, J.W., H.M. Hampton, Y. Xu, B.G. Dickson, N.L. Dodd, E.N. Aumack, and T.D. Sisk. 2005. Modeling the effects of forest restoration treatments on sensitive wildlife taxa: a GIS-based approach. Pp. 69-85 *in* C. Van Riper and D.J. Mattson (eds.), *The Colorado Plateau II: biophysical, socioeconomic, and cultural research*. University of Arizona Press, Tucson, USA.
- Prather, J.W., R.F. Noss, and T.D. Sisk. 2008. Real versus perceived conflicts between restoration of ponderosa pine forests and conservation of the Mexican spotted owl. *Forest Policy and Economics* 10:140-150.
- Pulliam, H.R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652-661.
- Radeloff, V.C., R.B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildland-urban interface in the United States. *Ecological Applications* 15:799-805.
- Radeloff, V.C., S.I. Stewart, T.J. Hawbaker, U. Gimmi, A.M. Pidgeon, C.H. Flather, R.B. Hammer, and D.P. Helmers. 2010. Housing growth in and near United States protected areas limits their conservation value. *Proceedings National Academy of Sciences* 107:940-945.
- Raffa, K.F., B.H. Aukema, B.J. Bentz, A.L. Carroll, J.A. Hicke, M.G. Turner, and W.H. Romme. 2008. Cross-scale drivers of natural disturbances prone to anthropogenic amplification: the dynamics of bark beetle eruptions. *Bioscience* 58:501-517.
- Reichenbacher, F.W., and R.B. Duncan. 1992. Diet of Mexican spotted owls on National Forest System lands in Arizona and New Mexico. Unpublished Report, USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.
- Reid, J.A., R.B. Horn, and E.D. Forsman. 1999. Detection rates of spotted owls based on acoustic-lure and live-lure surveys. *Wildlife Society Bulletin* 27:986-990.
- Reynolds, R.T., R.T. Graham, M.H. Reiser, R.L. Bassett, P.L. Kennedy, D.A. Boyce, Jr., G. Goodwin, R. Smith, E.L. Fisher. 1992. Management recommendations for the northern goshawk in the southwestern United States. USDA Forest Service, General Technical Report, RM-217, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Rickard, W.H., and C.E. Cushing. 1982. Recovery of streamside woody vegetation after exclusion of livestock grazing. *Journal of Range Management* 35:360-361.

- Ridgway, R. 1914. The birds of North and Middle America, part 4. Bulletin of the U.S. National Museum 50, pp. i-xx plus 1-882.
- Riebsame, W.E., H. Gosnell, and D.M. Theobald. 1996. Land use and landscape change in the Colorado mountains I: theory, scale, and pattern. Mountain Research and Development 16:395-405.
- Rinkevich, S.E. 1991. Distribution and habitat characteristics of Mexican spotted owls in Zion National Park, Utah. M.S. Thesis, Humboldt State University, Arcata, California, USA.
- Rinkevich, S.E., and R.J. Gutiérrez. 1996. Mexican spotted owl habitat characteristics in Zion National Park. Journal of Raptor Research 30:74-78.
- Root, T.L., T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J.A. Ponds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57-60.
- 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 81:1715-1725.
- Royle, J.A., and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777-790.
- Rummel, R.S. 1951. Some effects of livestock grazing on ponderosa pine forest and range in central Washington. Ecology 32:594-607.
- Ruyle, G.B., K.H. Reynolds, L.D. Howery, and M.P. McClaran. 2000. Guidelines for monitoring Arizona rangelands. Arizona Cooperative Extension Service, University of Arizona, Tucson, USA.
- Ryerson, D.E., T.W. Swetnam, and A.M. Lynch. 2003. A tree-ring reconstruction of western spruce budworm outbreaks in the San Juan Mountains, Colorado, U.S.A. Canadian Journal of Forest Research 33:1010-1028.
- Savage, M., and T.W. Swetnam. 1990. Early 19th Century fire decline following sheep pasturing in a Navajo ponderosa pine forest. Ecology 32:954-607.
- Scheaffer, R.L., W. Mendenhall, and L. Ott. 1986. Elementary Survey Sampling. Third edition. Duxbury Press, Boston, Massachusetts, USA.
- Schelz, C., D. Kent, D. Chalmers, and D. Svendsen. 2004. Mexican spotted owl inventory in Canyonlands National Park 2002-2003. USDI National Park Service, General Technical Report, SEUG-002-2003, Moab, Utah, USA.
- Schlesinger, M.D., P.N. Manley, and M. Holyoak. 2008. Distinguishing stressors acting on land bird communities in an urbanizing environment. Ecology 89:2302-2314.

- Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* 316:1181-1184.
- Seamans, M.E., J. Corcoran, and A. Rex. 2004. Southernmost record of a spotted owl x barred owl hybrid in the Sierra Nevada. *Western Birds* 35:173-174.
- Seamans, M.E., and R.J. Gutiérrez. 1995. Breeding habitat ecology of the Mexican spotted owl in the Tularosa Mountains, New Mexico. *Condor* 97:944-952.
- Seamans, M.E., and R.J. Gutiérrez. 1999. Diet composition and reproductive success of Mexican spotted owls. *Journal of Raptor Research* 33:143-148.
- Seamans, M.E., R.J. Gutiérrez, and C.S. May. 2002. Mexican spotted owl population dynamics: influence of climate variation on survival and reproduction. *The Auk* 119(2):321-334.
- Seamans, M.E., and R.J. Gutiérrez. 2006. Spatial dispersion of spotted owl sites and the role of conspecific attraction on settlement patterns. *Ethology, Ecology and Evolution* 18:99-111.
- Seamans, M.E., and R.J. Gutiérrez. 2007. Habitat selections in a changing environment: the relationship between habitat alteration and spotted owl territory occupancy and breeding dispersal. *Condor* 109:566-576.
- Seamans, M.E., R.J. Gutiérrez, and C.S. May. 2002. Mexican spotted owl population dynamics: influence of climate variation on survival and reproduction. *Auk* 119:321-334.
- Seamans, M.E., R.J. Gutiérrez, C.S. May, and M.Z. Peery. 1999. Demography of two Mexican spotted owl populations. *Conservation Biology* 13:744-754.
- SEMARNAT. 2002. Norma Oficial Mexicana NOM-059-SEMARNAT-2001. Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Diario Oficial de la Federación. 6 de marzo 2002. México. 153 pp.
- Shaffer, M. 1985. The metapopulation and species conservation: the special case of the northern spotted owl. Pp. 86-99 in R.J. Gutiérrez and A.B. Carey (eds.), *Ecology and management of the spotted owl in the Pacific Northwest*. USDA Forest Service, General Technical Report, PNW-185, Pacific Northwest Research Station, Portland, Oregon, USA.
- Shafroth, P.B., J.M. Friedman, and L.S. Ischinger. 1995. Effects of salinity on establishment of *Populus fremontii* (cottonwood) and *Tamarix ramosissima* (saltcedar) in southwestern United States. *Great Basin Naturalist* 55:58-65.

- Sheppard, G., and A. Farnsworth. 1997. Fire effects and use prescribed fire in Mexican spotted owl habitat. Pp. 131-135 in *Proceedings—Fire effects on rare and endangered species and habitats conference*. November 13-16, 1995; Coeur d'Alene, Idaho; International Association of Wildland Fire.
- Sheppard, P.R., A.C. Comrie, G.D. Packin, K. Angersbach, and M.K. Hughes. 2002. The climate of the US Southwest. *Climate Research* 21:219-238.
- Short, L.L. 1965. Hybridization in the flickers (*Colaptes*) of North America. *Bulletin of the American Museum of Natural History* 129:309-428.
- Short, L.L. 1972. Hybridization, taxonomy, and avian evolution. *Annals of the Missouri Botanical Garden* 59:447-453.
- Singleton, P.H., J.F. Lehmkuhl, 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.
- Sisk, T.D., H.M. Hampton, J. Prather, E.N. Aumack, Y. Xu, M.R. Loeser, T. Munoz-Erickson, B. Dickson, and J. Palumbo. 2004. Forest Ecological Restoration Analysis (ForestERA) project report, 2002-2004: executive summary. Available from: http://forestera.nau.edu/overview_2002-2004_project_report.htm.
- Skaggs, R.W. 1990. Spotted owl telemetry studies on the Lincoln National Forest—Sacramento Division. Progress Report, New Mexico Department of Game and Fish, Contract 516.6-76-17, Santa Fe, USA. (cited with author's express permission)
- Skaggs, R.W., and Raitt, R.J. 1988. A spotted owl inventory of the Lincoln National Forest, Sacramento Division. Final Report, New Mexico Department of Game and Fish, Santa Fe, USA.
- Skaggs, R.W., and Raitt, R.J. 1995. Densities of Mexican spotted owls in mixed-conifer, ponderosa pine, and pinyon-juniper habitats of southcentral New Mexico. *Journal of Raptor Research* 29:47-48. (Abstract)
- Smallwood, K.S., and C.G. Thelander. 2008. Bird mortality in the Altamont Pass wind resource area, California. *Journal of Wildlife Management* 72:215-223.
- Smallwood, K.S., C.G. Thelander, M.L. Morrison, and L.M. Rugge. 2007. Burrowing owl mortality in the Altamont Pass wind resource area. *Journal of Wildlife Management* 71:1513-1524.
- Smith, R.B., M.Z. Peery, R.J. Gutiérrez, and W.S. LaHaye. 1999. The relationship between spotted owl diet and reproductive success in the San Bernardino Mountains, California. *Wilson Bulletin* 111:22-29.

- Smith, S.D., D.A. Devitt, A. Sala, J.R. Cleverly, and D.E. Busch. 1998. Water relations of riparian plants from warm desert regions. *Wetlands* 18:687-695.
- Society for Range Management. [SRM]. 1998. Glossary of Terms used in Range Management—A Definition of Terms Commonly Used in Range Management. Society for Range Management, Denver, Colorado, USA.
- Sorrentino, G, and J.P. Ward, Jr. 2003. Analysis of Mexican spotted owl food habits gathered from two caves in the Guadalupe Mountains, Lincoln National Forest, New Mexico. Unpublished Report, USDA Forest Service, Rocky Mountain Research Station, Flagstaff, Arizona, USA.
- 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.
- Spittlehouse, D.L., and R.B. Stewart. 2003. Adaptation to climate change in forest management. *BC Journal of Ecosystem and Management* 4:1-11.
- Stacey, P.B. 2010. Spotted Owl (*Strix occidentalis*). Pp. 597-621 in: J-L.E. Cartron, *Raptors of New Mexico*. University of New Mexico Press, Albuquerque, USA. 710 pp.
- Stacey, P.B., and A. Hodgson. 1997. Impact of a large wildfire on the Mexican spotted owl. Unpublished Report. Available from P.B. Stacey, University of New Mexico.
- Stacey, P.B., and A. Hodgson. 1999. Biological diversity in montane riparian ecosystems: the case of the Mexican spotted owl. Pp. 204-210 in D.M. Finch, J.C. Whitney, J.F. Kelly, and S.R. Loftin (technical coordinators), *Rio Grande ecosystems: linking land, water, and people*. USDA Forest Service, Proceedings, RMRS-P-7, Fort Collins, Colorado, USA.
- Stacey, P.B., and M.Z. Peery. 2002. Population trends of the Mexican spotted owl in west-central New Mexico. *Bulletin New Mexico Ornithological Society* 30:42.
- Stage, A.R. 1968. A tree-by-tree measure of site utilization for grand fir related to stand density index. USDA Forest Service, Research Note, INT-77, Intermountain Research Station, Ogden, Utah, USA.
- Stella, K.A., C.H. Sieg, P.Z. Fulé. 2010 Minimal effectiveness of native and non-native seeding following three high severity wildfires. *International Journal of Wildland Fire* 19:746-758.
- Stephans, J.C., and B. Van der Zwaan. 2005. The case of carbon capture and storage. *Issues in Science and Technology* 3:68-76.
- Stubblefield, C.H., J.E. Lundquist, and B. van der Kamp. 2005. Chapter 10: Forest disease impacts on wildlife: beneficial? Pp. 95-104 in J.E. Lundquist (ed.), *From molecules to ecosystems—forest pathology in the era of genes and landscapes*. American Phytopathological Society Press, St. Paul, Minnesota, USA.

- Sureda, M. and M.L. Morrison. 1998. Habitat use by small mammals in southeastern Utah, with reference to Mexican spotted owl management. *Great Basin Naturalist* 58:76-81.
- Sureda, M. and M.L. Morrison. 1999. Habitat characteristics of small mammals in southeastern Utah. *Great Basin Naturalist* 59:323-330.
- Swarth, H.C. 1910. Two new owls from Arizona. *University of California Publications in Zoology* 7(1):1-8.
- Swarth, H.C. 1914. Status of the Arizona spotted owl. *Condor* 18:15-19.
- Swarthout, E.C., and R.J. Steidl. 2000. Effects of backcountry recreation on Mexican spotted owls in National Parks on the Colorado Plateau. Final Report to the National Park Service, USDI National Park Service, Resource Management Division at Southeast Utah Group, Moab, USA.
- Swarthout, E.C., and R.J. Steidl. 2001. Flush responses of Mexican spotted owls to recreationists. *Journal of Wildlife Management* 65:312-317.
- Swarthout, E.C., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican spotted owls. *Conservation Biology* 17:307-315.
- SWCA, Inc. 1992. Nest tree and nest tree habitat characteristics of the Mexican spotted owl in Arizona and New Mexico. Unpublished Report, USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.
- Swetnam, T.W. 1990. Fire history and climate change in the southwestern United States. Pp. 6-17 *in* J.S. Krammes (technical coordinator), Proceedings of symposium on effects of fire management of southwestern U.S. natural resources; November 15-17, 1988; Tucson, Arizona; USDA Forest Service, General Technical Report, RM-191, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Swetnam, T.W., and C H. Baisan. 1990. Fire-southern oscillation relations in the southwestern United States. *Science* 249:1017-1020.
- Swetnam, T.W., and C H. Baisan. 1996a. Fire histories of montane forests in the Madrean borderlands. Pp. 15-36 *in* P.F. Ffolliott, L.F. DeBano, M.B. Baker, G.J. Gottfried, G. Solis-Garza, C.B. Edminster, D.G. Neary, L.S. Allen, and R.H. Hamre (technical coordinators), Effects of fire on Madrean Province ecosystems: a symposium proceedings. USDA Forest Service, General Technical Report, RM-GTR-289, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

- Swetnam, T.W., and C H. Baisan. 1996b. Historical fire regime patterns in the southwestern United States since AD 1700. Pp. 11-32 *in* C.D. Allen (technical editor), Fire effects in southwestern forests. Proceedings of the 2nd La Mesa Fire symposium; March 29-31, 1994; Los Alamos, New Mexico; USDA Forest Service, General Technical Report, RM-GTR-286, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.
- Swetnam, T.W., and C H. Baisan. 2003. Tree-ring reconstructions of fire and climate history in the Sierra Nevada and southwestern United States. Pp. 158-195 *in* T.T. Veblen, W. Baker, G. Montenegro, and T.W. Swetnam (eds.), Fire and climatic change in temperate ecosystems of the western Americas. Ecological Studies Volume 160. Springer, New York, New York, USA.
- Swetnam, T.W., and A.M. Lynch. 1993. Multicentury, regional-scale patterns of western spruce budworm outbreaks. *Ecological Monographs* 63:399-424.
- Swetnam, T.W., Baisan, C.H., and Kaib, J.M. 2001. Forest fire histories in the sky islands of La Frontera. Pages 95-119 *In* Changing Plant Life of La Frontera: Observations on Vegetation in the United States/Mexico Borderlands. G.L. Webster and C.J. Bahre (eds.). University of New Mexico Press, Albuquerque, USA.
- Swetnam, T.W., Baisan, C.H., and Kaib, J.M. 2001. Forest Fire Histories of La Frontera: fire-scar reconstructions of fire regimes in the United States/Mexico borderlands. Laboratory of Tree-Ring Research, University of Arizona, Tucson, USA.
- Swetnam, T.W., A.M. Lynch, and J.M. Kaib. 1999. Forest fire histories of La Frontera: fire-scar reconstructions of fire regimes in the United States/Mexico borderlands. *in* G.L. Webster and C.J. Bahre (eds.), Vegetation and flora of La Frontera: historic vegetation change along the United States/Mexico boundary. The University of New Mexico Press, Albuquerque, USA.
- Tarango, L.A., R. Valdez, F. Clemente, and G. Mendoza. 2001. Roost-site characteristics of Mexican spotted owls in Sierra Fria, Aguascalientes, Mexico. *Journal of Raptor Research* 35:165-168.
- Tarango, L.A., R. Valdez, P.J. Zwank, and M. Cardenas. 1997. Mexican spotted owl habitat characteristics in southwestern Chihuahua, New Mexico. *Southwestern Naturalist* 42:132-136.
- Taylor, A.L., 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.
- Teng, T. 1998. The thermal environment of northern spotted owls in northwestern California: possible explanations for use of interior old growth and coastal early successional stage forest. M.S. Thesis, Humboldt State University, Arcata, California, USA.

- Theobald, D.M. 2000. Fragmentation by inholdings and exurban development. Pp. 155-174 in R.L. Knight, F.W. Smith, S.W. Buskirk, W.H. Romme, and W.L. Baker (eds.), Forest fragmentation in the southern Rocky Mountains. University Press of Colorado, Boulder, USA.
- Theobald, D.M. 2004. Placing exurban land-use change in a human modification framework. *Frontiers in Ecology and the Environment* 2:139-144.
- Theobald, D.M., and W.H. Romme. 2007. Expansion of the US wildland-urban interface. *Landscape and Urban Planning* 83:340-354.
- Thomas, N.J., J. Bunikis, A.G. Barbour, and M.J. Wolcott. 2002. Fatal spirochetosis due to a relapsing fever-like *Borrelia* sp. in a northern spotted owl. *Journal of Wildlife Diseases* 38:187-193.
- Thraikill, J., and M.A. Bias. 1989. Diets of breeding and nonbreeding California spotted owls. *Journal of Raptor Research* 23:39-41.
- Travis, J.M.J. 2003. Climate change and habitat destruction: a deadly anthropogenic cocktail. *Proceedings of the Royal Society of London* 270:467-473.
- UNEP-WCMC. 8 October, 2010. UNEP-WCMC Species Database: CITES-Listed Species.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 1983. Silvicultural systems for the major forest types of the United States. USDA Forest Service, Agricultural Handbook 445, U.S. Government Printing Office, Washington, DC, USA.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 1991. General ecosystem survey, general terrestrial vegetation, existing vegetation. USDA Forest Service, Southwestern Region and Technology Application Center, University of New Mexico, Albuquerque, USA.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 1996. Record of Decision for Amendment of Forest Plans. USDA Forest Service, Southwestern Region. June 5, 1996. 96 pp.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 2004. Insect and disease conditions in the Southwest Region, 2003. USDA Forest Service, Southwestern Region Forestry and Forest Health, R3-04-02, Albuquerque, New Mexico, USA.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 2005. Framework for streamlining consultation for livestock grazing activities. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.

- U.S. Department of Agriculture, Forest Service [USDA FS]. 2009. Forest insect and disease conditions in the Southwestern Region, 2008. USDA Forest Service, Forestry and Forest Health, PR-R3-16-5, Southwestern Region, Albuquerque, New Mexico USA. 45 pp. Available from: <http://www.fs.fed.us/r3/publications/documents/fidc2008.pdf>. [1 October 2009].
- U.S. Department of Agriculture, Forest Service [USDA FS]. 2010. Southwestern Region climate change trends and forest planning: a guide for addressing climate change in Forest Plan revisions for southwestern National Forests and National Grasslands. USDA Forest Service, Southwestern Region, Albuquerque, New Mexico, USA.
- U.S. Department of Agriculture, U.S. Department of the Interior 2001 [USDA and USDI]. Managing the Impacts of Wildland Fires on Communities and the Environment: A Report to the President in Response to the Wildfires of 2000. USDA Forest Service and US Department of Interior, Washington, DC.
- U.S. Department of Agriculture, U.S. Department of the Interior 2001 [USDA and USDI]. 2006. Interagency Burned Area Emergency Response Guidebook. Interpretation of Department of the Interior 620 DM 3 and USDA Forest Service Manual 2523. Version 4.0. February 2006. Washington, D.C., (Available at; www.fws.gov/fire/ifcc/esr/Policy/BAR_Guidebook11-06.pdf).
- U.S. Department of Commerce, National Marine Fisheries Service and U.S. Department of the Interior, Fish and Wildlife Service [USDC NMFS and USDI FWS]. 2010. Interim Endangered and Threatened Species Recovery Planning Guidance. Version 1.3. Rev. June 2010. 122 pp.
- U.S. Department of the Interior, Bureau of Land Management [USDI BLM]. 1993. Riparian area management—process for assessing proper functioning condition. USDI Bureau of Land Management, Technical Reference 1737-9, BLM Service Center, Denver, Colorado, USA.
- U.S. Department of the Interior, Bureau of Land Management [USDI BLM]. 1994. Riparian area management—process for assessing proper functioning condition for lentic riparian-wetland areas. USDI Bureau of Land Management, Technical Reference 1737-11, BLM Service Center, Denver, Colorado, USA.
- U.S. Department of the Interior, Bureau of Land Management [USDI BLM]. 1996a. Sampling vegetation attributes. Interagency Technical Reference 1730-2, USDI Bureau of Land Management, Denver, Colorado, USA.
- U.S. Department of the Interior, Bureau of Land Management [USDI BLM]. 1996b. Utilization studies and residual measurement. Interagency Technical Reference 1730, USDI Bureau of Land Management, Denver, Colorado, USA.

- U.S. Department of the Interior, Bureau of Land Management [USDI BLM]. 1998. Riparian area management—a user guide to assessing proper functioning condition and the supporting science for lotic areas. USDI Bureau of Land Management, Technical Reference 1737-15, BLM Service Center, Denver, Colorado, USA.
- U.S. Department of the Interior, Bureau of Land Management (USDI BLM). 2002. Biological assessment: Impacts to threatened and endangered species related to the resource management plan. U.S. Department of the Interior, Bureau of Land Management, Farmington Field Office, Farmington, NM.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1992. Draft final recovery plan for the northern spotted owl. USDI Fish and Wildlife Service, Portland, Oregon, USA.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1993. Endangered and threatened wildlife and plants: final rule to list the Mexican spotted owls as a threatened species. 58 FR:14248-14271.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1995. Recovery plan for the Mexican spotted owl: vol. I. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 2004. Final designation of critical habitat for the Mexican spotted owl. 69(168) FR:53182.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 2008. Final recovery plan for the northern spotted owl, *Strix occidentalis caurina*. USDI Fish and Wildlife Service, Portland, Oregon, USA.
- U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, National Oceanic and Atmospheric Administration [USDI FWS and USDC NOAA]. 2002. Alternative approaches for streamlining section 7 consultation on hazardous fuel treatment projects. Memorandum from Director of FWS and Assistant Administrator of Fisheries, NOAA, to FWS Regional Directors and NOAA Fisheries Regional Administrators.
- U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, National Oceanic and Atmospheric Administration [USDI FWS and USDC NOAA]. 2004. Joint counterpart Endangered Species Act section 7 consultation regulations. 69 FR:47732-47762.
- Urban, D., and T. Keitt. 2001. Landscape connectivity: a graph-theoretic perspective. *Ecology* 82:1205-1218.
- Van Horne, B. 1983. Density as a misleading indicator of habitat quality. *Journal of Wildlife Management* 47:893-901.

- van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and T.T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. *Science* 323:521-524.
- Van Riper, C., III, and D. Willey. 1992. Habitat ecology of Mexican spotted owls on the Colorado Plateau: annual report. Cooperative Park Service Study Unit, Northern Arizona University, Flagstaff, USA.
- Verner, J. 1997. Conservation strategies for spotted owls in relation to concepts of dynamic equilibria. Pp. 23-33 in S. Sommarstrom (ed.), Proceedings—6th biennial watershed management conference. Water Resources Center, Report 92. University of California, Davis, USA.
- Verner, J., R.J. Gutiérrez, and G.I. Gould, Jr. 1992. The California spotted owl: general biology and ecological relations. Pp. 55-77 in J. Verner, K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould, Jr., and T.W. Beck. The California spotted owl: a technical assessment of its current status. USDA Forest Service, General Technical Report, PSW-GTR-133, Pacific Southwest Research Station, Albany, California, USA.
- Vickery, W.L. and J.R. Bider. 1981. The influence of weather on rodent activity. *Journal of Mammalogy* 62:140-145.
- Wade, A.A., and D.M. Theobald. 2010. Residential development encroachment on U.S. protected areas. *Conservation Biology* 24:151-161.
- Wagner, P.W., C.D. Marti, and T.C. Boner. 1982. Food of the spotted owl in Utah. *Journal of Raptor Research* 16:27-28.
- Walters, C.J. 1986. Adaptive Management of Renewable Resources. MacMillan, New York, New York, USA.
- Ward, J.P., Jr. 2001. Ecological responses by Mexican spotted owls to environmental variation in the Sacramento Mountains, New Mexico. Dissertation, Colorado State University, Fort Collins, USA. Available from: <http://rydberg.biology.colostate.edu/research/jpward>.
- Ward, J.P., Jr. 2004. Relationships among herbaceous plants, voles, and Mexican spotted owls in the Sacramento Mountains: a review of current knowledge and procedures for monitoring vole habitat conditions in key grazing areas. Unpublished Technical Report, USDA Forest Service, Lincoln National Forest, Alamogordo, New Mexico, USA.
- Ward, J.P., Jr., and W.M. Block. 1995. Chapter 5: Mexican spotted owl prey ecology. Pp. 1-48 in Recovery plan for the Mexican spotted owl (*Strix occidentalis lucida*), volume II. USDI Fish and Wildlife Service Albuquerque, New Mexico, USA. Available from: <http://mso.fws.gov/recovery-plan.htm>.

- Ward, J.P., Jr., A.B. Franklin, S.E. Rinkevich, and F. Clemente. 1995. Chapter 1: Distribution and abundance of Mexican spotted owls. Pp. 1-14 in Recovery plan for the Mexican spotted owl (*Strix occidentalis lucida*), volume II. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA. Available from: <http://mso.fws.gov/recovery-plan.htm>.
- 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.
- Ward, J.P., Jr., and D. Salas. 2000. Adequacy of roost locations for defining buffers around Mexican spotted owl nests. *Wildlife Society Bulletin* 28:688-698.
- Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. *Conservation Biology* 11:1019-1022.
- Wauer, R. 1996. A field guide to birds of the Big Bend. Second edition. Gulf Publishing Company, Houston, Texas, USA.
- Weathers, W.W., P.J. Hodum, and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of California spotted owls. *Condor* 103:678-690.
- Weaver, H. 1951. Fire as an ecological factor in the southwestern ponderosa pine forests. *Journal of Forestry* 49:93-98.
- Webb, B. 1983. Distribution and nesting requirements of montane forest owls in Colorado. Part IV: spotted owl (*Strix occidentalis*). *Colorado Field Ornithology* 17-28.
- Weiss, J.L., and J.T. Overpeck. 2005. Is the Sonoran Desert losing its cool? *Global Change Biology* 11:2065-2077.
- Welty, J.C. 1975. The life of birds. 2nd edition. W.B. Saunders Company, Philadelphia, Pennsylvania, USA.

PART VII. APPENDICES (A – K)

APPENDIX A

RECOVERY TEAM MEMBERSHIP

Current Team Members

BRENT BIBLES

Education: B.S., Fisheries and Wildlife, Utah State University, 1987;
M.S. Wildlife and Fisheries Science, University of Arizona, 1992;
Ph.D. Wildlife and Fisheries Science, University of Arizona, 1999.
Current Position: Assistant Professor, Department of Wildlife Resources, Utah State University, Vernal, Utah.
Expertise: Avian ecology; wildlife-habitat relationships; threatened and endangered species conservation

WILLIAM M. BLOCK, Team Leader

Education: B.A., Economics, San Diego State University, 1974
B.S., Wildlife Biology Michigan State University, 1981
M.S., Wildlife Biology, Humboldt State University, 1985
Ph.D., Wildland Resource Science, University of California Berkeley, 1989
Current Position: Program Manager, Wildlife and Terrestrial Ecosystems, US Forest Service, Rocky Mountain Research Station, Flagstaff, AZ
Expertise: Wildlife biology; prey ecology; fire effects on wildlife; effects of fuels reduction on wildlife

JON COOLEY

Education: B.S., Wildlife Ecology, University of Arizona, 1982
M.B.A., WP Carey School of Business, Arizona State University, 1985.
Current Position: Region I Supervisor, Arizona Game and Fish Department; Pinetop, Arizona
Expertise: Endangered species program management; natural resource enterprise management; wildlife agency management/administration

JUAN MARIO CIRETT GALAN

Education: Ecologist
Current Position: Director, Ajos Bavispe National Forest Reserve and Wildlife Refuge, Sonora, Mexico
Expertise: Wildlife management (birds and mammals), natural resources management, protected areas planning

JOSPEH L. GANEY

Education: B.S., Wildlife Management, Humboldt State University, 1981
M.S., Biology, Northern Arizona University, 1988
Ph.D., Zoology, Northern Arizona University, 1991
Current Position: Research Wildlife Biologist, USDA Forest Service, Rocky Mountain Research Station, Flagstaff, AZ.
Expertise: Ecology of Mexican spotted owl; prey ecology; snag dynamics; wildlife-habitat relationships

SHAULA J. HEDWALL

Education: B.S., Natural Resource Sciences, Washington State University, 1993
M.S., Forestry, Northern Arizona University,
Current Position: Senior Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Flagstaff, AZ
Expertise: Threatened and endangered species conservation; forest and fire management; spotted owl ecology

FRANK P. HOWE

Education: B.A., Anthropology, St. Cloud State University, 1982
B.A., Biology, St. Cloud State University, 1982
M.S., Wildlife Science, South Dakota State University, 1986
Ph.D., Wildlife Biology Colorado State University, 1993
Current Position: University Research Liaison, Utah Division of Wildlife Resources; Assistant Professor, Department of Wildland Resources, Utah State University
Expertise: Avian ecology; neotropical migratory birds; riparian ecology; wildlife-habitat relationships; conservation

J. MARK KAIB

Education: B.S., Environmental Resource Sciences, Arizona State University, 1992
M.S., Watershed Management, The University of Arizona, 1998
M.S., Arid Lands Resource Sciences, The University of Arizona, 2005
Current Position: Deputy Regional Fire Coordinator, U.S. Fish and Wildlife Service, Southwest Region 2, Albuquerque, NM
Expertise: Fire history and ecology; dendrochronology; fire effects; monitoring; burned area rehabilitation and restoration; planning

DAVID KLUTE

Education: B.S., Fisheries and Wildlife, University of Missouri, 1992
M.S., Biology, Kansas State University, 1994
Ph.D., Wildlife and Fisheries Science, Pennsylvania State University, 1999
Current Position: Bird Conservation Coordinator, Colorado Division of Wildlife, Denver, CO
Expertise: Avian ecology; bird population monitoring; wildlife-habitat relationships.

CAY OGDEN

Education: B.S., Biology, Boise State University, 1979;
M.S. coursework Wildlife Management, University of Idaho, 1981-85.
Current Position: Regional Wildlife Ecologist, Intermountain Region, National
Park Service, Denver, Colorado.
Expertise: Wildlife biology; ESA Section 7 consultation and recovery
planning

SARAH E. RINKEVICH

Education: B.S., Wildlife and Fisheries Science, University of Arizona, 1987;
M.S., Wildlife Biology, Humboldt State University, 1991.
Current Position: Wildlife Biologist, U.S. Fish and Wildlife Service; Ph.D.
Candidate, University of Arizona.
Expertise: Wildlife ecology; threatened and endangered species; conservation;
conservation genetics.

JESÚS LIZARDO CRUZ ROMO

Education: Biologist, Universidad Nacional Autónoma de México (UNAM),
1998.
Current Position: Assistant Director for Conservation of Priority Species.
Expertise: Wildlife conservation; species at risk actions plans; binational
collaboration for wildlife recovery.

JERRY SIMON

Education: B.S. Range and Forest Management – Colorado State University 1975
Current Position: Forester, Southwestern Region, USFS
Expertise: Silviculture; forest management

STEVEN L. SPANGLE, Team Liaison

Education: B.S. Wildlife Management, Humboldt State University, 1977
Current Position: Field Supervisor, U.S. Fish and Wildlife Service, Arizona
Ecological Services Office, Phoenix
Expertise: Wildlife management, raptor ecology; Endangered Species Act

J. ROBERT VAHLE

Education: B.S. Wildlife Biology, Arizona State University, 1970
M. S. Zoology, Arizona State University, 1978
Current Position: Retired - Wildlife Biologist (22 Years U.S. Forest Service, 13
Years Arizona Game and Fish Department, 3 Years Intermountain West Joint
Venture).
Expertise: Forest/range ecology and management related to wildlife habitat
needs.

HIRA A. WALKER

Education: B.A. Biology, Environmental Studies, University of California at Santa Cruz, 1995; PhD Biology, University of New Mexico, Albuquerque, 2005.
Current Position: Non-game and Endangered Species Ornithologist, New Mexico Department of Game and Fish, Santa Fe, New Mexico.
Expertise: Bird conservation and management; stopover ecology; avian use of exotic vegetation; avian population monitoring techniques.

JAMES P. WARD JR

Education: B.S., Wildlife Biology, Humboldt State University, 1985; M.S., Natural Resources (Wildlife Management option), Humboldt State University, 1990; Ph.D., Zoology, Colorado State University, Fort Collins, Colorado, 2001;
Current position: College Professor, Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University Service, Las Cruces, New Mexico.
Expertise: Spotted owl ecology; wildlife population ecology; resource monitoring.

GARY C. WHITE

Education: B.S., Fisheries and Wildlife Biology, Iowa State University, 1970; M.S., Wildlife Biology, University of Maine-Orono, 1972; Ph.D., Zoology, Ohio State University, 1976;
Current Position: Professor Emeritus, Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, Colorado.
Expertise: Quantitative methods; population dynamics.

DAVID W. WILLEY

Education: B.A. Biology, 1981. Point Loma College, San Diego.; M.S. Wildlife Ecology, 1988. Colorado State University, Fort Collins; Ph.D. Zoology, 1998. Northern Arizona University.
Current Position: Adjunct Professor and Research Associate, Department of Ecology, Montana State University
Expertise: Wildlife ecology and management; raptor ecology; occupancy modeling and habitat analyses; small mammal ecology; university teaching.

GARY K. ZIEHE

Education: B.S. Range Science, 1982. Texas A&M University, College Station; M.S. Animal Breeding, 1989. Texas A&M University, College Station; Ph.D. Animal Breeding and Reproduction, 1993. Oklahoma State University, Stillwater.
Current Position: Natural Resources Staff Officer, Lincoln National Forest, Alamogordo, NM.
Expertise: rangeland ecology, quantitative genetics, biometrics

Past Team Members (Affiliation when serving on team)

REGIS CASSIDAY, USDA Forest Service, Southwestern Region (retired)
PAT CHRISTGAU, Arizona Game and Fish Department, Phoenix AZ
FERNANDO CLEMENTE, Colegio De Postgraduados, Campus San Luis Potisi, Mexico
JERRY CRAIG, Colorado Division of Wildlife, Fort Collins, CO
JAMES DICK, USDA Forest Service, Southwestern Region, Albuquerque, NM
ALAN FRANKLIN, Colorado State University, Fort Collins, CO
WIL MOIR, USDA Forest Service, Rocky Mountain Research Station, Flagstaff, AZ
(retired)
THOMAS SPALDING, Arizona Game and Fish Department, Phoenix AZ (retired)
STEVEN THOMPSON, San Carlos Apache Tribe, San Carlos, AZ
DEAN URBAN, Colorado State University, Fort Collins, CO, and Duke University,
Durham, NC
SARTOR O. WILLIAMS III, New Mexico Game and Fish Department, Santa Fe, NM
(retired)

APPENDIX B

ECOLOGY OF THE MEXICAN SPOTTED OWL

This appendix provides details on the biology and ecological relationships of the Mexican spotted owl (*Strix occidentalis lucida*). These details provided the background for recovery planning, but a lengthy discussion of ecology in the body of this Recovery Plan was considered too distracting. Thus, we provide the information here for the interested reader.

This appendix is intended to be an overview of this subspecies' biological characteristics and ecological relationships germane to recovering its populations. Emphasis is placed on information developed since the original Recovery Plan was published (USDI FWS 1995). Although major information gaps still exist, our understanding of the Mexican spotted owl's natural history has increased since 1995. In particular, the number of Mexican spotted owls found to dwell in canyon environments has greatly increased since that time. Thus, we also provide additional detail about the ecology of canyon-dwelling individuals, particularly when different from other Mexican spotted owls.

We have included results from both published and unpublished references. Although we prefer to rely on published information, considerable information regarding the Mexican spotted owl resides in unpublished reports. This summary is not exhaustive, because it is impossible to include or even locate every unpublished report. We have attempted to make it reasonably comprehensive, however, realizing that most biologists, resource managers, or other interested parties may not have time to locate and read the numerous references summarized here. In addition, a wealth of information exists for two other subspecies of spotted owls. Although different in some respects, many aspects of the owl's biology and ecology are similar among subspecies. Where appropriate, information from other subspecies was included for comparison or where data were limited regarding the Mexican subspecies.

1. Taxonomy and Genetics

A. Systematics

Knowledge of taxonomic relationships of threatened species is critical to their protection and recovery, particularly where protection is based on subspecific status, as is the case with the Mexican spotted owl. This owl is one of three subspecies of spotted owl recognized by the American Ornithologists' Union (AOU) in its last checklist that included subspecies (AOU 1957:285). The other two subspecies are the northern (*S. o. caurina*) and the California spotted owl (*S. o. occidentalis*).

Taxonomists have debated the systematics of the Mexican spotted owl for decades. The Mexican subspecies was first described from a specimen collected at Mount Tancitaro, Michoacán, Mexico and named *Syrnium occidentale lucidum* (Nelson 1903). The spotted owl was later assigned to the genus *Strix* (Ridgway 1914) and the subspecific name was changed to *lucida* to conform to taxonomic standards.

Swarth (1910, 1914) split the Arizona population of spotted owls out as *S. o. huachucae*, noting that they were paler than *S. o. lucida*. Ridgway (1914) applied the name *huachucae* to owls from Arizona east to the Guadalupe Mountains in Texas. In contrast, Oberholser (1915) concluded that *huachucae* was a synonym of *lucida*, and this taxonomic designation was followed by the AOU (1957). Monson and Phillips (1981) continued to recognize *huachucae* for Arizona owls, however, and Dickerman (1997) split the Mexican spotted owl into three subspecies, based on plumage differences noted in an examination of museum specimens. He proposed recognizing owls from the southwestern United States and northern Mexico (Sonora and Chihuahua) as *huachucae*, with a new subspecies, designated as the volcano owl (*S. o. juanaphillipsae*), recognized in the state of Mexico, and *lucida* occurring between the ranges of *huachucae* and *juanaphillipsae*. This debate over the subspecific status of the Mexican spotted owl continues today (Haig et al. 2004a, Funk et al. 2008, see below).

The Mexican subspecies is geographically isolated from both the California and northern subspecies (Figure B.3), with only a trace element of historical genetic contribution within the range of the northern spotted owl (Funk et al. 2008). Using electrophoresis to examine allozyme variation, Barrowclough and Gutiérrez (1990) found a major allelic difference between the Mexican spotted owl and the two coastal subspecies. They concluded from this difference that the Mexican spotted owl was isolated genetically from the other subspecies for considerable time, has followed a separate evolutionary history, and could therefore be considered a separate species (Barrowclough and Gutiérrez 1990:742). Most other recent studies (Barrowclough et al. 1999, Haig et al. 2001, Funk et al. 2008), as well as a recent review of all available genetic data, both published and unpublished (Fleischer et al. 2004), also supported designation of the Mexican spotted owl as an Evolutionarily Significant Unit. In a somewhat divergent view, Haig et al. (2004a) found little evidence to support subspecific differences between the California and Mexican subspecies on the basis of molecular genetics. Nevertheless, they suggested that these populations should be managed separately because of their current geographic separation (Haig et al. 2004a). Most recently, Funk et al. (2008) reported evidence of introgression of Mexican spotted owls into the northern portion of the range of the northern spotted owl, and suggested that this resulted from long-distance dispersal of Mexican spotted owls. We are unsure how to interpret these results, as this would require dispersal over distances that greatly exceed any documented movements of spotted owls. Funk et al. (2008) supported recognition of three subspecies of spotted owls despite this introgression, however.

Two other species within the genus *Strix* occur north of Mexico: barred (*S. varia*), and great gray owls (*S. nebulosa*). The great gray owl is a northern species that does not occur within the range of the Mexican spotted owl. Historically, barred owls also did not occur in sympatry with Mexican spotted owls within the United States. However, unconfirmed sightings of both species have been reported from the vicinity of Big Bend National Park in southern Texas in recent times (Wauer 1996), and there are recent confirmed records of barred owls in northern New Mexico (Williams 2005, cited in Cartron 2010). Whether these confirmed records indicate a range expansion by barred owls or simply vagrant individuals is unknown at this time.

Mexican spotted, barred, and fulvous owls (*S. fulvescens*) all occur in Mexico, and they are sometimes considered as a “superspecies” (Holt et al. 1999:199-200). The ranges of the Mexican spotted and barred owl may or may not overlap in Mexico (Williams and Skaggs 1993, Howell

and Webb 1995); little is known about local distributional patterns and habitats occupied in this zone of apparent overlap (Enriquez-Rocha et al. 1993). The fulvous owl does not appear to be sympatric with spotted owls in Mexico (but it may overlap the distribution of the barred owl slightly, Holt et al. 1999:198-200).

Patterns of range overlap may have significant implications for Mexican spotted owls. Barred owls are known to hybridize with northern spotted owls in the Pacific Northwest (Hamer et al. 1994, Dark et al. 1998, Haig et al. 2004b, Kelly and Forsman 2004, Funk et al. 2007, also see Gutiérrez et al. 2004, 2007). This hybridization is occurring in a relatively recent zone of contact caused by a rapid range expansion by barred owls into the range of the northern spotted owl in the Pacific Northwest (Taylor and Forsman 1976, Dark et al. 1998, Kelly 2001, Gutiérrez et al. 2004, 2007). Both hybrids between spotted and barred owls and backcrosses between these hybrids and the parental types have been found throughout much of the range of the northern spotted owl.

The implications of this hybridization for populations of northern spotted owls are currently unknown. Genetic analyses clearly indicate that spotted and barred owls are distinct species with no indication of previous gene flow across species boundaries (Haig et al. 2004b, Funk et al. 2007). Closely related species occasionally hybridize naturally, especially where habitat disruption has led to contact between previously geographically isolated species (Short 1965, 1972). Kelly and Forsman (2004) noted that relatively few hybrids have been identified to date, and they suggested that other isolating mechanisms (e.g., behavior or habitat selection) may be working effectively to maintain hybridization at low levels.

Holt et al. (1999:198) reported occasional hybridization between spotted and barred owls in Mexico but did not elaborate on sources for this information. Given the situation in the recent zone of contact discussed above for the Pacific Northwest, it seems likely that hybridization between Mexican spotted and barred owls could increase if barred owls expand their range into other portions of the range of the Mexican spotted owl.

B. Genetic Structure of Mexican Spotted Owl Populations

Knowledge on genetic structure of threatened populations can aid in conserving and recovering those populations. Barrowclough et al. (2006) investigated genetic structuring in Mexican spotted owl populations. Genetic diversity was high in most populations sampled, with approximately 17 and 7.5% of observed genetic variation distributed among populations and physiographic regions, respectively. Their data suggested substantial gene flow among populations sampled in the Mogollon Rim – Upper Gila Mountains region of central Arizona and New Mexico, with more restricted gene flow among other populations. The relatively dense population in the Sacramento Mountains showed evidence of isolation from other populations. Barrowclough et al. (2006) concluded that viability of the Sacramento Mountains population depends largely on internal population dynamics, suggesting that managers should maintain sufficient habitat to support a viable population in this range. Some smaller populations appeared to depend on immigration from larger concentrations of owls in the Upper Gila Mountains region. Barrowclough et al. (2006) concluded that maintaining stepping stone habitat fragments between the large Upper Gila Mountains populations and other populations in the rest of the

range would aid in maintaining viable populations of Mexican spotted owls (see additional discussion in sections on Landscape Connectivity and Metapopulation Ecology, below).

2. Description

A. Appearance

The spotted owl is mottled in appearance with irregular white and brown spots on its otherwise brown abdomen, back, and head (Gutiérrez et al. 1995). White spotting on brown breast feathers is one characteristic that distinguishes the spotted owl from the barred owl, which has brown and white vertical streaks on its breast (Figure E.2). Both spotted and barred owls have dark eyes in contrast to other medium to large North American owls that have colored irises (the small flammulated owl [*Otus flammeolus*] also has dark irises). Both spotted and barred owls lack external ear tufts, and the head has a rounded appearance. The large round facial disk has indistinct concentric circles around both eyes.

The three subspecies of spotted owls exhibit color variation in their body plumage. White spots of the Mexican spotted owl are generally larger and more numerous than in the other two subspecies, giving it a lighter appearance (*Strix occidentalis* translates as “owl of the west” and *lucida* means “light” or “bright”; Ganey 1998). Both remiges (wing feathers) and retrices (tail feathers) are dark brown barred with lighter brown and white.

Adult male and female spotted owls are mostly monochromatic in plumage characteristics, but several age classes can be distinguished by plumage characteristics (Forsman 1981, Moen et al. 1991). Juvenile spotted owls (hatching to approximately five months) have a downy appearance (Figure E.2, middle photo), which persists around the head even after the flight feathers grow in (i.e., until late August or September of their birth year). Subadults (5 to 26 months) closely resemble adults but have pointed retrices with a pure white terminal band (Forsman 1981, Moen et al. 1991). Two age classes of subadults (first- and second-year, respectively; Figure E.2, top photos) generally can be recognized, based on the amount of wear to the tips of the retrices and the date of observation (Moen et al. 1991). The retrices of adults (>27 months) have rounded tips, and the terminal band is mottled brown and white (Figure E2, bottom photos).

The spotted owl is a medium-sized owl and ranks fifth largest among the 19 North American owl species (Johnsgard 1988). Like many other raptors, spotted owls exhibit reversed sexual dimorphism where females are larger than males. Adult male Mexican spotted owls ($n = 68$) average 509 ± 33 (SD) g, and adult females ($n = 68$) average 569 ± 44 g (Gutiérrez et al. 1995: Appendix). There appears to be clinal variation among the three subspecies in a number of morphological characteristics, with size (or mass) generally greatest in the northern subspecies, intermediate in the California subspecies, and smallest in the Mexican subspecies (Gutiérrez et al. 1995: Appendix).

B. Vocalizations

The spotted owl, being territorial and primarily nocturnal, is heard more often than seen. It has a wide repertoire of calls (Forsman et al. 1984, Ganey 1990), most of which are relatively low in pitch and composed of pure tones (Fitton 1991). The low frequencies and pure tones

characteristic of these calls suggest that they are well-suited for accurate long-distance communication through areas of relatively dense vegetation (Fitton 1991, see also Morton 1975, Forsman et al. 1984). This likely is important in a nocturnally active animal that ranges over large areas and that needs to communicate effectively with both its mate and neighboring owls across large distances (Ganey 1990).

Male and female spotted owls can be distinguished by their calls. Males have a deeper voice than females (Forsman et al. 1984) and generally call more often than females (Ganey 1990: Fig. 2). There also appears to be intrasexual variation in calling rates (Laymon 1988, Ganey 1990: Fig. 2).

Forsman et al. (1984) described 14 calls for the northern spotted owl, at least 10 of which also are used by Mexican spotted owls in Arizona (Ganey 1990). Both sexes use most calls, but the frequency with which call types are used varies among sexes (Forsman et al. 1984). The most common vocalization, used more often by males (Ganey 1990, Kuntz and Stacey 1997), is a series of four unevenly spaced hoots (four-note location call; Forsman et al. 1984, see also Fitton 1991). Females frequently use a clear whistle ending with an upward inflection (contact call; Forsman et al. 1984) as well as a series of sharp barks (bark series; Forsman et al. 1984, Ganey 1990: Fig. 1).

Mexican spotted owls call mainly from March to November and are relatively silent from December to February (Ganey 1990). Calling activity increases from March through May (although nesting females are largely silent during April and early May) and then declines from June through November (Ganey 1990: Fig. 3). Ganey (1990: Fig. 4) reported that calling activity was greatest during the 2-hour period following sunset, with smaller peaks 4 to 8 hrs after sunset and just before sunrise.

Mexican spotted owls studied by Ganey (1990) called more than expected during the last quarter and new moon phases of the lunar cycle; and they called most frequently on calm, clear nights when no precipitation was falling. Forsman (1983) reported that northern spotted owls also called most frequently on calm, clear nights, whereas the generality of the relationship between moon phase and calling rates is unknown. Calling bouts of spotted owls lasted approximately twice as long when the focal owls' mate also was calling and over three times as long when "other" owls were calling (Ganey 1990). In most cases, the other owls calling were neighboring spotted owls or great horned owls.

Fitton (1991) and Kuntz (1998) studied variability among calls of spotted owls in northwestern California and New Mexico, respectively. Fitton (1991) found significant differences between call structure of neighboring and non-neighboring owls, with variance in call structure lower among neighboring owls than among non-neighbors. Similarly, Kuntz (1998) identified population-level differences between calls of populations of Mexican spotted owls in different mountain ranges. These findings suggest that spotted owls are able to use vocal learning to make fine adjustments to call structure (Fitton 1991). This development of a local dialect could allow owls to identify their neighbors without needing to be able to identify specific individuals. The ability to distinguish neighbors from non-neighbors by calls could provide a means to identify intruders, and thus trigger territorial defense when it is most needed.

The ability to distinguish between neighboring and non-neighboring owls could be particularly important if owls are not able to identify individuals by their calls. Whether or not these owls can identify individuals by their calls is unknown at this time. However, researchers can recognize individual male Mexican spotted owls using multivariate analysis of call structure (Kuntz 1998). Given the frequent vocal communication that occurs between mated owls during the nesting season, and the overall importance of vocal communication to a nocturnal, territorial animal, we would be surprised if spotted owls could not identify individuals by their vocalizations.

The fact that spotted owls are territorial and respond to calls is important in the context of research and management. Acoustic lure surveys (Reid et al. 1999) are used to locate owls for both research and management activities (see Appendix F: Survey Protocol). These surveys are proven to be effective at locating spotted owls (Reid et al. 1999), but the influences of factors such as topography, vegetation, and distance on survey effectiveness are poorly understood. In a preliminary analysis, Bowles et al. (2002; see also Denes et al. 2006) demonstrated that Mexican spotted owls could be detected at distances up to 2 km under ideal conditions but that topography and ambient noise greatly affected detection distance. They suggested that incorporating the effects of such factors could improve estimates of effective area surveyed and inform survey protocols.

3. Distribution

The Mexican spotted owl occurs in forested mountains and rocky canyonlands throughout the southwestern United States and Mexico (Gutiérrez et al. 1995, Ward et al. 1995). It ranges from Utah, Colorado, Arizona, New Mexico, and the western portions of Texas south into several States of Mexico (Figure E.3). While this owl occupies a broad geographic area, it does not occur uniformly throughout its range (Ward et al. 1995). Instead, the owl occurs in disjunct areas that correspond with isolated mountain ranges and canyon systems (Figure E.3).

The current distribution of Mexican spotted owls generally mimics its poorly known historical extent, with some exceptions (Ward et al. 1995). For example, the owl has not been reported recently as a breeding species from riparian corridors along most low- or mid-elevation rivers and creeks in Arizona and New Mexico (although it does use these areas during winter; see Movements and Migration, below). Nor has it been reported in recent times from historically occupied areas of southern Mexico (Williams and Skaggs 1993, Ward et al. 1995) or from areas where recent habitat models suggest these owls should occur in canyons (see Habitat Models, below). Riparian communities and many previously occupied localities in the southwestern United States and southern Mexico have undergone significant habitat alteration since the historical sightings (USDI FWS 1993). These areas, when occupied, likely aided in maintaining connectivity among populations throughout the southwest.

In the United States, the majority of owls are found on National Forest lands. Exceptions to this general pattern occur in parts of the Colorado Plateau and Basin and Range-East Ecological Management Units, where owls are found primarily in rocky-canyon habitats on National Park Service and BLM lands.

Surveys conducted since the 1995 Recovery Plan continue to locate new owl sites and increase our knowledge of owl distribution but not necessarily of owl abundance. For example, 758 owl sites were recorded for the period 1990–1993 (Ward et al. 1995). During a recent review for establishing Critical Habitat, 1,222 owl sites were recorded for the period 1990–2004 (USDI FWS 2004). A more recent tally through 2008 indicated 1,301 cumulative sites occupied by one or more Mexican spotted owls (Table E.1). This increase is mainly a product of new surveys being completed within previously unsurveyed areas, however. It represents a cumulative tally of all sites where spotted owls have been located over time, does not provide any information on how many of those sites are occupied at any particular time, and does not account for any sites lost due to high-severity wildfire or natural site-extinction processes. Thus, an increase in abundance cannot be inferred from these data. Likewise, the distribution of owl sites alone cannot indicate population density in various areas and may be more indicative of differences in survey effort than in owl density.

Information on the current status of Mexican spotted owls in Mexico is limited. This subspecies has been reported to occur within the mountain ranges of five general regions distributed through the Mexican states of Chihuahua, Sonora, Durango, Jalisco, Michoacán, Guanajuato, Sinaloa, San Luis Potosi, Nuevo Leon, Coahuila, Colima, and Aguascalientes (Williams and Skaggs 1993, Ward et al. 1995, Tarango et al. 2001). The majority of owls have been located in the Sierra Madre Occidental range, including in Sonora, Chihuahua, Sinaloa, Durango, Aguascalientes, and Zacatecas, and in the Sierra Madre Oriental range, including in Coahuila, Nuevo Leon, and San Luis Potosi; fewer have been found in the Transverse Volcanic Range in Jalisco, Michoacán, Guanajuato, and the state of Mexico (Williams and Skaggs 1993, USDI FWS 1995). The northern Sierra Madre area is ecologically similar to the Sky Island Mountains of southeastern Arizona (Marshall 1957, Cirett-Galan and Diaz 1993). It is not known if the distribution of spotted owls in Mexico has changed or how many additional sites have been recorded since 1994.

4. Habitat Use

The term habitat can convey many meanings (for a comprehensive discussion of the habitat concept as it applies to birds, see Block and Brennan 1993). Here, we follow the terminology summarized by Hall et al. (1997) and use the term habitat to mean the physical elements and biological resources required by the Mexican spotted owl to persist. This generalized definition includes climatic ranges, types of vegetation, food items, and non-biotic or physical features like topography or geologic structures. Habitat for a given organism is often explicitly defined by vegetative categories like cover-types with the implicit understanding that these categories are comprised of multiple resources which vary among those categories. Since an organism's habitat can be used for multiple reasons, it is useful to describe habitat requirements according to activity of the organism or the function provided by the habitat. Doing so requires not only a discussion of habitat features associated with a particular activity but also the spatial scale at which that activity occurs. In the following sections, we describe Mexican spotted owl habitat according to scale and activity.

A. Landscape Scale

This owl's habitat occurs as patches within uninhabitable portions of a larger land base. The term landscape refers to the combined space of habitat patches and a matrix of unusable areas. For Mexican spotted owls to persist through time, there must be adequate dispersion of individuals throughout the landscape and a means for population interchange. In addition, dispersing owls must be able to locate usable habitat if they are to survive and reproduce. Use of habitat at the landscape scale, then, includes use of patches and corridors for assuring connectivity among subpopulations as well as patch use by resident birds that form local populations. Here we first discuss studies of landscape connectivity, then focus on studies of landscape composition around owl use areas (see also Home Range Features and Microhabitat Features).

a. Landscape Connectivity.—Keitt et al. (1995, 1997) attempted to identify those habitat clusters most important to overall landscape connectivity, using maps based on forest and woodland cover to define habitat clusters. They first ranked habitats to emphasize the importance of large patches in the landscape, and second, they modified this approach to emphasize positional effects (i.e., small clusters that are important because they act as “stepping stones” or bridges between larger habitat clusters).

In the first analysis, the largely contiguous forest habitat of the Mogollon Rim (Upper Gila Mountains Ecological Management Unit) emerged as most important overall, because of its large area. In the analysis emphasizing cluster position, the Upper Gila Mountains Ecological Management Unit again emerged as important, due to its central location. But a few small habitat clusters also emerged as particularly important. These included several fragments of the Cibola National Forest (Mount Taylor and Zuni Mountains, Colorado Plateau Ecological Management Unit) that may serve as stepping stones between other, larger clusters. These small patches may warrant particular management attention; they may be important to overall landscape connectivity despite supporting relatively few resident owls. However, conclusions about the importance of specific habitat clusters depend heavily on the accuracy of the underlying map of habitat clusters, which remains unknown.

In a separate analysis, Urban and Keitt (2001) used a graph-theoretic perspective to evaluate the effects of habitat loss on patch occupancy by Mexican spotted owls. They assumed that the Mexican spotted owl population functioned as a metapopulation (see Metapopulation Ecology, below) and used Hanski's incidence function (Hanski 1994, 1998) to simulate the effects of different patch-removal strategies on owl occupancy rates according to two different landscape models. The first model distinguished habitat as suitable versus unsuitable based on the presence of certain forest types, using the habitat map from Keitt et al. (1995, 1997). The second landscape model estimated habitat suitability in 25-km² blocks, based on a combination of forest type and forest density. The authors found differences between landscape models in the effects of patch removal, and differences between patch-removal strategies within landscapes. Similar to their earlier analysis (Keitt et al. 1995, 1997), retention of certain patches that maintained connectivity buffered occupancy rates against habitat loss far more than removal of other, less spatially important patches. As long as connectivity among patches was maintained, occupancy rates remained high even in the face of loss of significant amounts of habitat. However, these conclusions rely largely on the assumption that maintaining a connected landscape will maintain

dispersal processes regardless of population size. In reality, large losses in amount of habitat available to resident owls would result in fewer owls that could reproduce and fewer young to disperse. This ultimately could lead to the disconnection of subpopulations regardless of spatial aspects of connectivity.

In summary, landscape models evaluated by Keitt et al. (1995, 1997) and Urban and Keitt (2001) all highlight the importance of landscape connectivity (see also Barrowclough et al. 2006). Their findings further highlight the importance of both large patches of habitat, and of some small patches based on their location and consequent influence on landscape connectivity. Their results suggest that management plans should be concerned with those stepping-stone areas, and that conservation efforts focused in such areas may pay large dividends relative to land area involved in conservation measures. We view this general conclusion as robust to violations of model assumptions, although the specific patches involved obviously depend on those assumptions.

b. Landscape Composition.—Understanding landscape composition of sites occupied by Mexican spotted owls clearly would aid in developing conservation strategies for this species. To date, three studies have examined landscape composition around sites occupied by Mexican spotted owls at various spatial scales. These are discussed below.

Grubb et al. (1997) used air-photo interpretation to compare relative area of four canopy-cover classes between 47 owl nest and randomly located sites in the Coconino National Forest, north-central Arizona, at five different spatial scales. They analyzed landscape composition in both circles (radii = 0.1, 0.4, 0.8, 1.2, and 1.6 km) and concentric “rings,” where outer rings did not include areas sampled in inner rings, and included owl nest sites in landscapes dominated by mixed-conifer forest, pine-oak forest, and rocky canyons containing mixtures of forest types.

Landscape composition (based on concentric rings) differed between owl nest and random sites at all scales, but differences were greatest within 0.8 km of nest or roost sites and decreased at increasing spatial scales (Grubb et al. 1997: Fig. 2). Owl sites contained more area in the >70% canopy-cover class and less area in the <10% canopy-cover class than random sites. The most abundant canopy-cover class on the landscape was 41-70%, except within 0.1 km of owl nests, where the >70% canopy-cover class was most abundant.

Peery et al. (1999) evaluated the use of specific cover types by Mexican spotted owls in the Tularosa Mountains, New Mexico, and the spatial configuration of those cover types. This study area was dominated by mixed-conifer forest (Peery et al. 1999: Table 1). They compared landscape characteristics between 40 owl nest or roost sites and an equal sample of randomly located sites, based on a vegetation map derived from Landsat Thematic Mapper imagery. They evaluated landscape composition at eight spatial scales, in circles with radii ranging from 500 m (area = 78.9 ha) to 4,000 m (area = 5,030 ha). These circles thus were not spatially independent, because much of the area included in larger circles also was included within smaller circles. For example, 76.5% of their outermost circle consisted of area sampled in the next smaller circle.

In this study, areas around Mexican spotted owl nest and roost sites contained greater amounts of both mature mixed-conifer forest and mature ponderosa pine (*Pinus ponderosa*) forest than random sites. Differences between owl and random sites persisted across all spatial scales but

were most pronounced within 500 m of the nest or roost and declined with increasing spatial scale (Peery et al. 1999: Figs. 1 and 2). Visual inspection of Figures 1 and 2 in Peery et al. (1999) suggests that much of the difference in vegetation composition at larger scales was driven by differences at smaller scales (i.e., to inclusion of area sampled by smaller circles in larger circles). After controlling for the area in various vegetation types, they found no differences between owl and random sites with respect to five indices of spatial configuration of cover types (mean patch size, edge distance, mean nearest-neighbor distance, mean patch shape index, and habitat heterogeneity).

May and Gutiérrez (2002) conducted a similar analysis for owls in a study area dominated by ponderosa pine and Gambel oak (*Quercus gambelii*) forest in the Coconino National Forest, Arizona (this area was included in the study area in Grubb et al. [1997]). They compared 51 owl nest or roost sites with an equal sample of random sites at three spatial scales: a circular plot of 800-m radius (area = 201 ha), and two 400-m wide “ring” plots between 800 and 1600 m from each nest or roost tree. These scales thus were spatially independent in the sense that outer analysis areas did not include area sampled by inner analysis areas.

Landscape composition in this study area differed between owl and random sites only within the 201-ha analysis area. Areas around owl nest and roost sites contained more mature and young mixed-conifer forest with canopy cover >55% than expected based on availability. Young forests were used only where residual large (≥ 45.7 cm [18 in] diameter at breast height [dbh]) trees were present. Again, no differences were noted between owl and random sites in three indices of landscape configuration (mean patch size, mean patch shape index, and contagion).

In summary, current studies of landscape composition suggest that owls locate home ranges non-randomly, placing them in areas such that the center of the home range contained greater than average amounts of mature forest or in areas of younger forest with high canopy cover and containing residual large trees. Differences in landscape composition between owl and random sites generally were greatest near nest or roost sites and decreased with increasing area. This may indicate that owls are most selective for nesting or roosting core areas, or simply that larger circular analysis areas included more unused habitat or habitat used primarily for foraging (see below). In general, the scale at which differences between owl and random sites were most pronounced (201 ha; Grubb et al. 1997, May and Gutiérrez 2002) correlated reasonably well with the size of Protected Activity Centers (243 ha) recommended in USDI FWS (1995) and in this Recovery Plan.

B. Home Range Scale

a. *Space Use.*—There are four concepts relevant to understanding space and habitat use by resident Mexican spotted owls: territory, home range, activity center, and core area. A territory is defined as an exclusive area defended by the occupant (Welty 1975:224-225). A home range is defined as the area used (but not always defended) by an animal during its normal activities (Burt 1943). Unlike territories, home ranges of adjacent pairs may overlap spatially. Home ranges more appropriately define the area from which all resources required for a given time period are obtained by an organism. An activity center is an area within the home range receiving concentrated use. The activity center could be the same size as a territory when the former is

small and consistently defended. A core area is a specific type of activity center that usually includes a minimum area for protecting special resources like trees and groves used for roosting, nesting, or rearing of young (Bingham and Noon 1992, Reynolds et al. 1992, Ward and Salas 2000). Activity centers and core-areas have been used to estimate the size of areas needed to protect habitat most commonly used by spotted owls (e.g., Bingham and Noon 1992, Gutiérrez et al. 1992, USDI FWS 1995).

Spotted owls are described as territorial in the sense that mated pairs defend a breeding territory, at least during the nesting season. Fidelity to these territories is apparently high in Mexican spotted owls, with many owls remaining on the same territory year after year (Gutiérrez et al. 1995). No direct estimates of territory size are available for Mexican spotted owls. However, estimates of nearest-neighbor distances between adjacent pairs may provide some insight into the size of exclusive areas used by this owl. Such estimates are available for two study areas where there is reasonable certainty that all pairs of owls in a given area were located. One of these study areas was located in the Tularosa Mountains, New Mexico (Peery et al. 1999) and one in north-central Arizona (May and Gutiérrez 2002). Mean distances between adjacent pairs in these areas were 2.1 km (1.3 mi) in New Mexico ($n = 31$ pairs) and 2.4 km (1.5 mi) in Arizona ($n = 42$ pairs), suggesting that exclusive use areas average approximately 346 to 452 ha (855 to 1115 ac), respectively.

Investigators have studied home-range size of Mexican spotted owls directly by monitoring movements of radio-marked owls in a number of different geographic areas and/or habitats (Table E.2). Home-range size appears to vary considerably both among these studies (Table E.3) and between the breeding and non-breeding seasons. The factors underlying variation among studies are unclear, however. For example, various studies used different sampling methods or home-range estimators, and studies were conducted in different years. All of these factors can influence estimates of home-range size (Kernohan et al. 2001), making direct comparisons among studies difficult. Consequently, observed differences among studies could be due to differences in methodology, local habitat quality including abundance of prey, biogeographic effects (e.g., differences in climate pattern or biogeographic region), temporal variation (studies conducted in different years), or all of the above.

One study that used consistent methodology simultaneously across two study areas in the Sacramento Mountains, New Mexico, suggested that differences in local habitat quantity and/or quality influenced home-range size (Ganey et al. 2005). Home-range size was greater during both the breeding and non-breeding seasons in a study area dominated by xeric forest types than in a study area dominated by mesic mixed-conifer forest (Tables E.2 and E.3). Further, range size was inversely related to the proportion of the home range consisting of mixed-conifer forest. This relationship held both within study areas and across both study areas considered together, and in both seasons (Ganey et al. 2005). Owls roosted primarily in mixed-conifer forest in both study areas, and observed fecundity and survival rates of radio-marked owls were lower in the area dominated by xeric forests than in the area dominated by mixed-conifer forest (Ganey et al. 2005). Collectively, these observed patterns suggested that differences in local habitat quality helped explain the variation in home-range size.

Some investigators also estimated size of seasonal activity centers (Table E.3). Again, considerable variability was observed across studies. In general, however, activity centers were considerably smaller than home ranges of radio-marked owls. Noting this concentration of activity in a portion of the home range, the recommended size of Protected Activity Centers (PACs) in USDI FWS (1995) and in this Recovery Plan was based on activity centers rather than home ranges, in an attempt to focus management on the areas most used by the owls.

Thus, available information suggests that Mexican spotted owls use relatively large home ranges, with smaller areas of concentrated use embedded within those home ranges. Home-range size appears to vary among geographic areas and/or habitats. Some of that variation may be due to differences in methodology among studies, but we assume that some of the observed variation is real rather than an artifact of methodology. At this time, the relative influences of biogeographic regions versus local differences in habitat quality on home-range size of Mexican spotted owls remain unclear, although limited information suggests that such local differences can be important (Ganey et al. 2005, see also Carey et al. 1992, Zabel et al. 1995).

b. Habitat Use Within the Home Range.—Within their home range, Mexican spotted owls nest, roost, forage, and disperse in a diverse array of biotic communities. They can be found in heavily forested areas as well as in rocky canyons with sparse or no forest cover (Ganey and Dick 1995, Ward et al. 1995). Although these forest and canyon environments appear very different in terms of habitat conditions, they represent end points on a gradient of habitat conditions rather than discrete environments for use by Mexican spotted owls (Ganey and Balda 1989a). That is, these owls occur along a gradient ranging from areas that are extensively forested and largely lack significant rock outcrops or cliffs, to steep rocky canyons that lack significant forest cover. The Sacramento Mountains of south-central New Mexico provide a good example of forest-dwelling spotted owls. There, owls occur in heavily forested mountains and typically are not closely associated with rock outcrops or cliffs (Ganey et al. 2000, Ward 2001, Lavier 2006). In contrast, spotted owls in the canyonlands of southern Utah and northern Arizona (e.g., Zion, Canyonlands, Capitol Reef, and Grand Canyon National Parks) occur in narrow slickrock canyons, are closely associated with cliff-forming rock formations, and are not reliant on extensive forest cover (Kertell 1977, Rinkevich and Gutiérrez 1996, Willey 1998b, Willey and van Riper 1998, 2007, Willey and Ward 2004).

Throughout their range, Mexican spotted owls are often, but not always, associated with steep topography (Ganey and Dick 1995). This association is particularly prominent in the canyonlands, where the topography likely contributes directly to habitat suitability. Owls in these areas frequently nest and roost on ledges on steep cliffs, or in caves, potholes, or alcoves formed in these cliffs (e.g., Rinkevich and Gutiérrez 1996, Willey and van Riper 1998, Willey and Ward 2004, Bowden 2008, Mullet 2008, see also Johnson 1997). These types of structures tend to occur most frequently in the same formations that form deep, narrow, complex canyon systems with exposed cliffs (see Box E.1 for a fuller discussion of Habitat of Canyon-dwelling Owls). In more heavily forested areas, the reasons underlying the frequent association between owls and steep topography are less clear. Owls in these areas typically inhabit mature forests, and in many cases these forests are restricted to steep topography due to past harvest of forests elsewhere (Ganey and Balda 1989a, Ganey and Benoit 2002). In at least some areas, however, owls occur in gentle terrain where suitable forest structure is present (Ganey et al. 1999, 2000). This

suggests that the association between owls and steep terrain in forested areas may be driven more by the influence of forest structure than by topography itself. However, diverse topography also contributes to diversity in vegetation types and structure in the southwest. This diversity in turn contributes to habitat complexity, a feature that seems to be common to areas occupied by Mexican spotted owls (Ganey and Balda 1989a, Willey and van Riper 1998, Willey and Ward 2004). Areas of diverse topography, especially where significant rock outcrops or cliffs are present, also may serve as fire refugia (Camp et al. 1997), reducing the frequency of widespread surface fires and allowing longer periods for development of forest structure. Regardless of the underlying mechanism, the association between owl occupancy and steep terrain is strong, even in forested terrain (see Bowden et al. 2003, Ganey et al. 2004). Indeed, this association is strong enough that several investigators have based predictive models of owl habitat primarily on topographic features (see Habitat Models).

In both forest and canyon environments, spotted owls tend to select roosting and nesting sites that provide thermal protection. In the case of forested sites, large trees, dense canopy cover, and first or second order tributaries all act to create a cooler microclimate during warm ambient temperatures of the breeding season (e.g., Ward and Salas 2000, Ganey 2004).

c. Cover Types.—Use of cover types by Mexican spotted owls varies according to geographic region. Much of this regional variation likely reflects regional variation in habitat composition, climate pattern, and prey availability.

In the northern portion of the range, including Utah, Colorado, and parts of far northern Arizona and New Mexico (Colorado Plateau and Southern Rocky Mountains Ecological Management Units), owls occur primarily in steep-walled, rocky canyons (Kertell 1977, Rinkevich and Gutiérrez 1996, Johnson 1997, Willey and van Riper 1998, Willey and Ward 2004, Bowden 2008). These canyon systems vary in the amount of forest cover present, but in general they are less heavily forested than are canyons occupied farther south. Pinyon-juniper woodlands and mixed-conifer forest are prominent cover types used in these canyon systems (Ganey and Dick 1995:Table 4.1, Willey 1998b), but in some cases these canyons are entirely or largely lacking forest or woodland cover.

Farther south, a wider range of cover types is used. For example, along the Mogollon Rim in Arizona and New Mexico (Upper Gila Mountains Ecological Management Unit), spotted owls occur in mixed-conifer forests, ponderosa pine-Gambel oak forests, and associated riparian forests (Ganey and Balda 1989a, Ganey and Dick 1995, Seamans and Gutiérrez 1995, Peery et al. 1999, Stacey and Hodgson 1999, May and Gutiérrez 2002, Stacey 2010). They frequently occur in canyon systems and in association with steep terrain in this region as well. These canyons generally have greater forest cover than canyons in the northern portion of the range, however, and owls are not restricted to canyons and steep terrain in this region.

BOX B.1

HABITAT OF CANYON-DWELLING MEXICAN SPOTTED OWLS

In parts of its range, the Mexican spotted owl occupies a variety of steep, rocky-canyon habitats (Kertell 1977, Ganey and Balda 1989, Rinkevich and Gutiérrez 1996, Willey 1998b, Willey and Ward 2004, Willey and van Riper 2007, Bowden 2008, Mullet 2008). A complex of physical gradients (including water availability, amount of sunlight, slope, and elevation) can produce a “canyon effect” (Dick-Peddie 1993). The physical shape and dimension of canyons can affect local temperature, humidity, and vegetation, enhancing key welfare factors (e.g., nest and roost habitats) for the owl, particularly within arid portions of its range (Barrows 1981, Rinkevich and Gutiérrez 1996, Willey 1998b). Rocky cliffs and canyon rims can modify the amount of direct sunlight penetrating inner-canyon habitats, so that vegetation communities and microclimates may vary greatly among topographic zones (e.g., washes, benchlands, talus slopes, cliffs, and rim habitats). Canyon walls also can create complex habitat structure, a feature typically associated with habitats used by forest-dwelling spotted owls (Forsman et al. 1984, Ganey and Dick 1995).

Rocky canyon habitats used by Mexican spotted owls typically include dendritic watersheds with myriad tributary canyons, a variety of vegetation communities (ranging from arid to mesic), and prominent vertical-walled or overhanging cliffs (Rinkevich and Gutiérrez 1996, Willey 1998b, Swarthout and Steidl 2001). Within canyon habitats, Mexican spotted owls may nest and roost on cliff faces using protected caves or ledges (Rinkevich and Gutiérrez 1996, Willey 1998b, Bowden 2008) or roost in small patches of riparian tree species (Bowden 2008, Mullet 2008), and forage among caves, cliff faces, and rim or canyon-bottom vegetation for various small mammals, including mice (*Peromyscus* spp.), woodrats (*Neotoma* spp.), and bats (*Vespertilionidae*) (Ganey 1992, Ward and Block 1995, Rinkevich and Gutiérrez 1996, Willey 1998b, Johnson 1997, Sorrentino and Ward 2003).

We recognize several broad patterns of habitat use by Mexican spotted owls that occupy rocky-canyon habitats:

- Spotted owl home ranges include a significant component of vertical walled rocky canyons with numerous cliffs, caves, ledges, and branching tributary canyons. Spotted owls use nest, roost, and foraging habitats that are strongly associated with complex vertical and horizontal landscape structure, complex geomorphology, and canyon- and cliff-forming geologic substrates. Rocky architecture (e.g., slope, aspect, and ruggedness) may provide important habitat components (e.g., nest sites, roost sites, shade, foraging surfaces) normally associated with forest vegetation structure.
- Home ranges and activity centers used by spotted owls in canyon habitat can include a diversity of vegetation types, including desert-scrub, pinyon (*Pinus* spp.) –juniper (*Juniperus* spp.) woodland, riparian, ponderosa pine-oak, and mixed-conifer forest. Therefore it may be difficult to rely on vegetation alone to identify suitable habitat.
- Mexican spotted owls in canyon habitats primarily use rugged terrain located below canyon rims, and all known breeding sites and associated nesting cores areas have been located below the canyon rims (Willey and van Riper 2007, Bowden 2008). However, home-range data in some areas also indicate that the owls may use rims and mesa tops when hunting and vocalizing (Willey and van Riper 2007, Bowden 2008). Thus, adjacent highlands should not be ignored in management planning.

Canyon habitats occupied by Mexican spotted owls possess some common emergent properties. These primary elements include rocky cliffs, parallel-walled canyons, relatively long canyon complexes, cool north-facing aspects, complex branched tributary side-canyons, and a mosaic of vegetation communities ranging from cool riparian through montane forest to arid scrub desert. There are exceptions to these emergent properties, however, including occasional use of small side canyons and areas not on north-facing aspects.

South of the Mogollon Rim, in southern New Mexico, and into Mexico (Basin and Range-East, Basin and Range-West, and Mexican Ecological Management Units) an even wider range of cover types are used, including mixed-conifer, Madrean pine-oak, and Arizona cypress (*Cupressus arizonica*) forests, encinal oak woodlands, and associated riparian forests (e.g., Ganey and Dick 1995, Tarango et al. 1997, 2001, Young et al. 1998, Márquez-Olivas et al. 2002, Mullet 2008, Mullet and Ward 2010). Some owls are found in association with canyon systems or steep montane terrain. But, as along the Mogollon Rim, many of these canyons contain extensive forest or woodland cover, and owls are not restricted to deep rocky canyons except for small populations of owls occurring in southern portions of the Basin and Range-East EMU (e.g., Guadalupe and Davis Mountains, Mullet 2008). Thus, there appears to be a north-south gradient in diversity of habitats used, with a wider range of both cover types and terrain types used in the southern portion of the range than in the northern portion (Ganey and Dick 1995).

Despite the diversity of cover types where Mexican spotted owls have been found, these owls most commonly use mixed-conifer forests throughout their range within the United States (e.g., Ganey and Dick 1995, Seamans and Gutiérrez 1995, Willey 1998ba, Stacey and Hodgson 1999, Ganey et al. 2000, Ward 2001, Stacey 2010). These forests are dominated by Douglas-fir (*Pseudotsuga menziesii*) and/or white fir (*Abies concolor*), with co-dominant species including southwestern white pine (*P. strobiformis*), limber pine (*P. flexilis*), and ponderosa pine (Brown et al. 1980). The understory often contains the above coniferous species as well as broadleaved species such as Gambel oak, maples (*Acer* spp.), box elder (*A. negundo*), and New Mexico locust (*Robinia neomexicana*). These broadleaved species may be important (Ganey et al. 1992, 1999, 2003, Seamans and Gutiérrez 1995, Stacy and Hodgson 1999, May and Gutiérrez 2002, May et al. 2004), either in adding to structural complexity or by providing nest sites (SWCA 1992, Fletcher and Hollis 1994, May and Gutiérrez 2002, May et al. 2004) or additional food sources for prey species (Ward 2001).

Madrean pine-oak forests used by spotted owls are dominated by an overstory of various pine species in conjunction with species such as Douglas-fir and Arizona cypress. In southern Arizona, pine species represented include primarily Apache (*P. engelmannii*), Chihuahua (*P. leiophylla*), and Arizona (*P. arizonica*) pine. Farther south, a number of other pine species are present. For example, a study area in the state of Chihuahua, Mexico, included the pines discussed above as well as Durango (*P. durangensis*), Mexican white (*P. ayacahuite*), and weeping (*P. patula*) pine (Tarango et al. 1997). Still farther south, in Aguascalientes, Apache and Arizona pines dropped out, whereas ocote (*P. oocarpa*), nut (*P. cembroides*), and Michoacán (*P. michoacana*) pine were present (Tarango et al. 2001, Márquez-Olivas et al. 2002). Evergreen oaks were prominent in the understory in all of these pine-oak types (Brown et al. 1980, Tarango et al. 1997, 2001, Young et al. 1998, Márquez-Olivas et al. 2002).

In areas where Mexican spotted owls inhabit canyons, canyon and cover types can vary according to geographic region. The following sections provide separate canyon habitat descriptions for the Colorado Plateau, New Mexico portion of Southern Rocky Mountains, and Basin and Range – East Ecological Management Units.

d. Colorado Plateau Ecological Management Unit.—In Utah, the type of incised canyon habitat occupied by spotted owls is present in Dinosaur National Monument, Desolation Canyon,

the San Rafael Swell, Zion National Park, Grand Staircase-Escalante National Monument, Glen Canyon National Recreation Area, Capitol Reef National Park, and Canyonlands National Park. Canyon habitat also occurs in the Dixie, Manti LaSal, and Fishlake National Forests and on large tracts of land managed by the Bureau of Land Management. In Colorado, examples of rocky canyon habitat occur in and around Mesa Verde National Park and on Ute Tribal Lands. In Arizona, similar canyon habitat is present on Navajo Tribal Lands, in Grand Canyon National Park, and in BLM lands (e.g., Paria Canyon).

Willey (1998a, see also Willey and van Riper 2007) studied movements and habitat associations of radio-marked owls in canyon habitat in southern Utah. Radio-marked owls inhabited areas featuring steep cliffs, rocky topography, and canyons with complex vertical and horizontal structure (Willey 1998b). They typically used roost sites characterized by cool daytime temperatures (relative to nearby randomly located sites) and relatively high overhead cover provided by canyon walls and vegetation (Willey 1998b: Table 4-2). Many roost sites had large conifers or deciduous trees nearby, but others were in areas dominated by pinyon-juniper woodland or desert-scrub vegetation (Rinkevich and Gutiérrez 1996, Johnson 1997, Willey 1998b). Tall cliffs and/or small stands of mixed-conifer forest provide the owls with cool microsites for roosts and nests. Although pinyon-juniper woodland was the most common vegetation type present in owl home ranges in Utah and in the Grand Canyon (Bowden 2008), mixed conifer forest, including Douglas-fir and white fir, was present within one-third of habitat plots randomly located within owl home ranges (Willey 1998b). Eighty-eight percent of telemetry locations occurred below the canyon rims (Willey and van Riper 2007). Thus, suitable canyon habitat can include canyon, rim, and adjacent mesa and plateau landscapes (see also Bowden 2008).

e. Southern Rocky Mountains Ecological Management Unit (New Mexico portion).— Within this Ecological Management Unit, spotted owls occur across a wide elevational gradient and occur in both forested mountains and canyons (Johnson and Johnson 1985, Hathcock and Haarmann 2008). Owls are more likely to be found in rocky canyons toward the lower end of their elevational range in this region, and more likely to inhabit forests at higher elevations (where forest cover tends to be more continuous on the landscape; Terry Johnson, pers. comm., 7 Sep 2005). For example, many owls occur in rocky canyons incised into volcanic-tuff at lower elevations in the Jemez Mountain Range in northern New Mexico (Santa Fe National Forest and Bandelier National Monument, Johnson and Johnson 1985). These canyons provide many potholes, ledges, and small caves for owls to use for roosting and nesting (Johnson and Johnson 1985). Owls at higher elevations, both in the Jemez and Sangre de Cristo Mountains, are less restricted to rocky canyon situations but generally still occur in areas characterized by high topographic relief. Even at higher sites in the Jemez Mountains, however, many owls nest in cavities in small outcrops of tuff (Terry Johnson, pers. comm., 7 Sep 2005).

Vegetation in canyon bottoms and on canyon slopes includes species typical of mixed-conifer forest, such as Douglas-fir, white fir, and ponderosa pine. Deciduous species such as cottonwoods (*Populus* spp.), Gambel oak, boxelder, and alder (*Alnus* spp.) also are present in canyon bottoms (Johnson and Johnson 1985). Patches of pinyon-juniper and aspen (*P. tremuloides*) also occur within these canyons. At higher elevations, common species include Engelmann spruce (*Picea engelmannii*), subalpine fir (*A. lasiocarpa*), blue spruce (*P. pungens*),

and limber pine (Hathcock and Haarmann 2008). As in many areas in the northern portion of the owls' range, high-elevation forests appear to contain greater amounts of spruce, true firs, and aspen than the mixed-conifer forests occupied by owls farther south.

f. Basin and Range – East Ecological Management Unit.—Spotted owls in this Ecological Management Unit also occur in both forests and rocky canyons. For example, owls are abundant in mixed-conifer forests within the Sacramento Mountains, but they also have been found in the rocky-canyon networks of the Guadalupe and Davis Mountains in southern New Mexico and West Texas, as well as in Carlsbad Caverns National Park, New Mexico. These canyons contain riparian vegetation and encinal woodlands (Brown et al. 1980). In the latter cover type the dominant non-coniferous trees are evergreens, especially oaks and Texas madrone (*Arbutus xalapensis*). Coniferous trees such as pinyon pine (*P. edulis*), junipers, and ponderosa pine occur in low to moderate densities. Owls in these canyons roost in caves, cliff crevices, or in trees associated with springs or riparian corridors (Bryan and Karges 2001, Mullet 2008). In the Guadalupe Mountains, nest and roost sites occurred in steep, mesic canyons containing big-toothed maple (*A. grandidentatum*), western hop-hornbeam (*Ostrya knowltonii*), Chinkapin oak (*Q. muhlenbergii*), Douglas-fir, southwestern white pine, and Gambel oak (Mullet 2008, Mullet and Ward 2010).

g. Space Use of Resident Owls During the Non-breeding Season.—Resident owls expanded their home range during the non-breeding season in all areas where seasonal home range estimates were available, although the magnitude of this seasonal expansion varied among areas (Table E.3). Clearly, owl home ranges were larger than Protected Activity Centers (PACs) as defined in USDI (1995:84-89). But PAC size was based on the size of owl activity centers, not home ranges. Size of owl activity centers was more comparable to PAC size in the three study areas where estimates were available (Table E.3). Spatial overlap between seasonal activity centers was considerable (Table E.4). In general, non-breeding-season activity centers contained most of the breeding-season activity center. The mean proportion of the non-breeding-season activity center contained in the breeding-season activity center was lower but still indicated considerable spatial overlap. Further, the smaller size of breeding-season activity centers relative to non-breeding-season activity centers effectively limits the possible range for this measure of overlap (Table E.4). Thus, protection of nesting areas provides protection to areas used by resident owls throughout the year, not only during the breeding season.

h. Habitat Use by Resident Owls During the Non-breeding Season.—Little detailed information is available on habitat use by resident owls during the non-breeding season, but there is some evidence for use of more open habitats at this time. For example, Zwank et al. (1994) reported that owls in the Sacramento Mountains roosted in “shorter trees with less dense foliage” during the winter. Willey (1998a:73) reported that “during winter... spotted owls were observed roosting in more open habitats.” In contrast to this trend, however, he also reported that some owls moved out of steep slickrock canyon terrain and into forested uplands during winter. Johnson (1997:49) noted that wintering owls used “...canyons with a north-south orientation dominated by pinyon-juniper woodlands with scattered patches of ponderosa pine.” This latter description included owls classified as both residents and migrants by Ganey and Block (2005a; see also Seasonal Migration section).

In a study of radio-marked owls in pine-oak forests of north-central Arizona, relative areas of cover types did not differ between seasonal home ranges, but relative area in canopy-cover classes did (Ganey et al. 1999). Relative to non-breeding-season ranges, breeding-season ranges contained more area with canopy cover $\geq 60\%$ and less area with canopy cover ranging from 20 to 39%. Structural features of forest stands used by foraging owls did not differ between seasons, but structure of stands used by roosting owls did. Stands used for roosting during the breeding season had greater live-tree basal area, oak basal area, and canopy cover than stands used during the non-breeding season (Ganey et al. 1999: Table 5). In an analysis focused on a finer spatial scale, canopy cover surrounding roost “microsites” also was greater during the breeding than the non-breeding season in this area (Ganey et al. 2000).

Ganey et al. (2000, 2003) also reported on aspects of habitat use by radio-marked owls in the Sacramento Mountains at these same spatial scales (stand and roost microsite). They found little evidence for differences in seasonal habitat use at either scale within the Sacramento Mountains, for either foraging or roosting use.

Thus, there is evidence for shifts in habitat use in some areas, but not in others. In general, evidence for seasonal differences in habitat use appears strongest where owls occupy rocky canyons in the northern portion of their range. In mixed-conifer forests farther south, seasonal differences in habitat use were less pronounced, and patterns were intermediate in an area where owls occupied pine-oak forest. Where resident owls do use different habitats during the winter, available evidence suggests that those habitats generally are more open in structure.

C. Microhabitat Features

a. *Nests and Roosts.*—Mexican spotted owls nest and roost primarily in closed-canopy forests or rocky canyons. In the northern portion of the range (southern Utah, Colorado, and parts of northern Arizona and northern New Mexico) and extreme southeastern portions of the range (Mullet 2008), most nests are in caves or on cliff ledges in steep-walled canyons (Johnson 1997, Willey 1998b, Terry Johnson, pers. comm., 7 Sep 2005). Elsewhere, the majority of nests appear to be in trees (Fletcher and Hollis 1994, Seamans and Gutiérrez 1995, May and Gutiérrez 2002, May et al. 2004), but cliffs and caves can be locally important (e.g., Bryan and Karges 2001, Márquez-Olivas et al. 2002).

Where owls occupy rocky canyons, roost sites typically are located in deep, narrow canyons, often with vertical or near-vertical cliffs (Rinkevich and Gutiérrez 1996, Johnson 1997, Willey 1998b, Bowden 2008, Mullet 2008). Owls in these canyons roost on cliff ledges, cliffs, in caves or potholes, or in trees (Rinkevich and Gutiérrez 1996, Johnson 1997, Willey 1998b, Márquez-Olivas et al. 2002, Bowden 2008, Mullet 2008). Roost trees often are located in canyon bottoms near the base of cliffs. Roosting areas typically occur in narrow portions of canyons (Rinkevich and Gutiérrez 1996, Johnson 1997, Willey 1998b, Willey and Ward 2004, Mullet and Ward 2010) in areas featuring complex geomorphology with numerous caves, ledges, and potholes (Rinkevich and Gutiérrez 1996, Willey 1998b). In the canyonlands of Utah and northern Arizona, these canyons tend to be found in particular rock formations, apparently because these formations are suitable for the formation of canyon systems with the type of structural complexity described (Kertell 1977, Willey 1998b, Bowden 2008).

In forested environments, owls tend to roost and nest in mature or old-growth forests with complex structure (e.g., Ganey and Dick 1995, Seamans and Gutiérrez 1995, Ganey et al. 1999, 2005, Peery et al. 1999, May and Gutiérrez 2002, May et al. 2004). These forests are typically uneven-aged, are multistoried, and have high canopy closure (e.g., Grubb et al. 1997). Where owls occur in younger forests, those forests typically contain large legacy trees (May and Gutiérrez 2002, May et al. 2004). Nest trees are typically large in size (SWCA 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez 1995, May and Gutiérrez 2002, May et al. 2004), whereas owls roost in both large and small trees (Ganey 1988, Willey 1998b, Zwank et al. 1994, Ganey et al. 2000, May et al. 2004).

Tree species used for nesting vary somewhat among areas and habitat types. Douglas-fir is the most common species of nest tree in many areas, particularly areas dominated by mixed-conifer forest (SWCA 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez 1995, Johnson 1997). In pine-oak forests where nesting has been studied in the United States, nests were commonly found in cavities in large oak trees, followed by platforms in ponderosa pine trees (Ganey et al. 1992, SWCA 1992, Fletcher and Hollis 1994, May and Gutiérrez 2002, May et al. 2004). Only one nest has been reported from Mexican pine-oak forest. This nest was in a 30-cm dbh Mexican white oak tree (*Q. polymorpha*, nest structure type not reported; Tarango et al. 1997).

A wider variety of trees are used for roosting, but patterns again vary among forest types and geographic regions. Again, Douglas-fir is the most commonly used species in many areas dominated by mixed-conifer forest (Ganey 1988, Fletcher and Hollis 1994, Zwank et al. 1994, Johnson 1997, Stacey and Hodgson 1999, Ganey et al. 2000). In contrast, owls roost primarily in oaks and pines in areas dominated by pine-oak forests (Ganey et al. 1992, Young et al. 1997, Ganey et al. 2000, Tarango et al. 2001, May et al. 2004, Márquez-Olivas et al. 2002). The most frequently occurring tree species at roost sites in canyons in south-eastern New Mexico and West Texas are big-tooth maple (*A. grandidentatum*), western hop hornbeam (*O. knowltonii*), and chinkapin oak (*Q. muhlenbergii*) (Mullet and Ward 2010).

b. Foraging.—Most studies of foraging habitat are based on triangulated locations of radio-marked owls, because it is impossible to observe foraging behavior of wide-ranging owls at night. Such locations are inherently inaccurate in the types of terrain and forests occupied by Mexican spotted owls (e.g., Ganey et al. 2003). As a result, our understanding of habitat use by foraging owls is limited. Available studies suggest considerable variability in use of foraging habitat, however, both among study areas and among individuals within study areas (Ganey and Balda 1994, Hodgson 1996, Willey 1998b, Ganey et al. 1999, 2003).

Owls in the canyonlands of southern Utah apparently forage primarily in rocky canyons, as 88% of locations of radio-marked owls fell within canyons (Willey and van Riper 2007, Bowden 2008). Specific features of foraging habitats were not reported in these studies. Owls in most forested study areas show some selectivity for foraging habitat relative to randomly available habitat, but the level of selectivity is reduced relative to habitat-use patterns for roosting and nesting. For example, owls typically forage in all forest stands used for roosting but do not roost in all stands in which they forage (Ganey et al. 1999, 2003). Areas used for foraging typically were in closed-canopy forests featuring high basal area of trees and high volume of logs (Ganey and Balda 1994, Ganey et al. 1999, 2003). Structural characteristics of areas used for foraging

differed from those of proximal but random areas in some study areas (Ganey and Balda 1994, Hodgson 1996, Ganey et al. 1999) but were more variable than characteristics of stands used for roosting in all areas (Ganey and Balda 1994, Hodgson 1996, Ganey et al. 1999, 2003). Additional information on variability of the owl's foraging habitat also can be inferred from microhabitat descriptions for the owl's common prey (see Food Habits and Prey Habitat).

D. Summary of Habitat Use

Most studies of how Mexican spotted owls use their habitat have sampled habitat characteristics or otherwise quantified habitat use at relatively fine scales (<0.2 ha, reviewed in Ganey and Dick 1995). As a result, we know relatively little about patterns of habitat use at coarser scales, including structure of forest stands and landscape composition (but see Grubb et al. 1997, Ganey et al. 1999, 2003, Peery et al. 1999, May and Gutiérrez 2002).

Patterns of habitat use vary with owl activity, seasonally, and regionally. For example, owls appear to be far more selective in habitats used for roosting and nesting than in habitats used for foraging (Ganey and Balda 1994, Ganey et al. 1999, 2003). Within areas that contain suitable roosting and nesting habitat, owls forage in a broader array of both cover types and structural conditions (Ganey and Balda 1994, Ganey et al. 1999, 2003). Similarly, selection for particular types of habitats appears to be relaxed during the non-breeding season, when owls wander more widely and use a wider array of habitats, which also tend to have a more open structure. Based on this finding, USDI FWS (1995) explicitly assumed that the presence of suitable habitat for roosting and nesting limited distribution of Mexican spotted owls and primarily based management recommendations on retaining and enhancing such habitat.

a. *Reasons Underlying Habitat-Use Patterns.*—There are several possible mechanisms underlying habitat use and selection by Mexican spotted owls. For example, several hypotheses have been proposed to explain why spotted owls nest and roost in late-seral, closed-canopy forests (reviewed by Carey 1985, Gutiérrez 1985). These include better thermal protection, greater access to prey, protection from predation, and availability of required nesting structures. Information documenting the relative importance of these factors is limited, with the exception of information relating to thermal and prey ecology.

Barrows (1981) suggested that spotted owls are relatively intolerant of high temperatures and roost and nest in shady forests because they provide favorable microclimatic conditions. This explanation seems particularly attractive with respect to Mexican spotted owls, because it provides a unifying explanation for the use of extremes along the habitat gradient that is occupied. Both closed-canopy forests and deep rocky canyons with caves, potholes, and alcoves provide well-shaded and cool microsites relative to surrounding areas, and owls typically use such areas for roosting and nesting (e.g., Ganey and Dick 1995, Seamans and Gutiérrez 1995, Grubb et al. 1997, Willey 1998b, Ganey et al. 1999, 2000, Willey and Ward 2004).

There is empirical evidence in support of this hypothesis in addition to observed patterns of habitat use. Ganey et al. (1993) observed that Mexican spotted owls produced more metabolic heat than great horned owls and were less able to dissipate that heat through evaporative cooling. Teng (1998) compared thermal environments of northern spotted owl roost and random sites in

interior forests in northwestern California and estimated that roosting in randomly sampled areas would increase energy costs for thermoregulation by 5 to 34% per day and evaporative water loss by up to 5% per day relative to the sampled roost sites. Weathers et al. (2001) studied metabolic rate and water flux of California spotted owls in the field using doubly-labeled water. They determined that rates of water flux were high relative to metabolic rates and suggested that minimizing water loss might contribute to the owls' preference for cooler environments. Ganey (2004) sampled thermal environments throughout most of the breeding season (May – Aug) in 30 paired nest and random areas in northern Arizona. Owl nest areas were significantly cooler than random areas, and evaporative water loss modeled for Mexican spotted owls was significantly lower in nest than in random areas.

Potentially conflicting with this hypothesis is the presence of owls in canyons and riparian areas at relatively low elevations (e.g., Willey and Ward 2004, Bowden 2008). Although owls appear to select microsites in these canyons that are cooler than surrounding areas, summer daytime temperatures in some of these areas become quite warm. However, owls may be able to maintain favorable water and energy balance even in warm environments if water and prey resources are readily available in sufficient quantities. The ultimate quality of these sites is unknown, as both vital rates of owls using such sites and availability of prey resources in these sites remain unknown.

Taken together, the above research findings suggest that thermal environments may be important in shaping patterns of habitat selection by Mexican spotted owls but do not rule out other explanations. The same types of structural features that result in cooler microclimates may be correlated with factors such as prey abundance, protection from predators, or availability of nest structures. For example, relatively dense forests with closed canopies and high basal area may provide improved hiding cover for owls in general, especially for inexperienced juvenile owls. Such forests also may provide more and better den structures for small mammals, as well as large, decadent trees that provide suitable nest structures for owls. Similarly, canyon bottoms may be more productive sites for the owl's prey in northern regions of the owl's range (Sureda and Morrison 1998). Individual owls that select roosting and nesting sites that are also closer to other required resources will presumably save energy in acquiring those resources, spend less time away from young, and potentially decrease risk of detection by predators. It seems unlikely that habitat selection is based solely on thermal constraints and more likely that such constraints interact with these other factors (see also Carey et al. 1992, Zabel et al. 1995, Ganey et al. 1997, Ward et al. 1998, Ward 2001, May et al. 2004).

E. Habitat Models

A number of efforts have been made to develop and test predictive models for Mexican spotted owl habitat. These efforts have been conducted independently, and efforts were not coordinated until recently. Although specific objectives and approaches differ among efforts, most have focused on nesting and roosting habitat, because of the apparent importance of this type of habitat in explaining owl distribution (USDI FWS 1995). Efforts and models can be loosely grouped by six sets of investigators; efforts of these groups are discussed briefly below.

a. Terrell H. Johnson.—From 1988 to 2003, T. H. Johnson developed a series of predictive models for Mexican spotted owl habitat. This series of models began with a timber-type model for the Jemez Mountains, New Mexico (Johnson and Johnson 1988, refined and expanded in Johnson 1990). This model predicted availability of suitable habitat within these mountains, based on USFS stage 1 timber inventory data. Johnson and Johnson (1988) reported that the model successfully discriminated owl from random sites and concluded that it could prove useful in other areas with available timber type data.

The timber-type model was superseded by a topographic model of potential owl habitat throughout New Mexico, with model predictions based on topographic characteristics derived from a 1-degree digital elevation model (DEM; Johnson 1993). This model again showed promise for predicting potential owl habitat, and it had the decided advantages that it was based on topographic data available for all land ownerships and might explain owl distribution better in canyon landscapes than did vegetation data. Johnson (2001) tested this model across the range of the owl in the southwestern United States, using a database of owl locations compiled in 1993 in conjunction with recovery planning efforts (Ward et al. 1995). The model generally performed well in New Mexico and eastern Arizona, but accuracy declined along an east to west gradient. Johnson (2001) concluded that a longitudinal function should be included in future models and that such models should be based on higher-resolution topographic data.

Johnson (1996) reformulated the topographic model for higher-resolution 7.5-minute DEM data in northern New Mexico, then added Landsat imagery to a model covering the Los Alamos National Laboratory, New Mexico (Johnson 1998). Later, he developed a geophysical model of potential owl habitat for the southwestern United States (Johnson 2003). This model used the higher-resolution (7.5-min) topographic data and used variables related to winter and summer precipitation to model the east-west gradient observed in tests of the earlier topographic model throughout the southwest (see Johnson 2001). This model performed reasonably well in tests using independent owl locations. The model assigns a potential habitat index to locations, rather than simply defining habitat as suitable or unsuitable, which may allow greater flexibility in using the model. Johnson (2003) noted that coordinates of some of the locations used in model development were inaccurately or imprecisely recorded and that this error hampered the model's ability to discriminate between owl and background sites. He suggested that future models could be improved simply by eliminating spatial error in owl locations and by incorporating additional data resulting from ongoing survey and research efforts on spotted owls.

b. David W. Willey and Colleagues.—D. W. Willey and colleagues also developed and tested a series of GIS-based models based largely on topographic characteristics, with their efforts focused on the canyonlands of the Colorado Plateau. Their initial model identified predicted breeding habitat for owls throughout the state of Utah based on physical landscape features (Willey and Spotskey 1997). The model identified three habitat classes: predicted breeding habitat, predicted marginal habitat, and predicted non-habitat. The model incorporated data on slope, aspect, slope curvature (an index of ruggedness), and crude vegetation (e.g., forest, shrubland, or grassland). This model was designed to predict the general location of breeding habitat across large landscapes, and it was not intended for use at finer spatial scales (Willey 2002a).

Subsequent efforts expanded that modeling effort to cover northern Arizona as well and focused on producing a model that could be used at multiple scales (Willey and Spotskey 2000, Willey 2002a). This model incorporated data on slope, aspect, slope curvature, vegetation at the species association level, surface geology, soil moisture, and an index of surface temperature (Willey 2002a). Tests of this model using different techniques and in different areas suggested that it was useful at identifying owl breeding habitat in canyon landscapes at relatively fine scales (<1:100,000; Willey and Spotskey 2000, Willey 2002b). However, Willey and Weber (2003) noted that predictions generated confusion among land managers, so they developed a third-generation model using finer-grained spatial data. Field tests of this model were conducted during 2004 with mixed results. In several cases, owls were not detected where probabilities of suitable roosting or nesting habitat were predicted to be high. This result could have been due to a year of low occupancy caused by factors independent of habitat suitability, however (e.g., Willey and Willey 2010). A more refined procedure was used in 2005 to generate and select among competing models developed with different geomorphological and vegetation-based variables. Models with the best performance based on two different selection criteria (Akaike's model selection criteria versus a stepwise optimization procedure) produced similar results. In either case, maps based on confidence intervals (e.g., 95% or 99%) for prediction of occupancy could be produced. Percent slope was found to be the most useful variable in predicting owl roosting and nesting habitat regardless of model selection technique. The steepest slopes were identified as the most likely locations to find Mexican spotted owls in the study canyons of Utah.

Willey et al. (2007) further refined this model, again using model selection to rank competing GIS-based habitat models. Model parameters were generated using geomorphological and vegetation-based habitat variables, and habitat associations were identified by comparing occupied and unoccupied sites located during extensive field surveys (Willey et al. 2007). The set of habitat covariates included (1) landscape ruggedness, slope, and complexity (Rinkevich 1991, Willey 1998b); (2) relative surface temperature and presence of cool zones (Rinkevich 1991, Willey 1998b); and (3) vegetation cover, which provides shelter as well as microenvironments for prey species (Ganey and Balda 1989, Willey 1998b, Ganey et al. 2004). Willey et al. (2007) used model averaging across the three top habitat models to produce a predictive equation to identify potential spotted owl habitat in canyon terrain within the Utah study areas. The probability of owl occupancy was strongly and positively associated with percent slope and negatively associated with elevation range and selected vegetation covariates. Field testing included surveys in 487 1-km² test plots with 1,430 calling stations distributed across 22 USGS quad maps during the 2007 field season. Spotted owls were detected in 14 map quads, including 57 owl detections within 22 individual test plots. The mean habitat suitability for the 22 test plots as estimated by the best approximating model was 60% (SD = 25%). In addition, 70% of the owl detections occurred within plots whose average suitability score was >50% and, for the 22 occupied study plots, only six showed habitat suitability less than 50%.

c. Tim Mullet.— In more recent work, Mullet (2008) examined the applicability of the two models described above (Johnson 2003) for predicting occupancy of Mexican spotted owls in the Guadalupe Mountains of southeastern New Mexico and West Texas. This work focused primarily on the zones of high-probability (>75%) of owl occurrence predicted by the two models. The two models produced slightly different maps of predicted habitat, with some (overlapping) areas predicted to contain suitable habitat by both models.

Mullet (2008) used formal occupancy surveys (during a single breeding season, in a random set of 25 2-km² survey cells, each with two to five stations) and modeled detection probabilities and the probability of site occupancy for each survey cell using various covariates. Covariates included the amounts of high-probability predicted habitat from a given model in each cell. Despite being smaller than the area predicted separately by either model, the overlapping area of habitat predicted by both models provided the same level of accuracy and precision as either model separately. This area of overlap between the two models primarily coincided with narrow, steep-walled canyons. Mullet (2008) therefore concluded that both models were useful for identifying habitat that had a high-probability of being occupied, but that the area of overlap of the two predicted habitat maps was much more efficient in predicting habitat that would be occupied by Mexican spotted owls in the Guadalupe Mountains.

d. Joseph L. Ganey and Colleagues.—Efforts by this group focused on National Forest System lands in northern Arizona. In an early effort, Ganey et al. (1990, see also Ganey 1991) used GIS, a DEM, and Landsat multispectral scanner imagery to develop a predictive model for Mexican spotted owl habitat on four National Forests in north-central Arizona. Model output was a spatially explicit map of predicted owl habitat. The model defined suitable owl habitat as occurring where slope was >15% and cover type was dense mixed-conifer, ponderosa pine, or deciduous forest.

Ganey (1991) tested this model at the landscape scale by evaluating agreement between model predictions and independent survey locations of spotted owls (i.e., locations not used in model development). Prediction accuracy generally was high in mixed-conifer forests, intermediate in pine-oak forests, and lowest in rocky-canyon areas.

Ganey (1991) also tested this model using data from eight radio-marked owls representing five territories in three study areas. Owl locations occurred in predicted habitat significantly more than expected by chance at four of these sites. Agreement between model predictions and owl locations was low at the fifth site, where the owls occupied a rocky canyon. He concluded that the model could be used to prioritize general survey areas, and might be useful for identifying specific areas for habitat protection in mixed-conifer forest, but it was not useful at that scale in rocky-canyon landscapes. This relatively crude model was used by forest biologists to prioritize survey areas but was not developed further.

Ganey and Benoit (2002) evaluated the use of Terrestrial Ecosystem Survey (TES) data to identify potential spotted owl habitat on National Forest System lands. TES is a spatially explicit data set that uses information on soils, vegetation, and climatic conditions to define and map a set of ecological Map Units depicting potential vegetation. Using three separate owl data sets (locations from the 1993 survey database [USDI FWS 1995], locations of radio-marked owls, and results from complete surveys of selected quadrats [see Ganey et al. 2004]), they identified subsets of map units that were strongly associated with owl use on three national forests in northern Arizona. These map units generally consisted of mixed-conifer or pine-oak forest, and those most strongly associated with owl use generally occurred on steep slopes containing rocky outcrops. They concluded that, with some caveats, TES data could be used to identify and map potential owl habitat.

e. William J. Krausmann and Colleagues.—This group also focused on National Forest System lands, but their modeling efforts were specifically directed at assessing gross changes in amounts of spotted owl habitat over time (i.e., change detection, Krausmann et al. undated, Mellin et al. 2000). Thus, their efforts focused on products that could be used to monitor changes in amounts of owl habitat over time. They identified forest types “associated” with spotted owls on National Forest System lands in Arizona and New Mexico, using TES (see above) and Generalized Ecosystem Survey data (essentially a coarser-scale version of TES) and USFS timber stand data. They then assessed changes within those vegetation types using two Landsat images acquired approximately five years apart (1991/93 and 1997/98; Mellin et al. 2000).

Approximately 28.2% of National Forest System lands within Arizona and New Mexico were identified as belonging to vegetation units associated with spotted owls. Within those vegetation units, 4.2% underwent some form of vegetation removal or reduction over the five-year period, for an annual rate of change of <1%. Fire was the principal cause of habitat change identified and accounted for 60.5% of the change area. Timber harvest accounted for another 19.2%, with infestations of forest insects or pathogens accounting for 17.3% of the change area.

The conclusions regarding changes in amount of owl habitat obviously depend heavily on the assumptions about which vegetation units were associated with spotted owls. The accuracy of these assumptions, and the resulting classification of “owl-associated” habitat, is unknown. To address this uncertainty, Mellin et al. (2000) also summarized change based on the area contained within owl PACs. This analysis, which included nine national forests that had digitized GIS coverages of PAC boundaries, avoids the need to classify habitats as associated or not associated with owls. Vegetation removal or reduction occurred on 3% of the total PAC area, with 80, 14, and 5% of the change due to fire, mechanical treatments (timber harvest and/or thinning), and infestations of forest insects or pathogens, respectively.

This modeling effort demonstrated that Landsat imagery could be used to detect gross changes in habitats over time, as recommended in USDI FWS (1995). Thus, continued change-detection efforts could form part of a strategy to monitor trend in amounts and spatial distribution of owl habitat. However, no follow-up efforts have occurred, nor are there any plans to conduct follow-up analyses (W. J. Krausmann, pers. comm., Sep 2005). Further, the change-detection analysis focused mainly on obvious loss or reduction in vegetation. Identifying areas that may have matured toward suitable owl habitat during this time frame was beyond the scope of this effort but would obviously be important in a comprehensive effort to monitor trend (including both gains and losses) in owl habitat.

f. Forest Ecosystem Restoration Analysis Project (ForestERA).—The Forest ERA program also developed a predictive model for Mexican spotted owl habitat covering a study area of approximately 8,100 km² (2 million ac) near Flagstaff, Arizona. ForestERA is a collaborative project headquartered within the Center for Environmental Science and Education at Northern Arizona University. They provide data, tools, and analytical frameworks for developing landscape-level strategies for ecosystem restoration, and assessing the impacts and implications of alternative management scenarios (Sisk et al. 2004). This effort modeled spotted owl habitat as one data layer facilitating landscape-level assessments within their Western Mogollon Rim study area (Prather et al. 2005). Their model defined spotted owl nesting and roosting habitat as

areas where the dominant overstory vegetation consisted of pine-oak, mixed-conifer, or ponderosa pine cover types on steep slopes (>12 degrees), and where basal area exceeded 17 m² ha⁻¹ (75 ft² acre⁻¹). They assessed predicted habitat using the Mahalanobis distance statistic and vegetation (tree density, canopy cover, basal area) and terrain (slope, aspect) characteristics around known owl nest sites. This statistic was used to determine how divergent a given location on the landscape was compared to the typical characteristics of the landscape at known nest sites, and it allowed them to assess the likelihood that owls would use a particular area. Preliminary assessments of model accuracy suggested that it successfully predicted the locations of most owl nest and roost sites, despite classifying only about 30% of the assessment area as nest/roost habitat (Forest Ecosystem Restoration Analysis Project 2005).

ForestERA also produced a spatial coverage representing management definitions of Mexican Spotted Owl habitat across the assessment area. This data layer depicted habitat categories as defined in USDI FWS (1995). Categories modeled included protected habitat, restricted habitat, and areas with no specific owl-related guidelines (other forest and woodland types; USDI FWS 1995). This allowed for comparisons of overlap between predicted habitat and areas managed for owls under USDI FWS (1995). Although no quantitative analysis is available, a visual comparison of maps of predicted habitat and management guidelines suggests that (1) areas managed for Mexican spotted owls under USDI FWS (1995) cover less of the assessment area than is predicted to contain nesting and roosting habitat for owls, but that (2) areas managed as protected or restricted habitat for owls generally are predicted to be owl habitat (Figure E.4). ForestERA recently updated this coverage based on definitions in this revised Recovery Plan. Results again indicated that plan recommendations target a relatively small proportion of the study area (approximately 20%; see Part II.E).

g. Other Recent Efforts.— Two other recent efforts focused on developing habitat models at more localized scales. Danzer (2005) used existing data on owl occupancy, fire history, and site characteristics to describe features of Mexican spotted owl territories in the Huachuca Mountains, Arizona. Owl territories were variable, but most occurred in canyons with riparian, mixed-conifer, and oak components, a finding consistent with previous analyses in this region (Ganey and Balda 1989a: Fig. 2, Duncan and Taiz 1992, Ganey et al. 1992, Ganey and Dick 1995: Table 4.1). Hathcock and Haarmann (2008) developed a vegetation-based predictive model for Mexican spotted owl habitat in the Jemez Mountains, New Mexico. Compared to random sites, sites used by owls had greater tree species diversity, tree density, tree height, canopy cover, and shrub density. Again, these features generally agree with other evaluations of owl habitat, both locally and in a broader sense. Model testing suggested that the model performed adequately, and Hathcock and Haarmann (2008) suggested that this model could be used to delineate habitat on a relatively fine scale.

h. Summary of Spotted Owl Habitat Models.—In summary, a number of predictive models have been developed for Mexican spotted owl habitat. Modeling efforts have occurred throughout much of the range and have incorporated many different approaches and objectives (e.g., prediction of breeding habitat versus change detection). These efforts have produced a number of useful products, including maps of predicted habitat for different areas and maps useful in detecting changes in habitat amount or condition. The ongoing efforts by T. H. Johnson and D. W. Willey and colleagues appear to hold considerable promise for future efforts. Both

have the advantage that they are based largely on topographic and/or climatic data that are available for all land ownerships across the range of the owl. Models incorporating topography also appear to hold the most promise for modeling owl habitat in areas such as rocky canyonlands, where topography and geology appear more important in determining owl distribution than vegetation type. The recent work by Mullet (2008) demonstrated the utility of these types of models in predicting occupancy of Mexican spotted owls in the Guadalupe Mountains and how structured validation surveys can lead to a more efficient model. In this case, the overlap between habitat predicted by two models provided the most efficient model (i.e., a model with less predicted habitat to search while conveying the same probabilities of occupancy).

In some areas, however, data on vegetation type and composition may improve models significantly. For example, the model produced by Forest ERA used data on vegetation structure and composition to model nesting and roosting habitat structure. These types of data are not as readily available as topographic data and typically require analysis of satellite imagery to derive useful data layers (Forest ERA 2004). Such data also can be used to detect changes in vegetation structure, however, and this ability would be critical in efforts to monitor amounts and distribution of spotted owl habitat. That is, topographic models can be used to model potential owl habitat but cannot effectively model current owl habitat except in areas where topography is more important than vegetation, such as in the canyonlands.

These habitat models also have produced some useful insights unrelated to their original intent. For example, Ganey and Benoit (2002) noted that TES data identified most of the map units strongly associated with owl use in their study area as not well suited for timber harvest, due to either steep slopes or soil-based considerations. Similarly, comparison of owl-related maps with other maps produced by Forest ERA suggests that there is high overlap between owl habitat, either as predicted by their habitat model or as defined based on protective categories in USDI FWS (1995), and predicted habitat for the northern goshawk (Figure E.5a), a species of special management concern (e.g., Reynolds et al. 1992). Another such comparison suggests that species diversity of breeding birds is generally greater in owl habitat than elsewhere (Figure E.5b). Together, these results suggest that (1) it might be feasible to protect owl habitat while simultaneously minimizing impacts to timber harvest programs, and (2) this protected habitat appears to be particularly important to other wildlife species of interest as well. Finally, the owl habitat coverages developed by ForestERA also allowed Prather et al. (2008) to evaluate potential conflicts between management to reduce fuels and risk of severe wildfire and management to retain spotted owl habitat. This analysis demonstrated that although some conflicts exist between these objectives, their magnitude has been overstated (see also Box E.2). They concluded that the majority of the landscape could be managed to reduce fire hazard without eliminating owl habitat (see also James [2005] for a concurring view).

F. Disturbance Ecology and Owl Habitat

Several disturbance factors can influence Mexican spotted owls through their effects on the owl's habitat. For example, a change-detection analysis focused on Mexican spotted owl habitat (Krausmann et al. undated, Mellin et al. 2000) suggested that wildland fire, mechanical treatments, and forest insects and pathogens (in that order) were key disturbance agents affecting owl habitat. Other potential disturbance agents that may threaten the owl indirectly through

habitat alteration include excessive grazing by ungulates, concentrated housing development or urbanization, and shifts in the distribution of dominant plants and their associations driven by change in climate. All of these disturbance agents may alter habitat structure, reducing the quality or availability of habitat to individual owls. If habitat alteration is extensive, habitat loss can result in negative impacts on spotted owl populations by limiting the number of occupants and their reproduction. Indeed, presumed habitat loss due to timber harvest was one of the factors that precipitated listing the owl as threatened (USDI FWS 1993).

The majority of disturbance agents that can alter Mexican spotted owl habitat are discussed elsewhere in this Recovery Plan (Parts I and II). No studies are available on the specific effects of forest insects and pathogens on this owl's habitat, and only Seamans and Gutiérrez (2007) have evaluated effects of mechanical treatments on the habitat of spotted owls (specifically California spotted owls in the Sierra Nevada Mountains). As a result we know relatively little about the effects of these disturbance agents. However, several studies or analyses have focused on wildland fire, and this disturbance agent appears to have the greatest potential to greatly alter the owl's habitat over vast areas in a relatively short time period (e.g., Krausmann et al. undated, Mellin et al. 2000). Therefore, this disturbance agent and its potential influence on the ecology of Mexican spotted owls warrants specific discussion. There also is limited information about three other disturbances that may influence the owl's habitat: grazing by domestic livestock and wild ungulates, urban development, and shifts in biological communities caused by climate change. Below, we discuss the potential influences of these four disturbance agents.

a. Wildland and Prescribed Fire.—Fire has always been a major disturbance agent in southwestern forests (Swetnam 1990), and Mexican spotted owls co-evolved with this disturbance. However, the structure of southwestern forests, the frequency with which they experience fire, and the types of fires experienced have changed greatly following increased human settlement of these lands (Covington and Moore 1994). These forests evolved with a fire regime characterized by relatively short return intervals, but the advent of effective fire-suppression activities disrupted that cycle. As a result, many southwestern forests have not experienced fire for long intervals. Effective fire suppression and heavy grazing in combination also favored the development of dense stands featuring multiple age classes of trees and heavy loads of ground fuels (Rummel 1951, Madany and West 1983, Savage and Swetnam 1990, Covington and Moore 1994). These changes in fire frequency and forest structure affect fire behavior in southwestern forests. Forests that once were subject to relatively frequent, low-severity wildfires are now more prone to infrequent, high-severity wildfires. Further, these fires are far more likely to reach the forest canopy than in historical times, due to the presence of heavy ground fuels and fuel ladders reaching into the canopy. Once fire reaches the canopy, it becomes very difficult to contain, resulting in a trend toward increasing size of wildfires in the southwest in recent years (USDI FWS 1995:60–61).

Recognizing these aspects of southwestern forest ecology, USDI FWS (1995:82) explicitly recognized stand-replacing wildfire as one of the primary threats to the owls and their habitat, and emphasized that fire management aimed at reducing heavy fuel loads should be given high priority. The underlying assumption was that stand-replacing wildfire would destroy the aspects of stand structure that spotted owls utilize for roosting and nesting.

To better understand how much of the owl's habitat may be impacted by stand-replacing wildfire, the Recovery Team quantified recent trends in burn-severity within 90% of established owl PACs (Box E.2; we were not able to obtain spatial data for the other 10% of known PACs). The analysis showed variability among EMUs and National Forests. The Colorado Plateau EMU, with PACs comprised primarily by canyon cover-types, experienced much lower rates of high-severity fire than PACs in forested environments (Box E.2: Figure 1a). Of the PACs in National Forests within the Southwestern Region, those in the Gila, Lincoln, Coconino, and Cibola National Forests experienced less high-severity fire than those in the Kaibab, Santa Fe, Tonto, Coronado, and Apache-Sitgreaves National Forests. Combined, the regional rate of high-severity fire was 3.7% of the total PAC area burned in 10 years (or approximately 0.4% of PAC area yr⁻¹). Projections of habitat altered by high-severity fire, assuming the rate observed over the last 10 years, indicated that all PAC area would be consumed in three Southwestern National Forests within the next 95 years (Box E.2). Projections assuming twice the observed rate indicated that all PAC area in five Southwestern National Forests would be consumed by high-severity fire in the next 95 years, but that at least 60% of the PAC area on four National Forests would not be altered by high-severity fire within the next 95 years. Thus, even when allowing for a doubling in rates of high-severity fire, considerable owl habitat may escape high-severity fire in the National Forests where the majority of Mexican spotted owls dwell.

BOX B.2.

Rates and Severity of Wildland Fire in Mexican Spotted Owl Habitat

In this plan, we presume that loss of habitat from high-severity wildland fire is a threat to the Mexican spotted owl. Understanding the magnitude of this threat requires knowledge of two basic relationships. First, we need to know the magnitude and rate at which the owl's habitat is burned. Second, we need to know how the owl and its populations respond to the alterations to its habitat caused by wildland fire.

To understand better the potential impact of wildland fire on the owl's habitat (the first relationship), the Recovery Team examined recent trends in fire-severity within PACs. We quantified the number of PACs and amount of PAC area that were burned by different severities of fire over a 10-year period (1996 to 2005) and then used the rate of habitat burned by high-severity fire to project potential future losses of the owl's habitat through 2105 (110 years beyond the release of the 1995 Recovery Plan and 100 years beyond the original 10-year period for estimating rates). The results of this analysis are presented in this Box. Current information regarding responses of spotted owls to fire (the second relationship discussed above) are discussed following this Box.

To estimate the amount of owl habitat burned over the original 10-year period (1996 to 2005), we used geospatial boundaries of PACs to demarcate the habitat most likely to be used by Mexican spotted owls in most of their range, and we used annual boundaries of fires ≥ 405 ha (1,000 ac) to estimate area burned. Fire boundaries were derived from the USGS Monitoring Trends in Burn Severity database (MTBS; <http://mtbs.gov/index.html>), and this database showed only fires ≥ 405 ha. From the intersection of these two sets of boundaries, we estimated amounts and percentages of area (ha) burned annually in our sample set of PACs over the initial 10-year period. We examined PACs from 17 different public land units, including those from 12 National Forests (NF; six in Arizona, five in New Mexico, one in Utah), BLM lands in Utah, and from four National Parks (one in Arizona, three in Utah). The time period was chosen because it followed the release (and hence recommendations) of the original Recovery Plan for the Mexican Spotted Owl (USDI Fish and Wildlife Service 1995) and because burn-severity data were not available beyond 2007.

BOX B.2., continued

Rates and Severity of Wildland Fire in Mexican Spotted Owl Habitat

The MTBS data included five general classes of vegetation burn-severity: 1) unburned or undetected, 2) low-, 3) moderate-, 4) high-severity, and 5) burned, but with unknown severity (Eidenshink et al. 2007).

To project future loss of owl habitat, we used the rates of high-severity fire estimated from the first 10-year period and subtracted the PAC area that would be progressively burned in future 10-year increments, assuming two scenarios. The first scenario assumed that the area burned by high-severity fire was fixed during each 10-year period and equal to the amount of area burned in each land unit during that first 10-year period. In the second scenario, we doubled the area burned in each 10-year period to examine a more extreme situation and to allow for potential increase in high-severity fires from potential changes in climate and subsequent forest conditions. We limited the projection of severely burned habitat to areas where Mexican spotted owls primarily lived in forests (i.e., southwestern National Forests), assuming that owls dwelling in canyons would continue to be much less impacted by high-severity fire (as observed in the results, below). We focused on high-severity fire because it causes the greatest amount of tree mortality, loss of overhead canopy, and alteration in structural attributes that Mexican spotted owls use in selecting nesting and roosting habitat and, hence, in the potential for longer-term loss of that habitat.

Our analysis to estimate burn-severity rates included 1,170 PACs (90% of the 1,301 known site records presented in this plan) and encompassed 328,416 ha (811,188 ac) of the owl's most likely used habitat (Box E.2: Table 1). A total of 35,856 of those habitat hectares (10.9%) burned in 12 of 17 (70.5%) of the land units examined during the 10-year period. The percentage of habitat area burned by any type of fire was less in areas where owls more frequently occupied canyons (Box E.2: Figure 1a). This pattern was most apparent for habitat burned by high-severity fire (forests = 3.7% versus canyons = 0.1% of habitat area burned; Box E.2: Table 1).

Within the 11 southwestern National Forests, no fires >405 ha (1,000 ac) burned in the 15 PACs of the Prescott NF or the two PACs of the Carson NF during 1996-2005. However, we note that in 2002 the Ponil Fire burned 37,247 ha (92,000 ac) on the Carson NF, including potential owl habitat that had not been surveyed for owl presence (S. J. Hedwall, USFWS, pers. comm.). At the other extreme, nearly half of the area in six PACs of the Kaibab NF burned during the same period. The percentage of PAC area that burned by low-, moderate-, and high-severity fire in the nine southwestern NFs during this period ranged from 0.9 to 14.5%, 0.8 to 17.3%, and 0.4 to 16.4%, respectively. The overall rate of high-severity fire across the 11 NFs was 3.7% of PAC area over those 10 years (Box E.2: Table 1). Large-fire years were observed in 2000, 2002, and 2004, but total area burned declined during these successive years (Box E.2: Figure 1a). Amount (area) of owl habitat burned at all three severities generally was correlated with total area burned indicating that large fires burned with a mosaic of severities. Only slight differences were observed in the number of hectares and PACs burned during the initial 10-year period (Box E.2: Figures 1b and c). The SRM, BRW, and UGM showed slightly greater proportions of the owl's habitat burned by high-severity fire compared to that in the BRE and CP (the latter with primarily canyon-dwelling owls). However, variability in amounts of burned habitat was generally great.

BOX B.2., continued

Rates and Severity of Wildland Fire in Mexican Spotted Owl Habitat

Projections under the first and most conservative assumption about future frequency and extent of high-severity fire indicated that loss of the owl's habitat during the next 95 years in the nine southwestern NFs experiencing high-severity fire during 1996 to 2005 could range from 4.4 to 100% of current PAC area per forest (Box E.2: Figure 2a). Projected losses, assuming the constant rate of high-severity fire in each NF for each successive 10-year period, indicated that all habitat area in the six Kaibab NF PACs would be burned at high-severity by 2065, in the 48 Santa Fe PACs by 2085, and in the 74 Tonto NF PACs by 2095. In contrast, < 25% of the habitat area in the combined 434 PACs of the Gila and Lincoln NFs and < 10% of the habitat area in the combined 238 PACs of the Coconino and Cibola NFs was projected to be impacted by high-severity fire. Under the assumed rate of loss in this scenario, and under the extreme assumption that all PAC area burned by high-severity fire would result in abandonment by owls, then 107,252 ha (38.5%) of the known habitat present in the southwestern NFs in 1995 would be lost by 2105.

Under the second scenario, with double the rate of high-severity fire, potential habitat loss during the next 95 years would range from 8.8 to 100% per forest (Box E.2: Figure 2b). Under this worst-case scenario, all originally identified owl habitat would be burned by high-severity fire on the Kaibab, Santa Fe, and Tonto NFs within the next 50 years. In addition, all PAC habitat would burn with high-severity fire in the Coronado and Apache-Sitgreaves NFs by 2095. Despite doubling the original rate of habitat loss through high-severity fire, > 55% of the original habitat area (or a combined total of 452 PACs) would remain unburned by high-severity fire in each of four NFs (Gila, Lincoln, Coconino, and Cibola). These four forests currently have moderate to high numbers of known owl PACs.

Although these projections are based on very simplistic assumptions and forecasts, the analysis is useful for showing that fuel conditions and fire behavior vary by regions and National Forest, probably because of differences in fuel and burning conditions related to elevation, weather, topography, and vegetation. Under the conditions present from 1996 to 2005, our results indicate that owl's dwelling in canyon habitat were least disturbed by high-severity fire and that the National Forests where the majority of owls dwell in the Southwestern Region, USFS (e.g., Gila, Lincoln, and Coconino NFs) experienced lower rates of high-severity fire than did other National Forests within the Region. The observed rates of habitat loss for future time periods are certainly not exact and the amounts of presumed habitat were not offset by restored or newly developed habitat area or by the reduction of fire rates by continuing risk-reduction treatments. Nonetheless, they do suggest that even with an extreme rate of high-severity wildland fire, habitat for Mexican spotted owls will likely remain in critical portions of the range for the foreseeable future, particularly with continued efforts to reduce fuels in forested landscapes. Our results also demonstrate that high-severity fire will not be universal across the range of the Mexican spotted owl or as extreme in some areas as might be presumed. More advanced modeling of fire-behavior at a broader landscape scale (e.g., see Ager et al. 2007, 2010) will certainly provide additional and more refined information on the risk of high-severity fire in owl habitat, and research on owl habitat-use and demographic responses to burned habitat will provide a needed and more comprehensive understanding of the magnitude and ultimate consequences of wildland fire as a threat to this species.

Table B.1. Amount of Mexican spotted owl habitat (PAC area) burned by different severities of fire during 1996-2005.

Main Habitat / Administrative Unit	Total	Total	Total PAC Area (ha) Burned			
	No. PACs	PAC Area (ha)	Low- severity	Mod.- severity	High- severity	Any severity ^a
Forest /						
FS, Coronado NF	107	30,522	4,059	3,785	2,198	10,011
FS, Tonto NF	74	19,117	1,797	1,988	2,007	5,754
FS, Apache-Sitgreaves NF	134	34,962	1,433	909	1,853	4,161
FS, Santa Fe NF	48	13,068	601	745	1,581	2,953
FS, Gila NF	286	75,855	4,551	2,048	1,517	8,192
FS, Lincoln NF	148	37,198	335	335	632	1,414
FS, Coconino NF	183	49,735	647	398	398	1,442
FS, Kaibab NF	6	1,763	256	305	289	850
FS, Cibola NF	55	16,543	232	132	66	430
FS, Prescott NF	15	3,870	0	0	0	0
FS, Carson NF	<u>2</u>	<u>597</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Totals:	1,058	283,229	13,911	10,645	10,542	35,207
% of PAC area:			4.9	3.8	3.7	12.4
<u>% of burned PAC area:</u>			<u>39.5</u>	<u>30.2</u>	<u>29.9</u>	

Table B.1. (Continued).

Canyon /						
NPS, Zion NP	19	8,398	160	118	34	579
FS, Manti-La Sal NF	6	2,391	5	0	0	19
NPS, Grand Canyon NP	41	12,593	0	0	0	50
BLM, Utah	15	6,792	0	0	0	0
NPS, Canyonlands NP	22	9,838	0	0	0	0
NPS, Capitol Reef NP	<u>9</u>	<u>5,175</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Totals:	112	45,187	165	118	34	649
% of PAC area:			0.4	0.3	0.1	1.4
% of burned PAC area:			25.4	18.1	5.2	
All /						
Total burned, by severity:	1,170	328,416	14,076	10,762	10,575	35,856
% of PAC area			4.3	3.3	3.2	10.9
% of burned PAC area			39.3	30.0	29.5	

^a This category includes all PACs and areas that burned, including those that burned with unknown severity. It thus includes all other severity classes as well as areas burned with unknown severity.

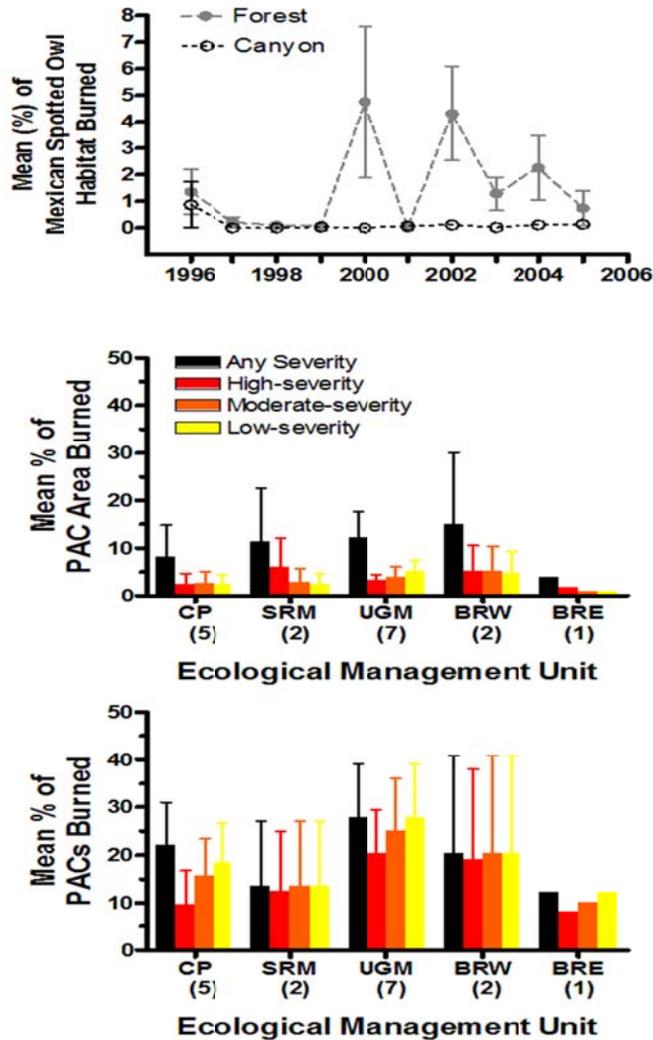


Figure B.1. Mean percentage (\pm SE) of Mexican spotted owl PAC habitat burned in forest or canyon dominated environments annually from 1996 to 2005 (top), or in each Ecological Management Unit over all 10 years (middle and bottom; middle figure shows percent of PAC area burned; bottom figure shows percent of PACs burned). Numbers in parentheses below Ecological Management Unit abbreviations are numbers of land units (e.g., National Forests) averaged to create the bar. CP = Colorado Plateau, SRM = Southern Rocky Mountain, UGM = Upper Gila Mountain, BRW = Basin and Range-West, BRE = Basin and Range-East.

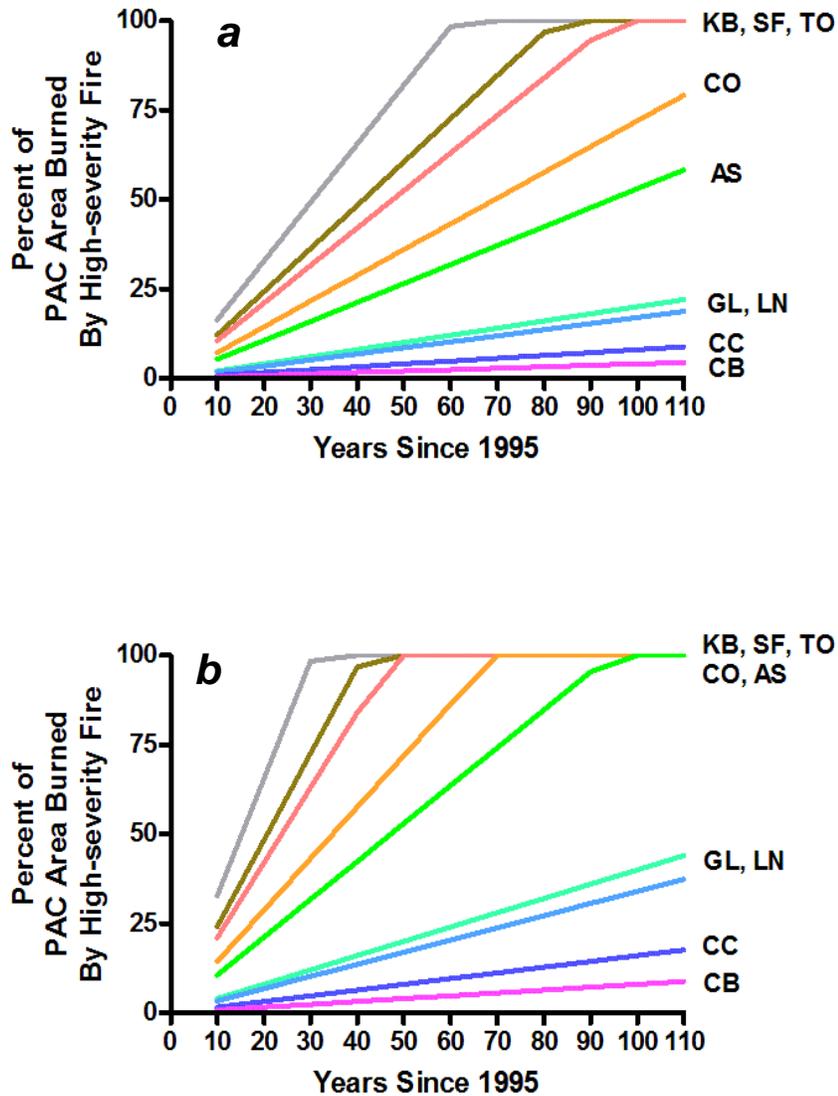


Figure B.2. Percentage of habitat for Mexican spotted owl known in 1996 in nine southwestern National Forests projected to burn by high-severity fire through the year 2105. Two scenarios are assumed. In (a), the amount of area burned in each administrative unit from 1996 to 2005 is also presumed to burn in each successive 10-year period. In (b), twice the original amount of area is presumed to burn in each 10-year time step. National Forests are: AS = Apache-Sitgreaves, CB = Cibola, CC = Coconino, CO = Coronado, GL = Gila, KB = Kaibab, LN = Lincoln, SF = Santa Fe, and TO = Tonto.

The above analysis summarizes only amount of owl habitat experiencing high-severity fire. Understanding the impact of wildland fire on Mexican spotted owls also requires knowledge of the owl's response to fire. Since 1995, several studies have examined short-term effects of fire on Mexican spotted owls. Here, we summarize briefly the important results of those studies and re-evaluate the importance of fire as a threat to owl habitat based on these results. Additional recent studies have evaluated or speculated on fire effects and/or historical disturbance patterns affecting northern and California spotted owls (Elliott 1985, Buchanan et al. 1995, MacCracken et al. 1996, Bevis et al. 1997, Everett et al. 1997, Gaines et al. 1997, Verner 1997, Franklin and Gutiérrez 2002, Irwin and Thomas 2002, Irwin et al. 2004, Lee and Irwin 2005, Clark 2007, Bond et al. 2009). We restricted our evaluation here mainly to studies on the Mexican spotted owl, because of regional variation in fire regimes and the resulting apparent differences in this owl's environment compared to that of the other two subspecies. However, we include results from two recent studies on other subspecies of spotted owls (Clark 2007, Bond et al. 2009) because these studies evaluated fire effects more rigorously than previous studies, and their results have potentially important implications.

To date there have been at least six studies or other evaluations on the effects of fire on Mexican spotted owls. These studies occurred in four Ecological Management Units, in a variety of geographic locations and forest types, and have included both wildfire and prescribed fire. Studies are discussed below in chronological order.

Johnson (1995:5–6) did not study fire effects explicitly but discussed fire and spotted owls in the area impacted by the 1977 La Mesa Fire in the Jemez Mountains, New Mexico (Southern Rocky Mountains Ecological Management Unit). Two territories within the boundary of this fire were occupied more consistently than other territories in the Jemez Mountains in the decade from 1985–1995. Data on owl reproduction were not sufficient to compare reproduction at these territories to other territories within the region, and owls were not marked, so survival data were not available from these territories. Owls were sometimes observed roosting in burned areas and were heard at night in burned areas on the mesa. Thus, at least some territories were occupied following the fire, and owls appeared to forage and occasionally roost in burned areas.

Sheppard and Farnsworth (1997) discussed potential impacts of fire on owls. They estimated that at least 10 Mexican spotted owl territories were impacted by fire in Arizona and New Mexico during the 1994 fire season alone. They further estimated that >20,000 ha (>50,000 ac) of owl habitat experienced stand-replacing wildfire from 1989 to 1994. They did not evaluate patterns of owl habitat use or territory occupancy relative to these fires, however.

Stacey and Hodgson (1997, with clarifications via e-mail from P. B. Stacey to J. L. Ganey; 28 Nov 2004 and 3 Jan 2005) observed spotted owls in the San Mateo Mountains, New Mexico (Upper Gila Mountains Ecological Management Unit), before and after a large wildfire. This wildfire burned through four adjoining owl territories, all of which were occupied by mated pairs prior to the wildfire. The fire began on 5 Jun 1994 and was declared controlled on 31 Jun 1994, although some areas continued to smolder for several months. Burning occurred in a patchy fashion, leaving considerable unburned habitat in all territories. All of the owls were observed within their historical territories later in the summer of 1994, indicating that all survived the fire (six of these eight owls were uniquely color-marked; clarifications via e-mail to J. L. Ganey; 28

Nov 2004). In 1995, Stacey and Hodgson (1997, with clarifications via e-mail to J. L. Ganey; 28 Nov 2004) located one mated pair and two single males within the area covered by the four 1994 territories. The pair consisted of the 1994 male from that territory and the female from the adjacent territory (these owls were color-marked). The other two owls were apparently new, unmarked birds (clarifications via e-mail to J. L. Ganey; 28 Nov 2004). Thus, results suggest that at least four of six marked owls disappeared from 1994 to 1995, overall occupancy declined from eight owls to four owls and from four occupied territories to three occupied territories, and pair occupancy declined from four pairs to one pair. The three occupied territories remained occupied until the end of the study (date unknown), however, and "...the owls in them reproduced at a rate comparable to the other owls in the San Mateos that were not impacted by the fire" (e-mail from P. B. Stacey to J. L. Ganey, 3 Jan 2005).

Willey (1998a) tracked three pairs of radio-marked Mexican spotted owls before and after prescribed burns in Saguaro National Park, southern Arizona (Basin and Range-West Ecological Management Unit). These burns increased canopy edge and structural diversity within stands (Willey 1998a:30–31). They created openings within the forest, but these openings were very small (<1 ha) relative to the size of owl home ranges (125 to 545 ha [310 to 1350 ac] pre-fire; Willey 1998b: Table 6), and no burning was done in the north-slope mixed-conifer forests where owls roosted and nested. Home range and activity centers decreased in size for two of three pairs following the burns, but increased in the third pair. Home range centroids shifted from 100 to 500 m (300 to 1500 ft) for all pairs. However, Willey (1998b) noted that both range shifts and changes in range size could be confounded by changes in nesting status pre- and post-fire and generally regarded these results as inconclusive. Clearly, however, owls continued to use these areas following relatively low-intensity prescribed burns, at least in the short term.

Bond et al. (2002) documented minimum survival and site and mate fidelity for four pairs of color-marked Mexican spotted owls in Arizona and New Mexico (Upper Gila Mountains Ecological Management Unit) after large wildfires (>525 ha [1300 ac]). Fire burned through the nest and primary roost sites in all four territories. Two territories experienced high-severity wildfire over >50% of the territory, one experienced relatively high-severity fire over approximately 40% of the territory, and one experienced primarily low-severity wildfire. Seven owls (87.5%) were known to have survived at least to the next breeding season. Three of the four pairs exhibited both mate and site fidelity, remaining paired and on the same territory. The male from the fourth territory was not re-sighted, and the female survived but did not return to that territory. This territory underwent the greatest burn severity, experiencing high-severity wildfire over 57% of the territory and low-severity wildfire over the remaining 43%. Results were similar for northern and California spotted owls that experienced wildfire on their territories (Bond et al. 2002). Thus, owls studied continued to occupy burned areas, even following relatively high-severity fires. Results further suggested that survival rates and mate and site fidelity in these owls were relatively high in the year following fire.

Jenness et al. (2004; see also Jenness 2000) surveyed historical Mexican spotted owl territories (as delineated by USFS biologists) in 1997 that had experienced some form of fire during the previous four years, and compared owl occupancy and reproduction in these territories to unburned territories that were located nearby and were similar in cover type and topography. They surveyed 33 burned territories and 31 unburned territories in the Upper Gila Mountains,

Basin and Range-West, and Basin and Range-East Ecological Management Units. Extent and severity of fire within these territories varied widely, ranging from prescribed burns to intense wildfires that burned across much of the territory.

In general, unburned territories surveyed had more pairs (55%) and reproductive pairs (16%) than burned territories (39 and 9%, respectively). Burned territories were more likely to contain single owls (21 vs. 16%) and almost twice as likely to be unoccupied as were unburned territories (30 vs. 16%). These differences were not statistically significant, but the significance test had low power due to small samples of sites (Jenness et al. 2004). Two of eight territories (25%) that burned one year prior to surveys were unoccupied, and eight of 25 territories (32%) that burned ≥ 2 years prior to surveys were unoccupied. Owls were present and reproducing in some severely burned sites, however. For example, three sites where $>50\%$ of the territory burned contained reproducing pairs, and a single owl was present at the most severely burned territory. No variables related to fire severity appeared correlated with patterns of occupancy or reproduction. These results again suggest that owls frequently continue to occupy burned areas, at least in the short term, and that some burned areas continue to be occupied even after severe, stand-replacing wildfires. None of the burned territories had $>55\%$ stand-replacing burn within the territory boundary delineated by USFS, however, so pockets of habitat remained in all cases. Further, because owls were neither radio- nor color-marked in this study, it is not known if the birds present after fires were the same birds present before the fires.

Recently, Clark (2007) studied territory occupancy, survival, reproduction, and habitat use by northern spotted owls in both burned and unburned landscapes in southwestern Oregon. Territory occupancy rates declined rapidly following wildfire, and survival rates for owls inhabiting burned areas were lower than rates for owls in unburned forests; no differences were observed between productivity of owls in burned and unburned landscapes. Owls did use burned areas, but they generally selected for either unburned forests or forests that burned with low severity and had little or no overstory canopy mortality (Clark 2007:112).

Bond et al. (2009) monitored movements and habitat use of radio-marked California spotted owls from four territories in the southern Sierra Nevada, California, four years following a large wildfire. Owls nested in all four territories, but only one pair was successful, fledging a single young. Two nests were located in moderate-severity burned mixed-conifer forest: one in low-severity burned mixed-conifer forest and one in unburned mixed-conifer-hardwood forest. Owls roosted selectively in low-severity burned forest, avoided moderate-severity and high-severity burned forest, and used unburned forest in proportion to availability. Within 1 km of their nest, owls foraged selectively in all severities of burned forests and avoided unburned forests. These results collectively suggest that post-fire landscapes contained enough suitable habitat to support pair occupancy and at least attempted nesting. They further suggest that burned areas may provide benefits to foraging owls. Bond et al. (2009) concluded that assessments of fire impacts should not assume that all fires have negative impacts on spotted owls and recommended that burned forests within 1.5 km of spotted owl roosts or nests not be salvage-logged.

In addition to these studies, there are numerous anecdotal observations of Mexican spotted owls occupying territories following wildfires and prescribed burns, as well as evidence of radio-marked owls moving into and foraging in burned areas during winter (Paul Boucher, Gila

National Forest retired, pers. comm.; Shaula Hedwall, USFWS, pers. comm., J. P. Ward and J. L. Ganey, unpublished data). Most wildfires burn in a patchy nature and leave pockets of useable habitat for owls, and owls appear able to locate and use these patches. Thus, Mexican spotted owls appear to be somewhat resilient to wildfire, at least in the short term. However, we have no data on long-term effects of these fires on occupancy patterns or on components of Mexican spotted owl fitness such as survival and reproduction, and the little data available from other subspecies is not entirely consistent (Clark 2007, Bond et al. 2009). Further, the effect of fire likely varies greatly with spatial pattern. That is, fires that burn most of a territory likely have a greater effect than fires that burn only portions of a territory, and fires that burn in a patchy mosaic likely have less effect than fires that burn with high severity throughout a territory. Similarly, fires that burn favored roosting and nesting habitat likely have a greater effect than fires that burn only foraging habitat. In the latter case, Bond et al. (2009) suggest that effects on owls may be largely positive by increasing prey access in areas proximal to nests or roosts (see Prey Habitat below), but results from Clark (2007) do not entirely support this view. Finally, spotted owls in general show high site fidelity (Gutiérrez et al. 1995). Because of this, owls might continue to occupy burned territories even if the habitat was degraded considerably. Thus, long-term data on owl demography, with information on the spatial pattern of fire severity and owl habitat use will be required to fully understand the effects of fire on spotted owls.

b. Grazing.—Intensive grazing by domestic livestock and wild ungulates can create a short to moderately long disturbance to vegetation that provides cover and food to the owl's prey, and it can influence both tree regeneration and dynamics and composition of understory vegetation in forests occupied by owls. Based on distribution of prey species and regional variation in the owl's diet (e.g., Ward and Block 1995), portions of the owl's range that are most susceptible to this kind of disturbance include regions where spotted owls commonly consume voles, hunt near the edges of montane meadows allocated as key grazing areas, or where domestic livestock are found grazing on forested slopes or in riparian habitats within canyons used by Mexican spotted owls.

Only one study has specifically addressed effects of grazing on spotted owls. This study examined small mammal abundance and diversity in adjacent grazed and ungrazed transects in two owl territories in the canyonlands of southern Utah. Both woodrat abundance and overall small mammal species diversity were greater in ungrazed than in grazed transects (Willey and Willey 2010). There also is circumstantial evidence that grazing may affect prey abundance and thus indirectly affect owls. The primary evidence here comes from (1) studies on impacts of livestock on plant communities and the features of those communities that influence prey populations (described below under Prey Habitat), and (2) the influence of abundance of various prey species or groups of species on the owl's feeding habits and reproduction (described below under Diet and Prey Selection, and Effects of Prey on Vital Rates). For example, species such as voles (and, to a lesser extent, woodrats) that are highly dependent on herbaceous plants for cover, food, and water are found in much lower abundance where drought combines with excessive grazing. These species can provide important contributions to owl diets in some regions and years (Ganey 1992, Ward and Block 1995, Seamans and Gutiérrez 1999, Ward 2001). Current evidence suggests that small mammal biomass (including voles and mice) drives spotted owl reproductive output. Hence, grazing can negatively influence owl abundance indirectly by decreasing populations of key prey species.

c. Urbanization.— Urbanization and land development can affect Mexican spotted owls both directly and indirectly. Development and urbanization can affect owls directly where suitable habitat is lost, or indirectly through effects on either ecological integrity or management practices. No studies have directly examined the effects of land development on Mexican spotted owls, so the extent of potential impacts remains largely unknown. Impacts may be significant, however. For example, an analysis of the effects of interspersed urban land development on the amount and availability of habitat suitable for California spotted owls demonstrated that such development could reduce the amount of suitable habitat by more than 50% over a 40-year period (Manley et al. 2009).

Development impacts may vary by area. For example, in some areas spotted owls occur in landscapes with small amounts of private land, whereas other populations occur in landscapes with far greater amounts of private land. Presumably, development impacts will be greater in landscapes with larger amounts of private land, although some forms of development may have greater impacts than others. Development impacts also may depend on spatial location. For example, development in suitable nesting habitat may be more detrimental than development in foraging habitat at the periphery of a home range, and development in key stepping-stone (see Landscape Connectivity, above) or wintering areas (see Seasonal Migration, below) may be more detrimental than similar development in areas that are not as important spatially. Finally, development can exert indirect impacts by affecting management policies and decisions. For example, managers may more aggressively reduce forest fuels and canopies in areas adjacent to private lands than in more remote areas, and these activities may negatively impact habitat quality for Mexican spotted owls. For a broader discussion of types of development and potential impacts to spotted owls, see Part I.C.2.a.xi.

d. Climate Change.— Climate change is the shift in previous long-term and wide-ranging patterns in meteorological parameters that are used to characterize weather. Climate and resulting weather patterns drive most ecological processes. Unfortunately, the science on ecological effects of climate change is just beginning to emerge, thus assessments of the effects on the spotted owl are speculative and based on circumstantial information. The emerging phenomenon of climate change has the potential to impact Mexican spotted owls in three general ways:

- directly, through impacts on key physiological processes like thermoregulation and water balance,
- indirectly, through similar impacts on desired prey species, and
- indirectly, by causing shifts in physical limits that control distribution of other animal or plant species that create biological communities that influence the owl.

Mawdsley et al. (2009) discussed these effects as: (1) shifts in the distribution of biological communities along elevational or latitudinal gradients; (2) direct loss of habitat due to increased fire frequency, bark beetle outbreaks, and direct warming of habitats; (3) effects on demographic rates, such as survival and reproduction; (4) reductions in population size; (5) changes in coevolved interactions, such as prey-predator relationships; and (6) increased population or range expansion of species that are direct competitors. In this section, we discuss topics 1 and 2. Topics 3-6 are discussed below under Population Ecology.

e. Shifts in Distribution.—Shifts in Mexican spotted owl distribution could occur in response to predicted warming in the Southwest region that may cause elevational and latitudinal shifts in tree species distribution. Predicted warming and drying in the American Southwest may cause both latitudinal and elevational shifts in tree species distribution, as well as tree species extinctions at higher elevations (Dale et al. 2001, Mueller et al. 2005, DeGomez and Lenart 2006, Archer and Predick 2008). Over a long period of time the shift in plant communities could result in shifts in the distribution of both the owl and many of its important prey species. Exactly how these shifts will play out remains unknown. But some tree species and forest types currently present may be lost or greatly reduced in extent, especially where such species or communities occupy the upper elevations of island mountain ranges. For example, Mexican spotted owls occur in mixed-conifer and pine-oak forests at the tops of many of the Sky Island ranges in Arizona and New Mexico. Conifers within the Sky Islands of southern Arizona may be eliminated as temperatures increase and snowpack runoff decreases (Archer and Predick 2008). Loss of these forest types in these mountains presumably would eliminate or greatly reduce habitat for owls in these ranges. This in turn would greatly reduce landscape connectivity for Mexican spotted owls, likely reducing population viability as well (e.g., Keitt et al. 1995, 1997, Barrowclough et al. 2006, see also Ganey et al. 2008).

In contrast, however, these species also may migrate northward in response to changing climate, and/or Cordilleran (Rocky Mountain) species could be replaced by species with more Madrean affinities (such as Apache or Chihuahua pines, or various species of evergreen oaks). We are aware of efforts to model and map shifting distributions of major southwestern conifers in relation to various climate-change scenarios, but results of these efforts have not yet been published. It seems likely, however, that loss of tree species or shrinkage in species' range extent will outpace colonization by new species in the face of rapid climate change. Further, spotted owls frequently inhabit late-successional forests, and it will take considerable time for such forests to develop even if appropriate tree species are able to colonize new areas. Thus, at least in the short term, spotted owls likely will face reductions in habitat extent and greater fragmentation of suitable habitat within their current range. Such possible shifts in distribution of owl habitat argue for preserving management options in areas not currently occupied by spotted owls, but where climate and tree species distribution models predict that owl habitat could develop in the future.

f. Direct Loss of Habitat.--Mexican spotted owls also may experience direct loss of or alteration of habitat due to other climate-induced disturbances such as heat stress to plants, increased fire frequency, and insect outbreaks (e.g., Ayres and Lombardero 2000, Dale et al. 2001, Breshears et al. 2009, Floyd et al. 2009, van Mantgem et al. 2009, Allen et al. 2010). For example, over multi-century periods, increased and decreased activity of spruce budworms coincided with wetter and drier periods, respectively (Swetnam and Lynch 1993, Ryerson et al. 2003), and bark beetle outbreaks have caused considerable tree mortality during a recent drought (e.g., Raffa et al. 2008, Negrón et al. 2009, USDA FS 2009). Increasing levels of drought, along with associated insect outbreaks and wildfires, could rapidly and dramatically affect the distribution, amount, and composition of spotted owl habitat. Finally, increasing temperatures may increase the prevalence of wildfire, both alone and in concert with other disturbance agents such as insects and disease (e.g., Dale et al. 2001, McKenzie et al. 2004). How resilient owls and their habitats will be to these types of disturbances remains unknown.

5. Prey Ecology

Understanding a predator's food choices along with the natural and life history of its common prey species can provide practical information for conserving and enhancing the predator's habitat. This section provides information on the owl's common prey species. Although the strong link between raptors and their food is well documented (e.g., Newton 1979), few studies have quantified the relationships among spotted owls, their prey, and the environmental factors that influence the availability of favored prey to this owl (Noon and Franklin 2002).

A. Hunting Behavior

Forsman (1976) described spotted owls as “perch and pounce” predators. They typically locate prey from an elevated perch by sight or sound, then pounce on the prey and capture it with their talons. Spotted owls also have been observed capturing flying prey such as bats, birds, and insects (Verner et al. 1992, Duncan and Sidner 1990). They hunt primarily at night (Forsman et al. 1984, 2004; Ganey 1988), although infrequent diurnal foraging has been documented (Forsman et al. 1984, Laymon 1991, Sovern et al. 1994, Delaney et al. 1999a).

B. Diet and Prey Selection

Numerous studies have provided information on diets of Mexican spotted owls based on examination of prey remains from regurgitated pellets (see summary in Ward and Block 1995, also Johnson 1997, Young et al. 1997, Willey 1998a, Seamans and Gutiérrez 1999, Ward 2001, Block et al. 2005, Bravo-Vinaja et al. 2005). Mexican spotted owls consume a variety of prey throughout their range but commonly eat small- and medium-sized rodents such as woodrats, mice, and microtine voles (Ward and Block 1995: Table II.5.7). Mexican spotted owls also consume rabbits, bats, birds, reptiles, and insects.

The diet of Mexican spotted owls varies by geographic location (Ward and Block 1995: Figure II.5.2). For example, woodrat consumption by Mexican spotted owls is far greater where owls occur in rocky canyons (e.g., southern Utah, Rinkevich 1991, Willey 1998) than where owls occur in dense forests (e.g., the Sacramento Mountains, New Mexico; Ward 2001). In contrast, spotted owls occupying mountain ranges with forest-meadow interfaces take more voles than in other areas (Ganey 1992, Ward and Block 1995: Figure II.5.2, Ward 2001). Regional differences in the owl's diet likely reflect geographic variation in prey abundance and habitats of both the owl and its prey. Forsman et al. (2001) documented similar spatial variation in a regional analysis of diets of northern spotted owls.

Ward and Block (1995) retrospectively examined the link between abundance or consumption of specific prey and successful reproduction by Mexican spotted owls in the Sacramento Mountains, New Mexico (Basin and Range-East EMU). They were not able to demonstrate strong relationships, but fecundity of spotted owls in this region appeared to be most associated with trends in abundance of peromyscid mice during the time period studied (Ward and Block 1995). Seamans and Gutiérrez (1999) also did not observe strong relationships between number of young produced and the proportion of biomass of any particular prey species consumed by Mexican spotted owls in two populations, one in northern Arizona and another in west-central

New Mexico. This does not necessarily mean that owl reproduction is not linked to prey abundance, however. More likely, it reflects difficulty in documenting that link using opportunistic sampling of prey remains without knowledge of prey abundance or prey selection (i.e., the ratio between amounts in the owl's diet and availability, Ward 2001:Chapter 3). As in other studies of this owl's diet, small mammals comprised > 88% of dietary biomass, and, according to biomass consumed, woodrats were relatively important prey to owls in both populations (Seamans and Gutiérrez 1999).

Ward (2001) expanded on the work in the Sacramento Mountains summarized in Ward and Block (1995), incorporating data from additional years. In this study, five species of rodents (deer mouse [*P. maniculatis*], brush mouse [*P. boylii*], Mogollon vole [*M. mogollonensis*], longtailed vole [*M. longicaudus*], and Mexican woodrat [*N. mexicana*]) provided from 53 to 77% of the diet by frequency and from 41 to 66% of the diet by biomass over a six-year period (1991 to 1996). Mean number of spotted owl young produced annually over this period was most strongly correlated with the combined available biomass of mice and voles. More intriguing was that consumption of woodrats was proportionally lower in the Sacramento Mountains owl population than in seven other populations of spotted owls that were studied, and temporal variability in owl reproduction was inversely related to the proportion of woodrats in the diet across these eight populations (Ward 2001: Figure 4.7). Based on this finding, and the dominance of woodrats in the diet throughout much of the owl's range, Ward (2001) suggested that woodrats likely were an important prey type for spotted owls in many geographic areas.

In rocky-canyon habitats in southern Utah, Willey and Willey (2010) examined prey abundance and owl diet composition within three owl territories. Owl diets were dominated (>80% of biomass consumed) by woodrats in this area. The first years of this study (2000 to 2003) coincided with a period of severe drought, followed by significant increases in local precipitation from 2004 to 2006. Rodent populations on three trapping grids showed strong increases in species richness and abundance during increasingly wetter study years. Spotted owl reproduction was low during the 2000 to 2003 dry period, and by 2003 only males were detected at the sites. All three sites were re-colonized by females during the period of increased precipitation from 2004 to 2006, and reproduction increased during this period. This study was observational and did not necessarily document cause-and-effect relationships, and inference is limited by small sample size. Nonetheless, results suggested that precipitation influenced site occupancy and reproductive rates of owls indirectly by increasing prey abundance (Willey and Willey 2010).

C. Prey Habitat

Understanding habitat relationships of important prey species can provide additional information relative to foraging behavior and ecology of a predator. Habitat correlates of the owl's common prey emphasize that each prey species uses unique microhabitat features (Ward and Block 1995, Sureda and Morrison 1998, 1999, Ward 2001, Block et al. 2005) and that these features may vary among vegetation types (Sureda and Morrison 1999). In general, deer mice appear relatively ubiquitous in distribution, occupying areas with variable conditions, whereas brush mice are more restricted to communities with a strong oak component and dry, rocky substrates with sparse tree cover (Block et al. 2005). Mexican woodrats typically occur in areas with considerable shrub or understory tree cover, low grass cover, high volumes of large logs, and/or

presence of rock outcrops (Sureda and Morrison 1998, 1999, Ward 2001, Block et al. 2005). In the canyonlands of southern Utah, Mexican woodrats were captured only in rocky canyons (Sureda and Morrison 1998, 1999), where radio-marked owls concentrated foraging activity (Willey and van Riper 2007). Mogollon voles occur in areas with high herbaceous cover, primarily grasses, and longtailed voles are associated with high herbaceous cover, primarily forbs, many shrubs, and limited tree cover (Ward 2001). Thus, to provide a diverse prey base, managers can provide a diversity of habitats for prey species when designating PAC boundaries or manipulating vegetative conditions in recovery habitat. Managing habitat for a diversity of prey species may help buffer against population fluctuations of individual prey species and provide a more constant food supply for the owl (Sureda and Morrison 1998, Ward 2001, Block et al. 2005).

Ward (2001) suggested that longer-term (50-year) management aimed at increasing late-seral conditions of mixed conifer forest should favor increased abundance of woodrats, and that increasing woodrat abundance would be more successful for recovering spotted owl populations than management aimed at increasing abundance of mice. This conclusion was based on the demonstrated inverse association between consumption of woodrats and temporal variability in the owl's reproduction across eight populations of spotted owls (Ward 2001:Figure 4.7). Given the relationships among key habitat variables and common prey abundance, shorter term management also should include fostering good to excellent conditions in key grazing areas (e.g., montane meadows) to ensure adequate vole populations near and within owl foraging areas. Of the common prey species examined, mice were considered less manageable because their abundances were correlated with habitat attributes that were much more difficult to manipulate (e.g., seed mast and rocky slopes; Ward 2001: Chapter 2). In contrast, vole numbers likely could be increased by managing for increased cover and height of grasses and forbs (Ward 2001), and woodrat numbers might be increased by promoting shrub diversity and increasing cover of large logs (Sureda and Morrison 1999, Ward 2001, Block et al. 2005). Because microhabitat features associated with small mammal species can vary among geographic regions and habitats within regions (Ward and Block 1995, Sureda and Morrison 1999, Block et al. 2005), management for small mammals may require site- or at least habitat-specific knowledge about relationships between mammal abundance and habitat features.

Habitat conditions for the owl's prey, access to those prey, and abundance of these prey species can also be changed by fire. Indeed, differences among areas in composition of prey communities may at least partially explain the apparent inconsistent response of spotted owls to fire (discussed above). To date, adequate long-term studies of small mammal populations have not been conducted to determine effects on of fire on many of the owl's prey species. Results of short-term studies suggest that individual small mammal species respond differently to fire, and that small mammal response is driven more by remnant understory composition and response than by fire severity itself (Kyle and Block 2000, Converse et al. 2006a, 2006b, 2006c), although severity can strongly influence understory composition.

6. Population Ecology

Knowing how and why populations change over time is a fundamental requisite for forecasting and developing strategies for species recovery. The change in size of any population during a

specified time period can be represented with the simple equation,

$$N_{t+1} = N_t - D_t + B_t + I_t - E_t$$

where N_t is the population size at time t , D_t is the number of individuals dying, B_t is the number of new individuals produced in the population (births), I_t is the number of individuals immigrating into the population, and E_t is the number of individuals emigrating from the population. The combined effect of births, deaths, immigrations, and emigrations dictate the viability of the population, and hence its long-term persistence. Three of these parameters for Mexican spotted owl populations, abundance, survival, and reproduction, are discussed below in greater detail. Knowledge regarding immigration or emigration is provided under the topic of dispersal because of the importance of inter-population movements to metapopulation structure and persistence.

A. Abundance

a. Density.—The number of individuals in a population (or population size, N) divided by the area used by those individuals is known as density. The most reliable estimates of Mexican spotted owl density come from mark-resighting data analyzed with closed-population estimators (e.g., Pollock et al. 1990). These procedures provide for estimating the probability of detecting individual owls and ultimately for correcting the sample count of owls to more truly reflect population size. Unfortunately, only one study has been implemented for the primary purpose of estimating density of Mexican spotted owls, and that study, although geographically extensive, was limited to a single year. By surveying and marking owls in a stratified-random set of 25 quadrats across the Upper Gila Mountains Ecological Management Unit (range in quadrat size = 43.7 to 76.4 km²), Ganey et al. (2004) estimated that 2,941 (Coefficient of Variation = 36.6%) territorial adult or subadult owls occupied this Ecological Management Unit (excluding tribal lands, which were not included in the sampling frame). Density of adult and subadult owls within individual quadrats ranged from 0 to 0.44 territorial owls km⁻².

Using a different study design, Seamans et al. (1999) reported from 0.026 to 0.075 territorial females km⁻² in a 585-km² area in northern Arizona and from 0.055 to 0.099 owls km⁻² in a 323-km² area in west-central New Mexico over the period from 1991 to 1997 (densities calculated from data in their Figure 1). Density of territorial females was consistently greater in the New Mexico population during this period. The study area in Arizona included large areas of ponderosa pine and ponderosa pine-Gambel oak forest interspersed among mixed-conifer forests, whereas the study area in New Mexico was dominated by mixed-conifer forest. Seamans et al. (1999) suggested that the greater density of Mexican spotted owls in the New Mexico study area was a function of the greater relative amount of mixed-conifer forest found in that study area.

Two other studies have used sample counts within fixed quadrat areas without estimating detection probabilities (Skaggs and Raitt 1988, 1995, Young et al. 1998). Ward et al. (1995) reanalyzed data from Skaggs and Raitt (1988) for the Sacramento Mountains, New Mexico. They reported mean densities of 0.275 owls km⁻² for six 23.1 km² quadrats dominated by mixed-conifer forest, 0.080 owls km⁻² for six quadrats dominated by ponderosa pine forest, and 0.022 owls km⁻² for six quadrats dominated by pinyon-juniper woodland. These results provide some idea of variation in abundance among areas that differ in habitat composition, without the confounding variation associated with time (all quadrats were surveyed in one year).

Young et al. (1998) reported densities for five randomly selected 70-km² quadrats surveyed in Chihuahua Mexico. The counts of territorial owls ranged from 0.055 to 0.111 owls km⁻² in the five quadrats. Vegetation composition was not described for individual quadrats but 71% of the overall area surveyed consisted of pine-oak forest, with pure pine and mixed-conifer forest comprising 17% and 12% of total area, respectively.

Densities of Mexican spotted owls in canyonlands have yet to be reported. As a reference point for estimates reported above, density of northern spotted owls in a study area containing large core areas of late-seral mixed-evergreen forest (perceived to be relatively high-quality habitat for these owls; Franklin et al. 2000) was 0.272 owls km⁻² in 1993 (Franklin unpublished data cited in Ward and Block 1995). Caution must be exercised in comparing densities among study types and different sized sampling areas, however. Size and shape of the bounded area can influence the calculation of density in small study areas, and if simple counts are not corrected by detection probabilities, results are further confounded if those probabilities differ between/among areas. But collectively, the above studies suggest that mixed-conifer forests support higher densities of Mexican spotted owls than areas dominated by other vegetation communities.

To date, three ecological factors have been associated with Mexican spotted owl density. These include vegetation composition (discussed above), the degree of topographic relief (greater relief corresponds to greater density; Ganey et al. 2004), and fecundity from two years prior to a given density estimate (higher fecundity results in greater density in subsequent years; Seamans et al. 1999). These factors may not act independently. Furthermore, although relative density among various forest-cover types or other categories is of interest, density alone can be a misleading indicator of habitat quality (Van Horne 1983). For example, Seamans et al. (1999) reported greater density in their New Mexico study area than in their Arizona study area, yet demographic rates were greater in the Arizona study area (see below). Consequently, it is important to assess demographic parameters such as survival, reproduction, or especially rate of population change, when attempting to define habitat quality (see Environmental Variation and Vital Rates).

b. Temporal Population Trends.—A fundamental parameter that describes population change is lambda (λ) or annual (finite) rate of population growth. Population trends can be shown as plots of density or population size over time and quantified as the average change in population size or mean λ during that period. Only a single study has been conducted long and effectively enough to quantify trends in Mexican spotted owl abundance and population change (Seamans et al. 1999, updated in Gutiérrez et al. 2003).

Based on estimates of vital rates and a Leslie stage-projection matrix model, Seamans et al. (1999) reported declining populations for two study areas in Arizona and New Mexico. Although the years covered by these estimates were not stated explicitly, the declining trends were supported by estimates of annual abundance-based counts of owls from 1992 to 1997 (Seamans et al. 1999: Figure 4). Gutiérrez et al. (2003) updated information on estimated trends in owl numbers (λ) for these study areas from 1993 to 2000. In the Arizona study area, mean λ (0.995, 95% confidence interval = 0.836–1.155) indicated a stable population (i.e., $\lambda \approx 1$) over this period. In contrast, the population of Mexican spotted owls from the New Mexico study area appeared to be declining (i.e., $\lambda < 1$) by approximately 6% per year during this period (mean λ = 0.937, 95% confidence interval = 0.895–0.979). However, analytical methods used in this 2003

report differed between the two study areas (see Gutiérrez et al. 2003 for details) and differed from the methods used by Seamans et al. (1999). These differences in methodology complicate interpretation of the difference in observed trends between study areas and/or time periods.

Gutiérrez et al. (2003) also provided point estimates of “realized change.” This measure uses consecutive annual estimates of λ to estimate the proportion of the initial population remaining in a given year, yielding a parameter that is more easily interpreted than λ (Franklin et al. 2004). They estimated that the owl populations remaining in their Arizona and New Mexico study areas in the year 2000 were 69.1 and 60.8% as large, respectively, as the 1993 populations. In other words, they estimated declines of >30% in both populations from 1993 (the first year in which they could estimate λ) to 2000.

Stacey and Peery (2002, see also Stacey 2010: Table 35.1) also reported declining trends in owl populations in the Black Range and Zuni, San Mateo, and Magdalena Mountains, New Mexico, based on data from 1991 to 1999. Declining trends were evident in all ranges studied, as well as when populations from these ranges were combined for an overall analysis (overall $\lambda = 0.803$, 95% confidence interval = 0.73 to 0.89). Populations in the Zuni and Magdalena Mountains apparently declined to zero during the study. Some re-colonization occurred in both ranges, but the populations were unstable, with territories typically occupied for only a year or two before becoming vacant again (Stacey 2010). Stacey (2010:615-616) also suggested that earlier (probably prior to 1994) local extinctions occurred in the Sandia and Manzano Mountains, and possibly in the Datil and LaDronnes Mountains, New Mexico. Seamans and Gutiérrez (2006; see also Seamans and Gutiérrez 2007 for effect of mates on breeding dispersal) suggested that spotted owls may use presence of conspecifics as cues in settling and therefore may be slow to re-colonize areas where they are locally extirpated (or even greatly reduced in number).

c. Temporal Trends in Occupied Sites.—Depending on the nature of the sampling design, time trends in the number or proportion of sites occupied in a study area can provide a surrogate index for trends in population numbers (MacKenzie et al. 2003). Studies of site occupancy through time that do not survey enough area to allow for detecting newly colonized or re-colonized sites will always show a decline, however.

There have been three studies that provide trends in number or proportion of sites occupied by Mexican spotted owls that may also be indicative of population trends. Johnson (2000) reported on occupancy of spotted owl territories in the Jemez Mountains, New Mexico from 1979 to 2000, with more formal monitoring conducted since 1989. Number of territories included in these annual estimates varied among years (maximum number in a year was 28 territories; average number monitored since 1989 was 20 territories), as did methodology (e.g., early estimates were based on passive listening surveys rather than calling surveys). Results suggest that occupancy rates declined from 1985 to 1989 and have been fairly stable since 1989 (Johnson 2000: Figure 1). Declines may have occurred earlier than 1985, but the change in methods makes it difficult to tell. By 2000, 14 of the 28 territories were known to be occupied by at least one spotted owl and eight of those territories were occupied by pairs.

Using a retrospective analysis of survey data gathered in the Sacramento Mountains of southern New Mexico, Lavier (2006) estimated the proportion of sites occupied by Mexican spotted owls

following procedures recommended in the population monitoring section of this Recovery Plan. These procedures (see also MacKenzie et al. 2003) enhance estimation of site occupancy by also estimating and incorporating probabilities that owls are detected. Lavier's (2006) study showed a dynamic but generally stable or slightly declining pattern of site occupancy by territorial owl-pairs in the Sacramento Mountains from 1989 to 2004. Estimated site occupancy by pairs in this population ranged from a high of 85.4% (SE = 0.03%) in 1992 to a low of 54.4% (SE = 0.05%) in 2000. Site occupancy was estimated at 71.0% (SE = 0.05) in 2004, the last year of the study.

In rocky-canyon habitats in southern Utah, Willey (2010) conducted occupancy based surveys for spotted owls at 47 historic territories in Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and on Cedar Mesa (Bureau of Land Management) from 2007-2009, following methods in MacKenzie et al. (2003). He classified owl territories as occurring either in xeric (Grand-Staircase and Capitol Reef) or mesic (Zion and Cedar Mesa) canyon habitat. Mesic sites included patches of mixed-conifer and riparian forest, whereas xeric sites were dominated by desert scrub vegetation. Estimated year one site occupancy at territories was 92% (SE = 0.075%) at the mesic sites and 47% (SE = 0.10%) at xeric sites. AIC-based selection of models of occupancy rate supported a model with detection probability constant across years and a strong habitat effect indicating that occupancy rates differed between mesic and xeric territories. Re-colonization rates also differed between habitats, with re-colonization rates more than twice as great at mesic territories, compared to xeric territories. Thus, Zion and Cedar Mesa populations experienced high occupancy and re-colonization rates, whereas the xeric study sites showed low rates of occupancy and re-colonization. Numerous additional xeric sites located in Capitol Reef and the Paria River that were occupied during the 1990s (Willey 1998, 2007) were no longer occupied during surveys conducted during 2007 and 2008, suggesting that populations in xeric locations may have declined in southern Utah.

In summary, data on trends in populations or occupancy rates are sparse, and methods and sample sizes differ among studies, making comparisons difficult. In general, however, results suggest that most populations of Mexican spotted owls studied either have declined in the recent past or are still declining. Further, some evidence suggests that owls may be slow to re-colonize areas where such declines have occurred (Seamans and Gutiérrez 2006, Stacey 2010, Willey and Willey 2010).

B. Life History Strategy

In general, the life history of the Mexican spotted owl appears similar to those of the better-known northern and California subspecies. These owls are characterized by high and reasonably constant adult survival rates, low juvenile survival rates, and relatively low and highly variable reproductive rates (e.g., Noon et al. 1992, Franklin et al. 2000, 2004, Blakesley et al. 2001, Gutiérrez et al. 2003, LaHaye et al. 2004, Anthony et al. 2006). This life history strategy allows owls to reproduce when conditions are favorable and to survive unfavorable periods with little or no reproduction, a strategy that has been coined "bet-hedging" (e.g., Boyce 1988, Franklin et al. 2000).

However, the Mexican spotted owl also differs from the other subspecies in important respects. In northern and California spotted owls, the population appears to contain numbers of non-

territorial “floaters” (Franklin et al. 2000, 2004; Franklin. 2001). These floaters fill vacancies in the territorial population, so that the territorial population remains relatively stable even during periods with little or no reproduction. In contrast, available evidence suggests that few such floaters exist in populations of Mexican spotted owls. Specifically, vacated territories may remain empty for years, and when territory vacancies are filled they are generally filled by subadult rather than older owls, suggesting that there is not a population of surplus owls unable to find vacant territories. As a result, population trend tracks changes in reproduction with a short time lag (Seamans et al. 1999, Gutiérrez et al. 2003). Because reproduction in this owl is inherently variable (see Reproductive Biology and Rates, below), we can thus expect to see large variability in owl populations over time. Much of this temporal variability likely relates to large-scale climatic patterns, which also are inherently variable within the range of the Mexican spotted owl.

C. Reproductive Biology and Rates

Like many temperate-zone *Strix* owls, Mexican spotted owls form a monogamous pair-bond for reproducing during a relatively set season of each year. The reproductive process is opportunistic during that season, and success is dependent in part on the physiological condition of the female and availability of prey (Hirons 1985, Gutiérrez et al. 1995). The typical chronology for successful reproduction entails (1) reformation of the pair bond, courtship and nest selection, copulation; (2) egg-laying, incubation, and brooding of young (all referred to as nesting); and finally (3) rearing of young outside of the nest.

Knowledge of the annual reproductive cycle of the Mexican spotted owl is important both in an ecological context and for placing seasonal restrictions on management or other activities that may occur within areas occupied by spotted owls to minimize disturbance to nesting owls. In Arizona, courtship begins in March with pairs roosting together during the day and calling to each other at dusk (Ganey 1988). Eggs typically are laid from late-March to mid-April. Incubation begins shortly after the first egg is laid and lasts approximately 30 days. Only the female incubates the eggs. During incubation and the first half of the brooding period, the female leaves the nest only to defecate, regurgitate pellets, or receive prey delivered by the male, who does most or all of the foraging (Forsman et al. 1984, Ganey 1988, Delaney et al. 1999). This phenology may vary slightly throughout the range of the owl and from year to year, depending on weather conditions during winter and spring.

Mexican spotted owls nest on cliff ledges, stick nests built by other birds, debris platforms in trees, and in tree cavities (e.g., Ganey and Dick 1995, Gutiérrez et al. 1995, Seamans and Gutiérrez 1995, Johnson 1997, Willey 1998a, May et al. 2004). Spotted owls have one of the lowest clutch sizes among North American owls (Johnsgard 1988, Gutiérrez et al. 1995). Females normally lay one to three eggs, two being most common, and four being observed rarely (LaHaye 1997, Gutiérrez et al. 2003). Re-nesting following nest failure is unusual but has been observed in Mexican spotted owls (Kroel and Zwank 1992, Gutiérrez et al. 1995).

The eggs usually hatch in early- to mid-May (Ganey 1988). Female spotted owls brood their young almost constantly for the first couple of weeks after the eggs hatch but then begin to spend time hunting at night, leaving the owlets unattended for up to several hours (Eric Forsman, FS,

Corvallis, OR, pers. comm., Delaney et al. 1999). Nestling owls generally fledge from early- to late-June, roughly four to five weeks after hatching (Ganey 1988). Owlets usually leave the nest before they can fly, jumping from the nest to surrounding tree branches or the ground (Forsman et al. 1984, Ganey 1988). Owlets that end up on the ground often will climb, using talons and bill, up an understory tree to a safe roost site. The mobility and foraging skills of owlets improve gradually during the summer. Within a week after leaving the nest, most owlets can make short, clumsy gliding flights between trees. Three weeks after leaving the nest, owlets can sustain flapping flight and hold and tear up prey on their own (Forsman et al. 1984). Fledglings depend on their parents for food during the early portion of the fledgling period. Hungry owlets give a persistent, raspy “begging call,” especially when adults appear with food or call nearby (Forsman et al. 1984, Ganey 1988). Begging behavior declines in late August, but may continue at low levels until dispersal occurs, usually from mid-September to early October (Arsenault et al. 1997, Ganey et al. 1998, Willey and van Riper 2000). Ward and Salas (2000) found that young of the year typically remained within a 40-ha (100-ac) area around the nest tree prior to 1 August.

Mexican spotted owls breed sporadically and do not nest every year (Ganey 1988, Gutiérrez et al. 1995, 2003, White et al. 1995). In good years, much of the population will nest, whereas in some years only a small proportion of pairs will nest successfully (Fletcher and Hollis 1994, Gutiérrez et al. 1995, 2003). For example, during 12 years of study in Arizona and New Mexico (Gutiérrez et al. 2003), 63.6% of owl pairs nested in a given year, on average (SE = 8.91; range = 9.1 to 100%, $n = 19$ to 45 owl pairs monitored per year), and 74.6% of those pairs nesting fledged young (SE = 8.61, range = 0 - 100%). Reasons for this pattern of sporadic breeding are unknown, but temporal variation in food resources and weather are suspected to influence both the proportion of pairs nesting and the proportion fledging young (see Environmental Variation and Vital Rates, below).

Annual reproductive output of Mexican spotted owls, defined as the number of young fledged per pair, varies both spatially, temporally, and by age-class (Seamans et al. 1999, Johnson 2000, Ward 2001, Gutiérrez et al. 2003, Stacey 2010). Fecundity, the number of female offspring produced per female in a population, is half of the value for reproductive output when the sex ratio in the offspring is 50:50. Similar to other spotted owl subspecies, average reproductive rates are generally low in Mexican spotted owl populations (Table E.5) and rarely exceed 1 young per pair per year, although higher rates may occur in some years (Ward 2001). However, average annual reproductive output in Mexican spotted owl populations can be as great as 1.4 young per pair (Ward 2001). Although all three subspecies of spotted owls exhibit temporal fluctuations in reproductive success, the amplitude of those fluctuations is generally greatest for the Mexican spotted owl (Ward 2001: Figure 4.7; see also reviews in White et al. 1995, Burnham et al. 1996, Franklin et al. 2004; Anthony et al. 2006). Adult individuals usually have higher reproductive rates than subadults (Table E.5).

D. Survival Rates

Annual survival is defined as the probability of an individual surviving from one year to the next, or as the proportion of individuals in a population that will survive from one year to the next. Survival rates of spotted owls typically are estimated either by marking individuals with leg-bands and documenting their presence through re-sighting in a spatially explicit population

through multiple years (e.g., Forsman et al. 1996), or by intensively monitoring fates of radio-marked owls over shorter periods of time.

Gutiérrez et al. (2003) estimated apparent annual survival rates of Mexican spotted owls over a 10-year period on two study areas in Arizona and New Mexico, using mark-resighting methodology. Estimates of adult survival were comparable to estimates derived using similar methods for northern (Anthony et al. 2006) and California (Franklin et al. 2004) spotted owls, and to estimates from radio-marked owls (Tables E.6 and E.7). In contrast, estimates from four other populations in New Mexico were slightly lower (Table E.7, Stacey and Peery unpublished data).

Mark-resighting estimates of survival may be biased low if owls in these age classes emigrate from study areas (Zimmerman et al. 2007). Such emigration does not appear to be common, but Gutiérrez et al. (1996) reported one long-distance movement that may represent an example of adult dispersal, Arsenault et al. (1997) noted apparent subadult dispersal in Mexican spotted owls, and Duncan and Speich (2002) reported instances of “temporary and permanent emigration in response to fire altered habitat.” Survival rates based on monitoring of radio-marked owls also could be underestimated if radios affect survival. Evidence on whether or not radios or their attachment affect survival of spotted owls is equivocal (e.g., Paton et al. 1991, Foster et al. 1992).

Estimates of juvenile survival rates are considerably lower and more variable than estimates for adult survival (Table E.7). Mark-recapture estimates of juvenile survival could be biased low if (1) substantial numbers of owls emigrate from the study area, or (2) a lag of several years occurs before marked juveniles reappear as territory holders, at which point they are first detected for recapture (White et al. 1995). As in all spotted owl subspecies, juvenile Mexican spotted owls have a high dispersal capability (Arsenault et al. 1997, Ganey et al. 1998, Willey and van Riper 2000). Consequently, a substantial portion of marked juveniles may emigrate from the study areas. This may explain why the apparent survival of juveniles was lower for the smaller New Mexico study area than for the larger Arizona study. Concerning the second point, available data (see Dispersal, below) indicates that most Mexican spotted owls settle in the first three years of life, suggesting that a bias in survival estimates caused by time lag in detection may not be large.

Estimates from radio-telemetry studies also suggested low juvenile survival rates (Ganey et al. 1998, Willey and van Riper 2000). Biases in radio-telemetry estimates of juvenile survival can result if radios significantly affect their survival, or if these studies were conducted during time periods with lower than usual survival (e.g., a period of low prey availability). As noted above, evidence for effects of radios on survival of spotted owls is equivocal (Paton et al. 1991, Foster et al. 1992). However, at least one of the radio-telemetry studies (Ganey et al. 1998) may have occurred during a period generally unfavorable for owls. Seamans et al. (1999) estimated fecundity and survival rates of owls over a seven-year period in two study areas, one of which overlapped with the study area in Ganey et al. (1998). The two years in which radio-marked juveniles were studied (1994 and 1995; Ganey et al. 1998) also had the lowest fecundity estimates within that seven-year period in both study areas (Seamans et al. 1999: Figure 2), and two of the three lowest estimates of adult survival (Seamans et al. 1999: Figure 3). Similarly, the two years of the juvenile dispersal study conducted by Ganey et al. (1998) corresponded with the

lowest recruitment rates estimated by Gutiérrez et al. (2003: Figure 7a) in their Arizona study area. Collectively, these findings suggest a generally unfavorable period for owls. As a result, estimated survival rates may not be representative of survival rates during more favorable periods.

In summary, considerable uncertainty exists concerning survival rates of Mexican spotted owls, and especially concerning juvenile survival rates. Despite that uncertainty, the available estimates are useful as qualitative descriptors of the life-history characteristics of Mexican spotted owls. Accordingly, Mexican spotted owls exhibit high adult and relatively low juvenile survival. In this respect, point estimates of Mexican spotted owl survival probabilities appear similar to those of both northern (Burnham et al. 1996, Anthony et al. 2006) and California (Franklin et al. 2004, LaHaye et al. 2004) spotted owls. However, it is important to note that the temporal variability of survival rates of Mexican spotted owls appears greater than that of the other subspecies (Gutiérrez et al. 2003).

E. Environmental Variation and Vital Rates

Conservation and recovery of wildlife populations requires information about the factors that influence rates of population growth. This entails knowledge of environmental and human-induced agents that influence the owl's reproduction, survival, and ultimately abundance over time. Several studies on northern and California spotted owl populations have examined sources of variation in associated vital rates (i.e., survival and reproduction; Franklin et al. 2000, 2004, Olson et al. 2004, Blakesley et al. 2005, Dugger et al. 2005, Anthony et al. 2006). However, only one study of two Mexican spotted owl populations has been conducted long enough (11 years) to examine rigorously sources of variation in both survival and reproduction (see Seamans et al. 2002, Gutiérrez et al. 2003). Another study (Ward 2001) was only able to examine influences of environmental variation on reproductive rates, and this study also was of shorter duration (six years in length). Here we briefly summarize some pertinent patterns in variation of vital rates, then discuss some specific environmental factors that may cause change in survival and reproduction of Mexican spotted owls.

a. *Types of Variation in Vital Rates.*—Spotted owls show considerable temporal and spatial variation in vital rates (Franklin et al. 2000, 2004, Ward 2001, Gutiérrez et al. 2003, Anthony et al. 2006). Franklin et al. (2000) found that climate explained all of the temporal process variation (variation due to ecological process rather than variation due to sampling) in vital rates of a northern spotted owl population, and habitat conditions explained most of the spatial process variation. This is intuitively logical: forest habitat conditions vary considerably over space but little over short time intervals such as annual breeding cycles of owls. Thus, we would expect habitat conditions to be linked to spatial variability in survival and fecundity, but not to short-term fluctuations in these vital rates. We also should expect that the magnitude of effects from various sources on spotted owl vital rates will differ among regions because environmental factors that can influence those rates also will vary (for example, see Ward and Block 1995, LaHaye et al. 2004).

Temporal and spatial variation in vital rates of two Mexican spotted owl populations studied by Gutiérrez et al. (2003) was roughly 2 to 5 times greater than in the population studied by

Franklin et al. (2000). In addition, Gutiérrez et al. (2003) found that temporal variability in fecundity was far greater than temporal variability in survival for these populations.

b. Effects of Weather on Vital Rates.— Both survival and reproduction of Mexican spotted owls can be influenced by weather. However, with the exception of the direct influence of overheating or chilling of young, most effects will be manifested through the interaction between energetic demands and food supply. Both thermoregulation and prey availability can be influenced by physical environmental variables determined by regional climate, such as temperature and precipitation.

Seamans et al. (2002) modeled the influence of climate-related factors on temporal variation in vital rates, and Gutiérrez et al. (2003) expanded this effort to include models of spatial variation. Both vital rates appeared to be influenced by precipitation, but the nature of the relationship varied between study areas. In Arizona, a moisture index (the Palmer Z index) explained much of the temporal variation in both owl survival and fecundity. In New Mexico, the best approximating model included rainfall from the previous monsoon season (Jul – Sep) but explained little of the temporal process variation in fecundity and none of the variation in survival. Survival varied more spatially than temporally in these populations (Gutiérrez et al. 2003). The examined habitat covariates explained little of the spatial variation in owl vital rates for either study area.

Ward (2001) examined factors that might influence reproductive potential (number of young produced in a territory relative to the maximum number of young that could be produced) of Mexican spotted owls in southern New Mexico. Several *a priori* models were developed and compared. These models included different combinations of covariates describing climate, cover type, and available prey biomass over a six-year period. He found that (1) models including factors describing climate or prey availability were better predictors of owl reproductive potential than models that included only habitat variables; (2) models that included factors related to both weather and prey availability were better predictors than models that included only weather or prey availability; and (3) models that included availability of prey aggregated among species were better predictors than models that included availability of single prey species. However, these models explained relatively little of the observed variation in owl reproductive potential and the strongest correlation observed was between a different measure of reproduction (reproductive output) and available biomass of mice and voles ($r = 0.77$, $P = 0.07$, $n = 6$ yrs).

Lavier (2006) studied the influence of temporal variation on aspects of site occupancy by Mexican spotted owls in the Sacramento Mountains, New Mexico. Winter precipitation was negatively correlated with site extinction, whereas spring precipitation was positively correlated. Both monsoon and winter precipitation were positively correlated with site colonization, while spring precipitation was negatively correlated with colonization. She suggested that spring, winter, and monsoon precipitation may influence probabilities of site extinction or colonization through their effects on Mexican spotted owl survival and reproduction, respectively, and concluded that variability in weather had a greater influence on site occupancy than spatially related habitat effects (see next section). As noted earlier (see Diet and Prey Selection, above), weather also appeared to influence owl territory occupancy and productivity in the canyonlands

of southern Utah indirectly by influencing prey abundance and diversity (Willey and Willey 2010).

c. *Effects of Habitat on Vital Rates.*— Expanding on their study of temporal variation and Mexican spotted owl vital rates, Gutiérrez et al. (2003) included models of spatial variation in habitat. They found that survival varied more spatially than temporally in two populations studied (one in northern Arizona and the other in west-central New Mexico), but the habitat covariates examined explained little of the spatial variation in owl vital rates for either study area.

Lavier (2006) evaluated amounts and spatial patterns of forested patches in areas occupied by Mexican spotted owls in the Sacramento Mountains, New Mexico. Few spatially explicit habitat variables were significantly correlated with rates of site extinction or colonization or the probability of site occupancy. Amounts and spatial arrangement of landscape habitat features showed no apparent influence on site extinction probabilities, but amount of interior forest and the density of interior forest patches within a site had a positive effect on site colonization, and amount of meadow habitat had a negative effect. In general, habitat variables appeared to influence site occupancy less than weather variables (see above section).

d. *Effects of Prey on Vital Rates.*— Several studies have shown that successfully breeding northern and California spotted owls consume more large prey (e.g., woodrats) than pairs that do not breed successfully (Barrows 1987, Laymon 1988, Thraillkill and Bias 1989, White 1996, Smith et al. 1999). However, this relationship did not hold in all studies of northern spotted owls, even in areas where this owl is known to select for larger prey like dusky-footed woodrats (Ward et al. 1998, Forsman et al. 2001). Similarly, successfully breeding Mexican spotted owls in northern Arizona and west-central New Mexico did not consume larger prey than non-breeding pairs (Seamans and Gutiérrez 1999). These inconsistent results may reflect the fact that diets are quantified from pellets gathered opportunistically, which may not adequately represent the diet of individual pairs of owls, or they may represent true regional and temporal variation in the owl's food habits and associations with reproduction.

Reproduction and survival of Mexican spotted owls are more likely a function of total prey biomass consumed by these owls than of the biomass of any single prey species (Ward and Block 1995, Ward 2001). Most predators are opportunistic and will shift to taking alternative prey when preferred prey species are not as available. In Ward's (2001) study in the Sacramento Mountains of southern New Mexico, Mexican spotted owls appeared to prefer Mexican woodrats, but the amount of woodrats consumed was not correlated with owl reproduction. Rather, owl reproductive output across six years of study was correlated with the combined biomass of two species of peromyscid mice and two species of voles in approximated home ranges of the owl. Ward (2001) suggested that woodrats may be selected for by Mexican spotted owls because they provide a consistent staple for survival, and individual owls must survive before they can reproduce. Reproduction in this population, however, occurred when mice and voles were more abundant. Thus, in this landscape, overall prey biomass exerted more influence on the owls' reproduction than did the abundance of any single prey species. Seamans and Gutiérrez (1999) reached a similar conclusion for Mexican spotted owls, and Rosenberg et al.

(2003) cautioned that simple prey-relationship models were unlikely to account for the highly synchronous temporal patterns observed in reproduction by northern spotted owls.

When comparing multiple spotted owl populations across the species range, Ward (2001) also demonstrated that the proportion of woodrat biomass in the diet was inversely related to temporal variation in reproductive output by spotted owls. Mexican spotted owls in the Sacramento Mountains, New Mexico, consumed the lowest proportion of woodrat biomass and showed the highest variation in young produced over time (Ward 2001: Figure 4.7). Two other populations of Mexican spotted owls, one in northern Arizona and one in west-central New Mexico (Seamans et al. 1999), consumed moderate amounts of woodrat biomass. These populations showed less variation in reproductive output than the population in the Sacramento Mountains but higher variation than recorded for northern spotted owls dwelling in northwestern California (Franklin et al. 2000). Based on these results, Ward (2001) suggested that management aimed at increasing woodrat abundance might reduce temporal variation in owl reproduction.

As noted earlier (see Diet and Prey Selection), prey abundance and diversity, as mediated by precipitation, also appeared to influence owl territory occupancy and productivity in the canyonlands of southern Utah indirectly, presumably by influencing food availability (Willey and Willey 2010).

Despite concerted efforts to understand the influence of environmental variation on owl vital rates, considerable uncertainty remains. Limited or inconsistent evidence indicates that temporal variation in owl vital rates is influenced directly by climate-related factors, especially precipitation, and by prey availability. Because estimated vital rates appeared responsive to precipitation several months prior to the estimation period, Gutiérrez et al. (2003) speculated that precipitation influences vital rates through an indirect mechanism that might involve precipitation influencing primary productivity, prey population dynamics, and ultimately owl vital rates, and work in southern Utah appeared to support this hypothesis (Willey and Willey 2010). However, when examined over the short-term and in a different study area and owl population (Ward 2001), these pathways were not supported by empirical data. That is, each of several common prey species showed different associations with precipitation, temperature, and abundance of different plant species, and they demonstrated asynchronous population dynamics. Key interactions among climate, microhabitat condition, and food will influence energy and water balance of individual members of spotted owl populations but these more complex interactions have not been quantified due to lack of long-term or experimental study. We still have much to learn about how these more complex interactions are related to vital rates of Mexican spotted owls.

E. Mortality Factors

Several mortality factors (discussed below) have been identified as potentially important with respect to the Mexican spotted owl. Remains of a number of radio-marked owls have been recovered following mortality and examined by both field biologists and laboratory personnel, but most owls simply disappear. Further, cause of death often is difficult to impossible to determine even for owls that are recovered, depending on the circumstances of the recovery.

Consequently, we know little about the extent or relative importance of factors that cause mortality.

Most known mortality of territorial adult and subadult owls occurred from November through February (Ganey and Block 2005a), suggesting that most mortality occurs during the winter months for territorial owls. In contrast, mortality was observed in juvenile owls even before they left their natal areas (late September through October). Mortality rates were high during the early dispersal period (October and November), and mortality was observed throughout the year (Ganey et al. 1997, Willey and van Riper 2000).

Some of the factors discussed below can influence owl populations by impacting reproduction in spotted owls as well as by causing mortality directly. To reproduce, individuals must not only survive to a breeding period, but also have sufficient energy resources to produce and rear offspring. Thus, owl abundance can be influenced not only by factors determining the number of owls surviving to breed, but also by factors determining how many of those owls obtain sufficient energetic resources to allow breeding.

a. Predation.—Predation may be a common mortality factor of spotted owls, accounting for at least five of 11 deaths documented among radio-marked adult and subadult Mexican spotted owls (Table E.7), and 14 of 29 documented mortalities of radio-marked juveniles (Ganey et al. 1998: Table 1 and Willey and van Riper 2000: Table 1). Predation may account for more deaths than indicated, because cause of death is often unknown. The specific predator is typically unknown. Procyonid mammals were observed attempting to raid cliff nests occupied by spotted owls in southern Arizona (Russell Duncan, Southwestern Field Biologists, Tucson, Arizona, pers. comm.), suggesting that they may prey on spotted owls. However, avian predation is suspected to be the main form of predation. Potential avian predators of Mexican spotted owls include great horned owls (*Bubo virginianus*), northern goshawks (*Accipiter gentilis*), red-tailed hawks (*Buteo jamaicensis*), golden eagles (*Aquila chrysaetos*), and barred owls (where they are sympatric; Leskiw and Gutiérrez 1998). Some of these predators occupy the same general habitats as the spotted owl, but there is little direct evidence that they prey on spotted owls (Gutiérrez et al. 1995). Ganey (1988) reported one instance of apparent great horned owl predation on an adult spotted owl, and Richard Reynolds (USFS, Fort Collins, Colorado, pers. comm.) observed a golden eagle preying on a spotted owl. Results from radio-marked Mexican spotted owls indicate that all age classes are preyed upon (Ganey 1988, Ganey et al. 1998, 2005, Willey 1998a, Willey and van Riper 2000).

b. Starvation.—Starvation may be another common source of mortality (Table E.7). Starvation has not been observed in many deaths of adult and subadult owls (Table E.7), and generally occurred in mid-winter (J. L. Ganey, unpublished data). In contrast, starvation apparently accounted for 15 of 29 documented deaths of radio-marked juveniles, and occurred throughout the dispersal period (Ganey et al. 1998: Table 1; Willey and van Riper 2000: Table 1). Juvenile spotted owls may be more vulnerable to starvation than adults because of their poor hunting skills (Gutiérrez et al. 1985, Miller 1989, Ganey et al. 1998, Willey and van Riper 2000). Starvation also could result from low abundance or availability of prey, which could affect both adults and juveniles, and which is most likely to occur from late fall through winter when prey resources generally are reduced in abundance (Ward 2001, Block et al. 2005: Figure 1). In

addition, starvation may predispose young or even adults to predation (see Ganey et al. 2005). When starvation occurs in resident adults due to low prey populations that are regionally synchronous, this form of mortality can influence a number of owls at one time. When low survival is combined with lack of reproduction, population decrease can be rapid. There is evidence that this occurs in some Mexican spotted owl populations (Seamans et al. 1999, Ward 2001).

c. Accidents.—Accidents may be another mortality factor. For example, in some portions of their range, Mexican spotted owls have been viewed perched on the ground or on fence posts adjacent to roads (J. P. Ward, pers. comm.) and there are documented cases of spotted owls being hit by cars (Roger Skaggs, Glenwood, New Mexico, pers. comm.; Russell Duncan, Southwestern Field Biologists, Tucson, Arizona, pers. comm., J. L. Ganey, unpublished data). The type of roads at which mortalities of spotted owls occurred ranged from unpaved forest roads to paved highways. Owls flying at night also might collide with power lines, tree branches, or other obstacles. This might be particularly true for birds migrating or dispersing through unfamiliar terrain (Martin 1986). Little information is available either on how frequently this might occur, or when it occurs. Again, starvation or at least hunger could predispose owls to accidents if it drives them to hunt along roadsides, in unfamiliar areas, or in weakened condition.

d. Disease and Parasites.—Little is known about how disease and parasites affect spotted owls. A northern spotted owl found dead was diagnosed with an infection by a relapsing fever-like *Borrelia* species (Thomas et al. 2002). The mechanism of exposure was unknown. The principal vectors known to transmit similar diseases are soft-bodied ticks, making transmission by nest-dwelling parasites a possibility. However, direct transmission through predation may be more likely, as small rodents, which constitute the primary food of spotted owls, serve as reservoirs for relapsing fevers (Thomas et al. 2002). Until more is known about the means of transmission, the potential importance of this disease with respect to spotted owls is unknown.

One disease of particular concern to birds in general is West Nile virus (WNV). This virus was first isolated in Africa and first appeared in the United States in 1999, in New York (see review in Blakesley et al. 2004). It spread rapidly across the country and has now reached the range of the Mexican spotted owl. The virus is commonly spread by transmission between mosquito vectors and bird reservoir hosts. However, birds can also become infected by means other than arthropod transmission (Marra et al. 2004). Komar et al. (2003) reported that ingestion of WNV in aqueous solution resulted in infection in several bird species, including great horned owls. It is not known whether ingestion of infected prey by raptors has resulted in bird mortality, but the risk exists (Marra et al. 2004). Finally, contact transmission has been documented in the laboratory in caged birds (McLean et al. 2001; Komar et al. 2003), perhaps from such behaviors as mutual preening and beak-to-beak contact.

Avian mortality from WNV has been extensive in North America (Komar et al. 2003). Natural fatal infections were detected between 1999 and 2002 in over 28,000 bird carcasses representing 198 species, including a captive spotted owl (subspecies not identified; CDC unpublished data). However, we are unaware of any records of wild spotted owls being infected with WNV. Hull et al. (2010) tested 209 California spotted owls in the Sierra Nevada of California between 2004 and 2007 and detected no antibodies in those specimens, despite numerous recorded infection

incidences in other avian species in the region during that time. Hull et al. (2010) concluded that WNV infection likely was absent in the area's spotted owls, but they also noted that an absence of detections could indicate that spotted owls exposed to WNV do not survive long enough to develop a detectable immune response.

We are unaware of any incidence of WNV in Mexican spotted owls, or of any program (systematic or otherwise) of surveillance for this disease in the subspecies. Nonetheless, the potential impact of the disease on threatened species and those of ecological importance is of great concern (Joyner et al. 2004). The scientific panel that reviewed the status of and threats to the northern spotted owl was unanimous in regarding WNV as a potential future threat (Blakesley et al. 2004).

Thus, the impact of WNV on Mexican spotted owls is difficult to predict. In general, we know little about the abundance and behavior of the relevant vectors in areas occupied by spotted owls, making it difficult to predict infection rates. We also do not know how many of the owls infected by WNV will die or suffer reduced viability, or whether or not owls will develop some level of immunity to the disease following initial exposure. Thus, all we can say with certainty at this time is that WNV has arrived and has the potential to significantly impact population viability of Mexican spotted owls.

Relative to parasites, Young et al. (1993) found hippoboscid flies on 17% of 382 live northern spotted owls examined for parasites, and Hunter et al. (1994) found hippoboscid fly larvae in the ears of six of 18 live Mexican spotted owls examined. Hunter et al. (1994) also found a larval mite and lice on two of 28 museum specimens of Mexican spotted owls examined, and some of the live owls examined also had lice. Neither study reached firm conclusions concerning mortality and ectoparasites in spotted owls, but Hunter et al. (1994) suggested that larval infestations in their ears could affect the owls' hearing. Because hearing is important for foraging at night, such infestations could eventually affect the birds' ability to hunt effectively. Further, Young et al. (1993) noted that hippoboscid flies are vectors for several hematozoan (blood-borne) parasites in birds.

Infection rates of such blood-borne parasites appear to be high in spotted owls. For example, Gutiérrez (1989) found an infection rate of 100 percent in a survey of blood parasites in all three subspecies of spotted owls. More recently, a survey in northern and California spotted owls found infection rates of 52 and 79% respectively (Ishak et al. 2008). Infection rates of spotted owls were far greater than rates in sympatric barred owls (15%), and spotted owls were far more likely than barred owls to harbor multi-species infections (Ishak et al. 2008). These high infection rates and the numbers of spotted owls with multiple infections support the hypothesis that spotted owls have weaker immune systems than sympatric barred owls, and this may provide barred owls with a competitive advantage (Ishak et al. 2008).

The effects of both parasites and disease likely vary depending on the condition of individual owls. Thus, infections that are normally nonpathogenic can assume greater importance in owls that are stressed or malnourished (Young et al. 1993). Therefore, both disease and parasites can interact with other factors such as climate and prey availability, and these interactions likely determine the ultimate effect of disease and parasite infections. Similarly, as noted above,

disease and parasite infections could influence the outcome of, for example, interactions with competitors.

F. Other Ecological Interactions

a. *Interspecific Competition.*—Several other species of raptors and owls occur within the range of the Mexican spotted owl. Raptors may compete with spotted owls for resources such as nest sites but prey primarily on diurnally active prey species. In contrast, most owls focus on the kinds of nocturnally active prey that dominate the diets of Mexican spotted owls. Thus, competition between owl species is suspected to be more important than competition between owls and raptors.

In general, we know little about potential competitive relationships between sympatric owl species within the range of the Mexican spotted owl. Logically, the two species most likely to compete directly with Mexican spotted owls are the great horned owl and the barred owl, based on their relative size, natural history, and, in the case of the barred owl, genetic similarity. Throughout much of the range of the Mexican spotted owl, the most likely competitor is the great horned owl (USDI FWS 1995). This owl is larger than the spotted owl, is sympatric with spotted owls throughout their range, and both owls are active at night, suggesting that they could compete for nocturnally active prey (Gutiérrez et al. 1995, Houston et al. 1998). The great horned owl and the barred owl may prey on spotted owls (Forsman et al. 1984, Ganey 1988:185, Gutiérrez et al. 1995), and spotted owls in turn may prey on other smaller owls (e.g., Ganey 1988: Table 20).

Despite this potential for competition and possible predation by great horned owls on Mexican spotted owls, little is known about interspecific interactions between the two. Some evidence suggests that spotted owls may avoid areas occupied by great horned owls (e.g., interference competition). For example, Phillips et al. (1964) reported that great horned owls colonized an area previously occupied by spotted owls following a fire that opened up the forest canopy. Spotted owls were not heard in this area in subsequent years. Similarly, Johnson and Johnson (1985) reported that once great horned owls moved into areas previously occupied by spotted owls, they seldom heard spotted owls in those areas.

In contrast, Ganey et al. (1997) reported considerable spatial overlap between home ranges of sympatric, radio-marked spotted and great horned owls in Arizona. On average, spotted owls shared $51.0 \pm 24.3\%$ (*SE*) of their breeding-season home range and $74.1 \pm 4.8\%$ of their non-breeding-season home range with great horned owls ($n = 6$ spotted owl and 3 great horned owl home ranges). The figures for proportions of great horned owl home ranges shared with spotted owls were similar (57.4 ± 12.2 and $70.5 \pm 12.3\%$ for breeding- and non-breeding-season home ranges, respectively; Ganey et al. 1997: Table 2). Both species of owls sometimes foraged in the same forest stands. These stands were not necessarily used at the same time, however, and spotted owls also foraged in many stands that great horned owls did not appear to forage in (Ganey et al. 1997: Table 3). Home-range composition, in terms of cover types and canopy-cover classes, did not differ between species in either the breeding or non-breeding season (Ganey et al. 1997: Table 4). In contrast, use of cover types and canopy-cover classes within the home range differed between species in at least some combinations of season and activity

considered (Ganey et al. 1997: Table 4). Differences were typically greatest with respect to roosting habitat used during the breeding season. For example, >90% of roosting locations for spotted owls during the breeding-season were in forests with canopy cover >40%, whereas >64% of great horned owl roosting locations were in forests with canopy cover <40% (Ganey et al. 1997: Table 5). Great horned owls also foraged primarily in forests with <40% canopy cover (78 and 71% of foraging locations during the breeding and non-breeding seasons, respectively). In contrast, >50% of spotted owl foraging locations occurred in forests with canopy cover >40% during both seasons. Spotted owls roosted primarily in pine-oak forest during both seasons, sometimes roosted in ponderosa pine forest, and did not roost in meadow cover types (Ganey et al. 1997: Table 6). In contrast, great horned owls frequently roosted in both pine-oak and ponderosa pine forest, and sometimes roosted in isolated clumps of trees within meadow cover types. Stands used by foraging spotted owls contained greater volumes of logs and greater shrub cover than stands used by great horned owls during both seasons. During the non-breeding season, stands used by foraging spotted owls also had greater canopy cover, whereas stands used by great horned owls had greater forb cover (Ganey et al. 1997). These observations are consistent with the hypothesis that spotted owls may be avoiding competition with great horned owls (and potentially predation) by partitioning use of habitat resources over space and through time. Similar patterns have been observed for northern spotted owls living in sympatry with barred owls in conifer forests of Washington (Buchanan et al. 2004, Hamer et al. 2007).

Avoidance of competition by partitioning food was less apparent. Diet overlap was considerable between Mexican spotted and great horned owls in the same study area where habitat partitioning was observed (Ganey and Block 2005b). Both species preyed primarily on nocturnally active small mammals, although both also ate birds and insects, and great horned owls occasionally preyed on lizards. Mammals comprised 63 and 62% of the diets of spotted and great horned owls, respectively, based on total numbers of identified prey items in regurgitated pellets ($n = 1125$ prey items for spotted owls and 94 prey items for great horned owls, respectively). In terms of prey biomass, mammals comprised 94 and 95% of the diets of spotted and great horned owls, respectively. Mean prey mass averaged 40.1 ± 1.8 g for spotted owls and 47.0 ± 7.4 g for great horned owls and when all prey were included. For all non-insect prey ($n = 746$ and 63 items for spotted and great horned owls, respectively), mean prey mass was 60.0 ± 2.4 g for spotted owls and 69.7 ± 9.8 g for great horned owl. Dietary overlap, calculated using Pianka's (1973) index, was 0.95. This index ranges from zero (no overlap) to 1 (complete overlap). Observed overlap in diet composition between species was greater than expected based on null models of diet overlap (null models generated using program ECOSIM; Gotelli and Entsminger 2001).

Thus, in this study area, home ranges of these species overlapped considerably. There also was overlap in areas used for foraging, as well as in the size and type of prey taken. This suggests a potential for both exploitation and interference competition for food resources, which are assumed to be limiting in some years (Verner et al. 1992, Ward 2001). There also were strong differences in habitat-use patterns between species, however. These differences suggest that these species may be able to partition habitats in areas of sympatry, with spotted owls primarily using forests with canopy cover >40%, and great horned owls primarily using forests with canopy cover <40%. Whether or not these patterns of habitat use are influenced by the presence of the other owl species is unknown. The observed habitat-use patterns for both species were

generally consistent with known patterns from other studies (reviewed in Ganey and Dick 1995, Gutiérrez et al. 1995, Houston et al. 1998), as well as with morphological and behavioral characteristics of both species (Ganey et al. 1997). This seems to suggest that habitat use was not strongly influenced by the presence of the potential competitor. We observed numerous instances of apparently agonistic calling encounters between radio-marked owls, however (J. L. Ganey, personal observation; see also Ganey 1990). This suggests the possibility that interference competition, where individuals physically interfere with each other, may occur, and may partially explain some of the apparent habitat partitioning observed. Regardless of the underlying mechanisms, at present these owls appear able to partition available forest habitats and likely take similar prey in different areas, minimizing direct competition for resources. This interaction could be altered if extensive forest management occurs and reduces the area of forests with canopy cover >40%. This change could benefit the great horned owl and reduce habitat quality for the spotted owl (Ganey et al. 1997).

We also know little about possible competitive interactions between barred owls and Mexican spotted owls. The barred owl is considered a significant threat to northern spotted owls, however (Kelly et al. 2003, Gutiérrez et al. 2004, 2007, Kelly and Forsman 2004, Levy 2004, Olson et al. 2005, Buchanan et al. 2007, Kroll et al. 2010). Overlap between northern spotted owls and barred owls appears to be high relative to both habitat use (Herter and Hicks 2000, Kelly et al. 2003, Pearson and Livezey 2003, Buchanan et al. 2004, Olson et al. 2005, Hamer et al. 2007, Bailey et al. 2009, Singleton et al. 2010) and diet (Hamer et al. 2001). In addition, these owls are known to hybridize (Hamer et al. 1994, Haig et al. 2004b, Kelly and Forsman 2004, Seamans et al. 2004), suggesting that competition for mates also occurs. In many areas, numbers of barred owls are increasing, whereas numbers of spotted owls are decreasing, suggesting that the larger and more aggressive barred owls dominate the competitive interaction between these species and are displacing spotted owls (Kelly et al. 2003, Gutiérrez et al. 2004, 2007, Kroll et al. 2010; but see also Crozier et al. 2006, Livezey and Fleming 2007). A recent study also suggested that barred owls may gain a competitive advantage over sympatric spotted owls due to lower infection rates with blood-borne parasites (Ishak et al. 2008; see Diseases and Parasites, above). Records of possible predation of spotted owls by barred owls also exist (Leskiw and Gutiérrez 1998).

The barred owl may be sympatric with Mexican spotted owls in Mexico (Williams and Skaggs 1993, Howell and Webb 1995, Holt et al. 1999), but little is known about patterns of either distribution or habitat use of either owl in the zone of apparent sympatry (Williams and Skaggs 1993, Enriquez-Rocha et al. 1993). Thus, there may be potential for interspecific competition to occur in Mexico, but the extent of such competition (if any) is unknown.

Barred owls historically have not co-occurred with Mexican spotted owls within the United States, with the possible exception of southern Texas. Both species have been reported occasionally from the vicinity of Big Bend National Park (Wauer 1996). We do not know if either or both species are regular residents in that area, however. There also are recent confirmed records of barred owls in northern New Mexico (Williams 2005, cited in Cartron 2010). Whether such records indicate a range expansion by barred owls or simply vagrant individuals is unknown. Thus, there does not appear to be much opportunity for competition between barred

and Mexican spotted owls in the United States at present, but that could change if the barred owl expands its range into the range of the spotted owl, as it did in the Pacific Northwest.

In summary, we know relatively little about competitive relationships between Mexican spotted owls and other owls. Competition for food resources also may extend to medium-sized and small carnivores that consume large amounts of nocturnal rodents and that hunt in habitats similar to Mexican spotted owls. This would include species like bobcat (*Lynx rufus*), gray-fox (*Urocyon cinereoargenteus*), ring-tailed cat (*Bassariscus astutus*), and coyote (*Canis latrans*). Better information clearly is needed to assess the potential occurrence and importance of such competition, as well as to understand the potential influence that forest management might have on competitive interactions.

b. Human Disturbance.—Although a variety of human-caused disturbances can affect birds of prey and other wildlife (Knight and Gutzwiller 1995), we know relatively little about the effects of human disturbance on spotted owls. Delaney et al. (1999) and Johnson and Reynolds (2002) studied the response of Mexican spotted owls to overflights by helicopters and fixed-wing aircraft, respectively. Both studies suggested that owls were fairly resilient to short-duration disturbance caused by overflights. Delaney et al. (1999) also developed an owl-weighted frequency curve to simulate hearing sensitivity of owls in various parts of the sound-frequency spectrum and used this curve to evaluate relative disturbance levels caused by chainsaws. Spotted owls were more sensitive to disturbance by chainsaws than by helicopter overflights at comparable distances, and chainsaw operation caused most owls to flush from their perches when chainsaws were operated <60 m from roosting Mexican spotted owls. Owl response decreased with increasing distance to noise source for both chainsaw operation and helicopter overflights, and Delaney et al. (1999) suggested that a buffer zone of 105 m would minimize impacts of helicopter overflights on spotted owls.

In a later study, Delaney and Grubb (2004) quantified relative, owl-weighted noise levels caused by road-maintenance equipment (rock crusher, loader, bulldozer/roller, and grader) in spotted owl habitat. They found consistent differences in noise levels between types of equipment, microphone positions (in trees versus on the ground), distance from noise source, and habitat (forest versus meadow). Rock crushers were louder than other equipment, sound levels were greater in trees than on the ground at all distances, sound levels decreased with distance, and sound levels were greater in meadows than in forests at comparable distances. Delaney and Grubb (2004) concluded that owls were capable of hearing all sound sources tested at distances of at least 400 m. Owl response to these noise sources was not evaluated in this study.

Swarthout and Steidl (2001, 2003) experimentally evaluated the effects of hikers on spotted owls in canyonlands terrain. They quantified both flush responses and activity budgets of owls exposed to hikers. Owls exposed to hikers sometimes flushed and spent more time vocalizing and less time handling prey and performing maintenance activities than owls not exposed to hikers. In general, owl response level was related to both perch height and distance to the hiker. Swarthout and Steidl (2003) concluded that cumulative disturbance caused by recreational hiking near nests potentially could be detrimental to owls, but likely would be detrimental only where owls occupied canyons receiving use by ≥ 50 hikers per day. Swarthout and Steidl (2001) concluded that placing a 55-m buffer zone around known owl roosting sites would eliminate

most flush responses. However, a buffer of this size also would restrict hiker access to 80% of the narrow canyons occupied by Mexican spotted owls. They concluded that a less conservative 12-m buffer zone likely would minimize flush response while excluding access to only 25% of canyons occupied by owls.

In summary, the limited information available suggests that owls may be disturbed by a variety of human-caused activities, that ground-based activities generally are more disturbing than overflights, and that decibel levels within the owl's hearing range and distance to the source of disturbance are significant factors in determining owl response.

G. Climate Change

In addition to changes in distribution and amounts of the owl's habitat, climate change may result in direct and indirect influences on the owl's population demography and interactions with other species. Much of the evidence for these potential influences was presented in the various preceding sections that detailed the owl's population ecology, but we summarize some additional examples here.

a. *Changes in Demographic Rates.*—Shifts in key weather variables may influence owl demography by influencing the physiology of individual owls. For example, if climate change results in more or longer periods where microclimatic temperatures exceed lower or upper critical limits, owls will require additional energy and/or water for owls to maintain homeostasis (Ganey et al. 1993, Weathers et al. 2001). If owls are not able to adopt new behaviors to counter these additional energetic demands, such as finding roost sites with greater thermal protection, they will have less energy to allocate to reproduction and/or survival. Should temperatures increase enough that all available microclimates exceed the owl's lethal limits, the owls must disperse elsewhere to inhabitable environments. Because climate change will likely create shifts in weather parameters over large areas and because long-distance dispersal (>150 km) is not very plausible for most Mexican spotted owls, shifts in temperatures that regularly exceed critical or lethal limits will result in greater mortality and declining populations. Changes in water balance may be as important as changes in energy balance (see Weathers et al. 2001), particularly if climates become both warmer and more arid.

Annual weather patterns are associated with survival and reproduction of spotted owls (Franklin et al. 2000, 2004, North et al. 2000, LaHaye et al. 2004, Olson et al. 2004, Dugger et al. 2005, Anthony et al. 2006, Seamans and Gutiérrez 2007). Precipitation may influence the owl's reproductive output either directly or indirectly. Direct negative effects of increased precipitation during the nesting period on survival and especially reproduction have been shown in other subspecies of spotted owls (e.g., Franklin et al. 2000, North et al. 2000, LaHaye et al. 2004). This direct negative effect has not been documented in Mexican spotted owls, however.

In a study on two populations of Mexican spotted owls, Seamans et al. (2002) documented positive relationships between precipitation (i.e., precipitation during the previous year, during the previous winter, or during the previous monsoon season) and survival and reproductive output. Seamans et al. (2002) speculated that precipitation was probably important in providing indirect benefits to Mexican spotted owls. Specifically, they hypothesized that germination and

sprouting of annual plants during the monsoon season may extend the breeding season of small mammals in the Southwest and may increase overwinter survival and therefore abundance of prey. Many prey species eaten by Mexican spotted owls exhibit high temporal variability in abundance (Ward and Block 1995, Ward 2001, Block et al. 2005), and owl reproduction appears linked to changes in prey biomass (e.g., Ward and Block 1995, Ward 2001). Thus, changes in climate that affect prey abundance likely also will affect owl reproduction. Interactions among temperature and moisture regimes may differ across elevational gradients in the Southwest, thus affecting small mammal populations differently in different areas (Seamans et al. 2002:331). Climate changes that decrease prey availability may also negatively influence the owl's water balance, especially when non-metabolic water is not available.

b. *Reduction in Population Size.*— At this time, little evidence exists suggesting that climate change is causing any changes in Mexican spotted owl distribution or population size. As mentioned above, however, both survival and reproduction were positively correlated with precipitation in two populations studied (Seamans et al. 2002). This suggests that increasingly warmer and drier climates may not benefit spotted owls.

c. *Changes in Co-evolved Interactions.*— Changing climates also could influence distribution patterns and abundance of major prey species, as well as potential competitors with and predators on spotted owls. Each species has different physical tolerances and resource requirements, including the small mammal species eaten by Mexican spotted owls (Ward 2001). This makes it hard to generalize about the effects of changing climates on prey distribution and availability. In examining the influence of habitat and weather-related covariates on the biomass (g ha^{-1}) of five common prey species of Mexican spotted owls in the Sacramento Mountains, Ward (2001) identified a spectrum of effects for each species. Deer mice were influenced by weather related effects that changed with time, whereas Mexican woodrats were more influenced by habitat related effects. Untested predictions about the order of species decline or loss of the five studied prey species in the Sacramento Mountains given their current distributions and natural histories (reviewed by Ward [2001: Chapter 2]) would suggest that drier warmer microclimates would result in loss of vole species first, followed by loss or a reduction in numbers of woodrats, and finally a reduction in numbers of peromyscid mice. The magnitude of such potential changes in the distribution and abundance remain untested at this time, however.

In rocky-canyon habitat in southern Utah, Willey and Willey (2010) documented increases in abundance and species diversity of rodents during a period of increased precipitation. Territory occupancy and territory re-colonization rates of spotted owls also increased during the period of increased precipitation, presumably in response to increases in prey abundance (Willey and Willey 2010). The strong apparent response of small mammals to precipitation in this study may have been a function of the semi-arid climate of the region. For example, a review of variation in responses by deer mice to increased precipitation in varying environments demonstrated that the greatest response occurred in arid regions and the lowest response occurred in the wet coastal forests of the Pacific Northwest (Ward 2001: Chapter 2).

d. *Interactions With Competitors and Predators.*— Changes in forest composition could also influence abundance and distribution of owl competitors and predators, but the magnitude and direction of such potential changes again are unknown at this time. Northern spotted owls are

being affected by a direct competitor, the barred owl, which recently expanded its range into the Pacific Northwest and California (Gutiérrez et al. 2007; see also barred owl discussion under Part I, Factor 2.e.ii, and Interspecific Competition, above). This species occurs in the eastern United States and portions of Mexico (Mazur and James 2000). Whether climate change will ultimately result in a sympatric distribution of Mexican spotted and barred owls is unknown. It is possible that warmer, drier conditions might favor such potential predators as great-horned owls (see Predation, above), which occur in habitats ranging from high-elevation and high-latitude forests to hot deserts (Johnsgard 1988).

7. Movements and Migration

The ability of Mexican spotted owls to move within and among habitats or across a landscape is a key factor for assessing function and viability of populations over time. For example, small populations often require recruitment from larger (core) populations to persist for long periods. Understanding how frequently and under what conditions owls are successful in completing movements can allow better predictions about long-term or local viability. Knowledge for mobile organisms like spotted owls is often difficult to obtain, however, and details about conditions that allow for successful dispersal or explanations for periodic migrations are limited. Nonetheless, a few studies have documented movements of this owl. This section summarizes existing knowledge about movement patterns of this owl and the processes that influence their movements.

A. Seasonal Migration

Ganey and Block (2005a) summarized available information on seasonal movements and range use of radio-marked Mexican spotted owls, supplemented by anecdotal observations of owls during the non-breeding season, and evaluated the adequacy of management guidelines in protecting habitats used by owls during the non-breeding season. They operationally defined all radio-marked owls that moved ≥ 2 km from their breeding-season home-range center as “migrants” and treated all other radio-marked owls as “residents,” with this distance criterion based on mean nearest-neighbor distances reported in studies of Mexican spotted owls in Arizona and New Mexico (see Space Use above).

Seasonal movements or migration occurred in most areas where movements of radio-marked owls were monitored (Table E.8). Seasonal migration generally involved a subset of the population, with the size of that subset varying both among study areas and among years within study areas (Table E.8). Migrating owls typically left study areas in November or December, and returned from January to April (Table E.9). Distance moved ranged from 5 to 50 km for owls whose wintering areas were located. Wintering areas of two owls from the San Francisco Peaks could not be located despite an aerial search covering thousands of square kilometers, suggesting that some owls may move long distances (see also Gutiérrez et al. 1996).

Some radio-marked owls moved only short distances and remained in the same forest types represented in their breeding-season home ranges (Table E.9). In contrast, other owls moved down in elevation, and most of these down-slope migrants wintered in habitats more open in

structure than typical breeding habitat, such as semi-desert scrub, pinyon-juniper woodland, or mountain shrub (Table E.9).

Duncan and Speich (1995) provided additional evidence for down-slope migration in Mexican spotted owls. They documented a subadult owl overwintering in Sonoran riparian deciduous woodland (Brown et al. 1980) at 838 m in the foothills of the Santa Catalina Mountains, Arizona. They relocated this owl five years later as a member of a territorial pair near the summit of this range, at an elevation of 2560 m. We also are aware of numerous anecdotal observations of Mexican spotted owls in woodland, semi-desert, and desert cover types during the winter months. In most cases, however, it is impossible to tell whether these represent migrating territorial owls or dispersing juveniles, which use similar habitats (Arsenault et al. 1997, Ganey et al. 1998, Willey and van Riper 2000, Duncan and Speich 2002).

Thus, available information suggests that seasonal migration of some individuals occurs in many or most populations of Mexican spotted owls, and that such migration occurs in both sexes (Table E.9). Partial migration also occurs in California spotted owls (*S. o. occidentalis*, Laymon 1989, Verner et al. 1992). In contrast, migration appears to be rare in northern spotted owls (*S. o. caurina*; Gutiérrez et al. 1995).

Reasons why only some owls migrate are unknown. In addition, some individual Mexican spotted owls migrate in some years but not others (Table E.8). Migration generally entails a change in elevation for both Mexican (Table E.9) and California spotted owls (Laymon 1989, Verner et al. 1992), with most owls moving down slope (but see Willey 1998a). Migration to lower elevations allows owls to winter in areas that are warmer than their breeding areas during the winter and that lack persistent snow. This may facilitate an energetic savings in maintaining homeostasis and hunting for small mammals, which comprise the bulk of the diet (Ward and Block 1995). It also may allow the owls to move to areas with more concentrated prey resources, as populations of small mammals reach their nadir in owl breeding areas during the winter months (Ward and Block 1995, Ward 2001, Block et al. 2005). For example, Block et al. (2005:625) used live trapping to estimate available prey biomass during the winter both in the traditional breeding area and a wintering area used by a pair of radio-marked Mexican spotted owls. They estimated that prey biomass was almost eight times greater within the winter range than within the breeding area (1,200 g ha⁻¹ vs. 155 g ha⁻¹). Although circumstantial, the evidence suggests that migration was driven by food availability.

Also presently unknown is how and why migrating owls select particular wintering areas, as we have little information on specific habitat features that migrating spotted owls use in wintering areas (but see Peterson 2003). Further, owls use these areas at a time of year when they are unlikely to vocalize (Ganey 1990), making it difficult to locate such areas through calling surveys.

From a conservation perspective, some migrating owls occupy cover types that have no protected status under the original recovery plan for the Mexican spotted owl (USDI FWS 1995). These cover types also are used by dispersing juvenile owls during the fall and winter (Arsenault et al. 1997, Ganey et al. 1998, Willey and van Riper 2000). The types of lowland areas in which wintering owls have been observed cover vast areas, however, and we have no evidence that

suitable wintering areas are limiting. Thus, there is little evidence that specific protective measures for wintering areas or habitats used by migrating spotted owls are necessary at this time, with the possible exception of portions of the foothills of the Front Range in Colorado. This region has experienced rapid growth and development since 1990.

B. Dispersal

Two forms of dispersal occur in spotted owls. Natal dispersal, or dispersal by young of the year from their birth sites, is the most common form and begins each fall following the production of young. Breeding dispersal, or movement by subadult or adult individuals from a previously occupied territory to another, occurs less frequently (Gutiérrez et al. 1995, Forsman et al. 2002, Blakesley et al. 2006).

a. Natal Dispersal.— Dispersal by juvenile Mexican spotted owls has been studied directly by monitoring movements of radio-marked individuals in New Mexico (Arsenault et al. 1997), Arizona (Ganey et al. 1998), and Utah (Willey and van Riper 2000), and indirectly in Arizona and New Mexico by monitoring movements of color-banded juvenile owls (Duncan and Speich 2002, Gutiérrez et al. 2003).

Radio-marked juvenile Mexican spotted owls began dispersing in September and October in all study areas, with most dispersing in September. Initial dispersal movements were rapid, abrupt, and random with respect to direction. In an effort to understand triggers of natal dispersal, Willey and Van Riper (2000) recorded observations of parent-offspring interactions and departure dates of juvenile Mexican that were supplemented with food and a control group without additional food. Juvenile owls that were provided with supplemental food all left their natal sites significantly sooner than juveniles that did not receive supplemental food. Aggressive behaviors among offspring and parents that might induce dispersal were not noticeably different between the two treatment groups, however. Thus, this study did not support the hypothesis that food shortage triggers natal dispersal in Mexican spotted owls. Rather, it suggested that body condition might positively influence departure. That is, acquiring sufficient energy reserves prior to embarking may be a key physiological factor in the timing of natal dispersal in spotted owls (Willey and van Riper 2000).

Two types of behavior during natal dispersal followed initial movements: rapid dispersal across the landscape and extensive local exploration. Many dispersing juveniles exhibited periods of both types of movements. Distance from the natal site to the last observed location for radio-marked juveniles ranged from <1 to >92 km. These distances likely represent minimum estimates of dispersal capability, as only one of 62 radio-marked juveniles was tracked until it settled on a territory and paired with a mate. Directions from natal sites to final observed locations did not differ from random, indicating that dispersing owls did not follow a singular path or corridor. In addition, dispersing juveniles from all studies used a wide variety of habitats, including some that were very different in structure and composition from typical breeding habitat. Because juvenile survival is typically low (<30% of these individuals apparently live to the next year), documenting final dispersal distances using radio-marked birds requires that a large number of young are radio-marked (>100) and followed for a longer (>3 years) period than most radio-transmitter batteries or funding for aerial monitoring will last (see for example Forsman et al. 2002). However, the patterns observed for the smaller samples of Mexican spotted

owls differed little from a more comprehensive study of natal dispersal of northern spotted owls in Oregon and Washington (Forsman et al. 2002). For example, natal distances observed in this long-term, large-sample study ($n = 324$ radio-marked and 711 banded juveniles followed from 1985–1996) ranged from 1.8 to 103.5 km for radio-marked juveniles and from 0.6 to 111.2 km for re-sighted individuals originally color banded at natal sites. The distribution of these dispersal distances was skewed toward shorter distances with only 8.7% of the final distances between the natal territory and location of settlement being >50 km. On average, male and female juveniles in this study eventually settled within an average of 4.2 and 7.0 territory widths from their natal sites after two to five years (Forsman et al. 2002).

Estimates of natal dispersal distances from mark-recapture studies also suggest that most California and northern spotted owls settle on territories within a few territory widths of their natal site (LaHaye et al. 2001, Forsman et al. 2003). These estimates may provide a better estimate of final distances traveled by successful dispersers than did the radio-telemetry studies discussed above, although the finite size of the mark-recapture study areas could underestimate this distance. For example, LaHaye et al. (2001) examined settling patterns of dispersing California spotted owls in the San Bernardino Mountains, California, within a 535-km² study area. They evaluated possible effects of study-area size on dispersal distances by nesting several successively smaller areas within their complete study area. They found that dispersal distances were underestimated when using band-resighting data for establishing settling patterns in the smaller nested study areas (see also Zimmerman et al. 2007). In contrast, Forsman et al. (2002) compared distance estimates based on radio-marked northern spotted owl juveniles with estimates derived from settling patterns and found no evidence that the small study areas used to study settling patterns biased distance estimates. Thus, it is unclear whether or not the finite size of demography study areas consistently results in underestimates of natal dispersal distances.

Unfortunately, few estimates of natal dispersal distance are available for the Mexican spotted owl. Duncan and Speich (2002) were able to document four instances of inter-mountain movement by dispersing Mexican spotted owl juveniles that had been marked with color bands at their birth sites. These movements required these owls to cross desert valleys between Sky Island mountain ranges in southeastern Arizona. Distances between natal sites and territories established by these four individuals ranged from 28 to 54 km.

It is not clear when natal dispersal typically ceases in spotted owls. Gutiérrez et al. (2003) reported that 90 to 100% of fledged young that occupied territories in two demography study areas did so within three years. Patterns differed between their Arizona and New Mexico study areas, however. In Arizona, over 60% of fledged young that settled did so in their first year, with declining proportions of young settling through year five (Gutiérrez et al. 2003: Figure 13a). In New Mexico, young settled in equal proportions in the first three years following fledging, with no recruitment observed in subsequent years (Gutiérrez et al. 2003: Figure 13b). LaHaye et al. (2001) noted that $>50\%$ of successful natal dispersers in their California study area occupied territories within one year and that virtually all successful dispersers occupied territories within three years. Forsman et al. (2002) noted variable patterns in northern spotted owls, with some owls settling permanently in their second summer while others did not settle permanently until they were two to five years old. Thus, available evidence suggests that most young occupy

territories in the first three years following fledging, but that dispersal movements may continue for up to five years for some owls.

b. Breeding Dispersal.— Reasons for and distances traveled during dispersal by previously settled subadult and adult Mexican spotted owls are poorly understood. Breeding dispersal is thought to occur when a mate is lost, or in some cases when a better reproductive opportunity is found elsewhere. Examples of both have been documented for all three subspecies (LaHaye et al. 2001, Forsman et al. 2002, Gutiérrez et al. 2003, J. L. Ganey and J. P. Ward, unpublished data).

Arsenault et al. (1997) noted apparent cases of dispersal in subadult Mexican spotted owls, and Gutiérrez et al. (1996) suggested that dispersal also may occur in adult Mexican spotted owls. In their more comprehensive study of northern spotted owls, Forsman et al. (2002) noted that breeding dispersal of northern spotted owls in Oregon and Washington occurred relatively infrequently. Based on settlement patterns of banded birds, distance dispersed ranged from 0.01 to 85.2 km between previously and newly occupied breeding sites for all age classes. However, first-year subadults ($n = 71$) moved farther than second-year subadults ($n = 75$) and adults (individuals ≥ 3 years; $n = 294$; median distances 5.1, 4.1, and 3.5 km, respectively). Most (83%) adults that did disperse only moved once. Of those that moved twice or more, 41% moved backed to an original territory (Forsman et al. 2002). There were no significant differences in breeding dispersal distances among the sexes. The odds that an individual would move were generally greater for females, however, and were greatly magnified for either sex if the pair bond was disrupted by disappearance (movement or death) of a mate.

In summary, juvenile dispersal appears to be obligate in Mexican spotted owls, and settled subadult or adult birds may on a much rarer and irregular basis move to another site. Juvenile owls leave the natal territory in September or October and wander the landscape. Many perish in the process. They are capable of moving long distances, but many successful dispersers occupy territories near their birthplace. Natal dispersers move through a wide variety of habitats during the dispersal period, many of which differ greatly from typical breeding habitat and have no formal protective measures under USDI FWS (1995, see also Ganey and Block 2005a) or this Recovery Plan. There is little evidence from study of movements that would allow us to identify common dispersal directions, movement corridors, or important areas or habitats. Many Mexican spotted owls appear to occupy territories at one to two years of age, while others may settle when older. Some of this variation may be driven by trends in owl density and fecundity, manifested through trends in numbers of territory vacancies. In general, however, we know little about dispersal behavior, and especially about dispersal movements of Mexican spotted owls during and following their second summer of life.

8. Metapopulation Ecology

Many authors have noted that the structure and spatial distribution of spotted owls at a rangewide scale suggests that groupings of individuals may occur as subpopulations and that these subdivided populations may function as a metapopulation (e.g., Levins 1970, Hanski 1998) or a series of subdivided populations where population interactions are much higher within than between populations (Gutiérrez and Harrison 1996; see also Shaffer 1985, Noon and McKelvey 1992, 1996, LaHaye et al. 1994). Indeed, Gutiérrez and Harrison (1996) argued that spotted owl

population dynamics and viability could be understood *only* in the context of a metapopulation. Of the three subspecies, the distribution of Mexican spotted owls appears to most naturally resemble the metapopulation construct, with perceived subpopulations existing in useable habitat created by elevation gradients and disconnected mountain or canyon systems, separated by a matrix of low-quality to non-useable habitat.

Despite the important contributions made by metapopulation theory and models to management of northern and California spotted owls (Shaffer 1985, Noon and McKelvey 1992, 1996, LaHaye et al. 1994, Gutiérrez and Harrison 1996), few studies have examined metapopulation structure of Mexican spotted owls. Keitt et al. (1995, 1997) examined the spatial pattern of forest habitat patches across the range of the Mexican spotted owl. Their objective was to gauge the extent to which the owl might behave as a metapopulation in the classical sense of a set of local populations linked by infrequent dispersal. Such a finding, if verified, would suggest that population dynamics of owls in one local population might be influenced by factors, including management activities, which affected nearby populations. Conversely, if local populations are functionally discrete, then those populations could be treated separately with some confidence that actions in one part of the owl's range would not greatly affect other populations.

Keitt et al. (1995, and refined by Keitt et al. 1997) reported that patches of forest habitat in the range of the Mexican spotted owl showed a connectivity threshold of approximately 45 km. They concluded that an organism capable of dispersing a distance of ≥ 45 km through inhospitable terrain, and with an average exponential dispersal distance of ≥ 15 km, would perceive the landscape as a series of connected patches. They further concluded that Mexican spotted owls met these criteria (see Dispersal, above), and that the distribution and temporal dynamics of this subspecies' populations probably behaves as a classical metapopulation over much of its range. That is, the level of habitat connectivity is such that many habitats are "nearly connected" at distances corresponding to the best empirical estimates of the owl's dispersal capability. At this scale, the landscape consists of a set of large, more-or-less discrete habitat clusters. For example, most of the Mogollon Rim functions as a single cluster, the Southern Rocky Mountains as another single cluster, and so on. This suggests that owls could successfully disperse within habitat clusters with very high probability and disperse between clusters with much lower probability. Thus, we would expect owls to disperse within clusters most of the time and between clusters rarely, which is consistent with the definition of a metapopulation. This finding suggests that the Recovery Plan should incorporate recommendations that maintain (or increase) habitat connectivity across the owl's range. Habitat connectivity buffers a population from stochastic variability through time by providing the opportunity for local population failures to be "rescued" by immigration from other populations, and it also facilitates gene flow among populations (Barrowclough et al. 2006).

Gutiérrez and Harrison (1996) noted two other concepts related to metapopulation dynamics that are relevant to spotted owls. The first is spatially structured population dynamics. The spatial structuring described by this concept arises from territorial behavior and is relevant in continuous or relatively continuous habitat. Individuals in such habitat will tend to interact mainly with neighboring owls, rather than mixing freely throughout the larger population. The dynamics of this situation can be modeled using individual territory models (Lande 1987, 1988, Noon and McKelvey 1996). Resulting models are similar to metapopulation models, except that extinction

and colonization is modeled for territories rather than for larger populations (Gutiérrez and Harrison 1996, Noon and McKelvey 1996). No individual territory models have been developed for the Mexican spotted owl. The approach may be relevant to particular areas where clusters of owls occur in relatively continuous habitat, however (e.g., Mogollon Rim, Sacramento Mountains).

The second concept relates to source-sink dynamics (Pulliam 1988). As typically defined, source populations occur in high-quality habitat and produce surplus individuals. In contrast, low quality habitats may act as population sinks, where reproduction is insufficient to balance mortality. Sinks may be occupied only when high quality habitat is fully occupied, in which case sinks can serve a valuable function by serving as a reservoir for surplus individuals (Pulliam 1988, see also Howe et al. 1991). Conversely, if dispersing individuals settle in sinks rather than continuing to search for higher quality habitat, sinks may be detrimental to long-term population viability (Lamberson et al. 1992, Zimmerman et al. 2003).

Little is known about potential source-sink dynamics in Mexican spotted owls. Ganey et al. (2005) reported an example of possible source-sink dynamics in two populations occupying different habitats in the Sacramento Mountains, New Mexico. This was based on a study of short duration involving relatively few owls, however. Consequently, we cannot be certain that the apparent sink functions as a sink over longer time frames. And, if it is indeed a sink, we do not know whether it serves as a reservoir for surplus owls when population levels are high, or as an ecological trap for individuals that might find better habitat if they continued looking.

Another important concept relevant to metapopulation dynamics deals with correlation (or lack thereof) among population growth rates of different subpopulations. LaHaye et al. (1994) demonstrated that high correlation in vital rates among subpopulations increased the risk that such populations would decline simultaneously. In contrast, lack of correlation among subpopulations resulted in situations where some populations were able to contribute surplus individuals to declining populations. The metapopulation dynamics evaluated were very different for these situations, with increased correlation among subpopulations resulting in an increased risk of rangewide population declines and ultimately extinction.

The extent of correlation in vital rates among subpopulations of Mexican spotted owls is only partly understood. Spotted owl vital rates appear to be partly influenced by large-scale climatic patterns (Seamans et al. 2002, Gutiérrez et al. 2003). Such patterns are likely to be at least somewhat correlated across much of the range of the owl, suggesting that correlation among subpopulations could be high. However, available evidence suggests that one vital rate, reproductive output, was only moderately correlated among three populations of Mexican spotted owls during a period of simultaneous study (1991-2000). Reproductive output was relatively high for all populations in 1991. Reproduction in the Sacramento Mountains declined steadily to low levels and remained there through 1995, rebounding in 1996 (Ward 2001: Figure 3.8). Reproduction was more variable in the other two populations, but declined abruptly in both from 1993 to 1994 (Seamans et al. 1999: Figure 2). Reproduction in the Coconino population then increased gradually from 1994 to 1996, whereas reproduction in the Gila population continued to decline through 1995 before rebounding in 1996. Thus, reproduction appeared to be somewhat, but not completely, correlated in these populations, with a period of low reproduction

occurring in all populations during the mid-1990s. This decline occurred earlier in the Sacramento Mountains than in the other two populations. However, these latter populations both were located in the Upper Gila Mountains Ecological Management Unit, and climatic patterns (and therefore population dynamics) may be more similar within than among Ecological Management Units. Survival estimates also are available for two of these populations during the same time period (Seamans et al. 1999: Figure 3). Survival trajectories were similar between areas for owls <1 year old, but not for older owls. Again, this suggests some level of correlation in vital rates among populations but that such rates are not completely correlated among populations.

In summary, the distribution of Mexican spotted owls throughout their range suggests a spatial distribution congruent with a group of subpopulations that may function as a metapopulation. The Upper Gila Mountain EMU includes the largest contiguous area of habitat for Mexican spotted owls, which is reflected in the large number of documented owls in that EMU (e.g., Ganey et al. 2004, see also Table B.2). Because of its size and central location to other areas inhabited by Mexican spotted owls, the larger subpopulation in this EMU likely serves as a core, source population for supplying new recruits to proximal outlying locations. Other subpopulations, particularly those occurring in the Basin and Range-East, appear isolated enough that recruitment must come primarily from reproduction within the local subpopulation. Limited evidence from simulation models and genetic analysis supports these aspects of metapopulation function and spatially structured population dynamics. Although temporarily asynchronous reproduction and survival may occur among some subpopulations, interstitial distances and dispersal ability may limit the beneficial traits of metapopulation function such as the numerical rescue effect. This may be the case for the concentrated population of Mexican spotted owls in the Sacramento Mountains of New Mexico (Barrowclough et al. 2006). Consequently, subpopulations that are large enough to produce surplus individuals (i.e., acting as a source population) in some years but isolated enough that external recruitment is rare will require more conservation attention to maintaining internal recruitment and viability, whereas conservation for smaller subpopulations near larger core populations may require a greater focus on identifying and enhancing dispersal corridors. More information is needed to identify the magnitude of numerical exchange of individuals among subpopulations and the relative influence on local, Ecological Management Unit-wide, and rangewide population viability.

9. Conclusions

In many ways, the Mexican spotted owl appears to be quite similar to both the northern and California spotted owls with respect to general behavioral patterns and ecology. For example, all three subspecies are most common in forests of complex structure, prey mainly on nocturnally active small mammals, and share similar vocalizations, reproductive chronologies, and population characteristics. However, important differences exist between the Mexican spotted owl and the other subspecies. The distributional pattern of the Mexican spotted owl is more disjunct and ranges over a much larger area than that of the other subspecies, with the possible exception of some California spotted owl populations that occur in disjunct mountain ranges of southern California (Noon and McKelvey 1992). The Mexican subspecies also appears to use a wider range of habitat types than the other subspecies and to date only the Mexican subspecies has been found to dwell and reproduce in rocky canyons in any significant numbers (although

cliff nesting has been documented in both northern [Hane et al. 2007] and California [Peyton 1910, Dickey 1914] spotted owls). These unique aspects of the ecology of the Mexican spotted owl require unique approaches to its management. For example, threats to owl habitat and management proposed to address those threats may well differ among the diverse habitats occupied by Mexican spotted owls. In addition, because of its disjunct distributional pattern, dispersal among subpopulations of Mexican spotted owls is an important consideration. Thus, habitat management plans may need to consider not only areas occupied by owls but also intervening areas, even where such areas are very different in habitat structure from those typically occupied by spotted owls.

We have learned a great deal about the Mexican spotted owl in the last three decades, but significant information gaps still remain. Most studies of the owl to date have been descriptive rather than experimental. Although we have identified patterns with respect to some aspects of this owl's ecology (e.g. habitat use), cause and effect relationships have not been documented. Much more information is needed on how specific factors alone and in combination affect change in Mexican spotted owl abundance. These considerations suggest that much additional research is needed, and that management recommendations in the near term must deal with extremely high levels of uncertainty.

Table B.2. Number of Mexican spotted owl site records summarized by U.S. Ecological Management Unit and land ownership. Numbers are cumulative since 1989. A site could include a single owl or a pair of owls. These numbers are best interpreted as minimum cumulative numbers of locations where at least one owl was recorded during at least one breeding season since 1989. It is not known if all of these sites are currently occupied. Data are from USDA Forest Service-PAC centers, Ward et al. (1995), Mullet (2008), and site locations provided by several people to several of the authors of this plan.

Ecological Management Unit / Land Jurisdiction	Site records ¹	
	Number	% of total
Colorado Plateau	197	15.1
USDI Bureau of Land Management	45	
USDI National Park Service	123	
State of Utah	1	
USDA Forest Service	28	
Southern Rocky Mountain²	71	5.5
USDI Bureau of Land Management	10	
Private	2	
USDA Forest Service	59	
Upper Gila Mountain	684	52.6
USDA Forest Service	684	
Basin and Range – East	188	14.5
USDI National Park Service	32	
Private	5	
USDA Forest Service	151	
Basin and Range – West	161	12.4
Department of Defense	6	
USDA Forest Service	155	
Total Among Ecological Management Units:	1,301	100.0

¹ Site as defined in Box 1 of the Recovery Plan.

² Colorado portion = 21 sites; New Mexico portion = 50 sites.

Table B.3. Characteristics of study areas where movements of radio-marked Mexican spotted owls were monitored (from Ganey and Block [2005a]).

Study area	State	General landform	Primary cover types ¹	Source ²
San Francisco Peaks	Arizona	Montane slopes	Mixed-conifer, ponderosa pine	1
Walnut Canyon	Arizona	Incised canyon	Mixed-conifer, ponderosa pine, riparian	1
Sacramento Mtns. ³	New Mexico	Montane slopes and canyons	ponderosa pine/pinyon-juniper/oak, Mixed-conifer, ponderosa pine, pinyon-juniper	2, 3
Sacramento Mtns. – mesic ³	New Mexico	Montane slopes and canyons	Mixed-conifer, ponderosa pine, pinyon-juniper	4
Sacramento Mtns. – xeric ³	New Mexico	Montane slopes and canyons	Mixed-conifer, ponderosa pine, pinyon-juniper	4
Bar-M Canyon	Arizona	Rolling hills, cinder cones	Ponderosa pine - Gambel oak, ponderosa pine	5
Colorado	Colorado	Incised canyons	Mixed-conifer, pinyon-juniper,	6
Southern Utah	Utah	Incised canyons	Pinyon–juniper, mixed-conifer	7
Grand Canyon	Arizona	Incised canyon	Pinyon-juniper	8

¹ Dominant species: Mixed-conifer = Douglas-fir (*Pseudotsuga menziesii*) and/or white fir (*Abies concolor*), with ponderosa pine (*Pinus ponderosa*) and southwestern white pine (*P. strobiformis*) common. Ponderosa pine = ponderosa pine. Riparian = box-elder (*Acer negundo*), narrowleaf cottonwood (*Populus angustifolia*), and quaking aspen (*P. tremuloides*). Ponderosa pine / pinyon-juniper / oak = ponderosa pine, pinyon pine (*P. edulis*), various juniper species (*Juniperus* spp.), and Gambel oak (*Quercus gambelii*). Pinyon-juniper = pinyon pine, various species of junipers. Ponderosa pine – Gambel oak = ponderosa pine, Gambel oak.

² Sources: 1 = Ganey and Balda (1989b; Upper Gila Mountains EMU); 2 = Zwank et al. (1994; Basin and Range – East EMU); 3 = Skaggs (1990; Basin and Range – East EMU); 4 = Ganey et al. (2005; Basin and Range – East EMU); 5 = Ganey et al. (1999; Upper Gila Mountains EMU); 6 = Johnson (1997; Southern Rocky Mountains EMU); 7 = Willey and van Riper (2000, 2007; Colorado Plateau EMU); 8 = Bowden (2008; Grand Canyon National Park, Colorado Plateau EMU).

³ Ganey et al. (2005) recognized two distinct study areas in the Sacramento Mountains, whereas Zwank et al. (1994) and Skaggs (1990) did not. The mesic area was dominated by mixed-conifer forest, the xeric area by drier forest and woodland types.

Table B.4. Size (ha) of home ranges or activity centers (where available) of radio-marked Mexican spotted owls during the breeding and non-breeding seasons, as estimated in various studies. Seasons followed Ganey and Balda (1989b) in all studies (breeding season = 1 Mar – 30 Aug). *N* = number of owls included in estimates. Home range estimates based on the minimum convex polygon estimator (Zwank et al. 1994) or 95% adaptive kernel estimator (Ganey et al. 1999, 2005; Willey and van Riper 2007; Bowden 2008). Activity_centers based on the 75% adaptive kernel estimator.

Parameter / Study area	Breeding season			Non-breeding season			Source
	<i>N</i>	Mean	SE	<i>N</i>	Mean	SE	
Home-range size /							
Sacramento Mtns. ¹	9	278	75.3 ²	9	365	100.3 ²	Zwank et al. 1994
Sacramento Mtns. – mesic ¹	6	228.1	37.3	6	328.0	59.3	Ganey et al. 2005 ³
Sacramento Mtns. – xeric ¹	6	458.9	83.4	6	895.5	304.8	Ganey et al. 2005 ³
Bar-M Canyon	8	392.5	70.0	14 ⁴	948.9	146.8	Ganey et al. 1999
Southern Utah	12	545	518 ⁵	12	1032	657 ⁵	Willey and van Riper 2007
Grand Canyon	5	562	84				Bowden 2008
Sacramento Mtns. – mesic ¹	6	69.9	9.5	6	89.3	14.4	Ganey et al. 2005 ³
Sacramento Mtns. – xeric ¹	6	156.2	22.0	6	352.1	131.1	Ganey et al. 2005 ³
Bar-M Canyon	8	121.7	21.8	14 ⁴	326.5	53.8	Ganey et al. 1999

¹ Zwank et al. (1994) pooled owls within the Sacramento Mountains when estimating size of seasonal home ranges, whereas Ganey et al. (2005) recognized two distinct study areas in the Sacramento Mountains. The mesic area was dominated by mixed-conifer forest, the xeric area by drier forest and woodland types.

² *SE* estimated from data in Zwank et al. (1994)

³ Results presented here were recalculated using data from the sample of owls discussed in Ganey et al. (2005). Ganey et al. (2005) did not present data on activity-center size and summarized data on home-range size in a figure.

⁴ Fourteen range estimates computed for 13 individual owls. One radio-marked female dispersed to a new territory during the study. Separate range estimates were computed for this owl in different years.

⁵ Standard deviation (Willey and van Riper 2007).

Table B.5. Spatial overlap between seasonal activity centers (AC; estimated as the 75% adaptive kernel contour) of radio-marked Mexican spotted owls in three study areas¹. *N* = number of owls included in estimate; only owls with valid range estimates during both the breeding and non-breeding seasons were included in estimates (from Ganey and Block [2005]).

Study area	<i>N</i>	% of breeding-season activity center contained in non-breeding-season activity center		% of non-breeding- season activity center contained in breeding- season activity center			
		Mean	SE	Observed		Maximum ²	
				Mean	SE	Mean	SE
Sacramento Mtns. –mesic	6	85.7	4.6	66.9	5.6	82.6	8.4
Sacramento Mtns. – xeric	6	78.0	7.1	48.8	6.7	65.4	14.0
Bar-M Canyon	8	91.4	3.1	35.5	9.0	42.6	13.0

¹ Based on data from a sample of radio-marked owls included in Ganey et al. (1999, 2005). The parameters estimated here were not included in previous papers.

² Theoretical maximum proportion of the non-breeding-season activity center that could be contained in a breeding-season activity center given observed size of those breeding-season activity centers, assuming maximum spatial overlap.

Table B.6. Summary of estimates of reproductive output (young fledged per pair) of spotted owls.

Subspecies	Age-class ¹	Area	Populations studied ²	Number of years ³	Reproductive output		Source ⁴
					Mean	SE	
Mexican	A, SA	Arizona	1	12	0.929	0.188	1
Mexican	A, SA	New Mexico	1	12	0.702	0.199	1
Mexican	A, SA	New Mexico	1	6	0.72	0.631	2
Mexican	A	New Mexico	4	NA	0.359	0.057	3
Mexican	SA	New Mexico	4	NA	0.150	0.107	3
Mexican	A, SA	New Mexico	1	18	0.97	No estimate	4
Northern	SA1	Rangewide	14	14	0.148	0.0584	5
Northern	SA2	Rangewide	14	14	0.416	0.064	5
Northern	A	Rangewide	14	14	0.744	0.058	5
California	A, SA	Rangewide	5	14	0.57-0.81 ⁵	0.16-0.82 ⁵	6
California	A	Southern	1	12	0.345	0.028	7
California	SA	Southern	1	12	0.139	0.050	7

¹ Age classes: A = adult, SA = subadult (first and second-year subadults combined), SA1 = first-year subadult, SA2 = second-year subadult. A, SA indicates that reproductive output was estimated for adult and subadult owls combined.

² Number of distinct study areas covered by estimate.

³ Number of years included in the study. NA = number not available.

⁴ Source: 1 = Gutiérrez et al. (2003); 2 = calculated from data in Ward (2001:Figure 3.8); 3 = Stacey and Peery (unpublished data); 4 = Johnson (2000); 5 = recalculated from fecundity in Anthony et al. (2006:Table 5); 6 = recalculated from fecundity in Franklin et al. (2004:Table 9); 7 = LaHaye et al. (2004).

⁵ Range across populations.

Table B.7. Summary of estimates of annual survival for spotted owls.

Subspecies	Age-class ¹	Sex ²	Area	Populations studied ³	Methodology ⁴	Survival estimate		Source ⁵
						Mean	SE	
Mexican	A, SA	B	Arizona	1	M-R	0.856	0.199	1
Mexican	A, SA	B	New Mexico	1	M-R	0.859	0.041	1
Mexican	A, SA	F	Rangewide	Several	RT	0.806	0.084	2
Mexican	A, SA	M	Rangewide	Several	RT	0.799	0.062	2
Mexican	A	B	New Mexico	4	M-R	0.769	0.037	3
Northern	A	B	Rangewide	14	M-R	0.750-0.886 ⁶	0.010-0.026 ⁶	4
Northern	SA1	B	Rangewide	14	M-R	0.415-0.860	0.010-0.111	4
Northern	SA2	B	Rangewide	14	M-R	0.626-0.886	0.009-0.079	4
California	A, SA	B	Rangewide	5	M-R	0.831	0.012	5
Mexican	J	B	Arizona	1	M-R	0.230	0.064	1
Mexican	J	B	New Mexico	1	M-R	0.080	0.028	1
Mexican	J	B	Arizona	1	RT	0.205-0.287 ⁷	0.028	6
Mexican	J	B	Utah	1	RT	0.096	No estimate	7
Northern	J	B	Rangewide	11	M-R	0.258	0.036	8
California	J	B	Southern	1	M-R	0.296	0.055	9

¹ Age classes: A = adult, SA = subadult, and J = juvenile. A, SA indicates that survival was estimated for adult and subadult owls combined.

² F = female, M = male, B= survival estimated for both sexes combined.

³ Number of distinct study areas covered by estimate.

⁴ Methodology underlying survival estimate. M-R = mark – recapture; RT = radio-telemetry.

⁵ Source: 1 = Gutiérrez et al. (2003); 2 = White et al. (1995:Table 2.4); 3 = Stacey and Peery (unpublished data); 4 = Anthony et al. (2006: Table 13); 5 = Franklin et al. (2004); 6 = Ganey et al. (1998); 7 = calculated from data in Willey and van Riper (2000); 8 = Burnham et al. (1996); 9 = LaHaye (pers. comm. in Noon et al. [1992:Table 4; San Bernardino Mountains]).

⁶ Range across populations studied.

⁷ Estimate differed depending on whether or not owls that were suspected to be dead were included as mortality events or censored.

Table B.8. Kaplan-Meier estimates of annual survival of adult or subadult radio-marked Mexican spotted owls in different study areas.

Study area(s) ²	Owls	Owl- years ³	Annual survival		Mortality factors ¹		
			Mean	SE	P	S	U
SFP, WM, WC	8	12	0.88	0.12	1	0	0
Bar-M	13	26	0.79	0.10	0	2	2
SM-mesic	6	20	0.87	0.09	2	0	0
SM-xeric	7	13	0.62	0.14	2	1	0

¹ P = suspected predation, S = starvation, U = unknown cause of death.

² Study areas: SFP = San Francisco Peaks; WM = White Mountains; WC = Walnut Canyon (all in Arizona, Upper Gila Mountains EMU, see Ganey [1988]); Bar-M = Bar-M Canyon, Arizona (Upper Gila Mountains, see Ganey et al. 1999); SM-mesic and SM-xeric refers to mesic and xeric study areas within the Sacramento Mountains, New Mexico, respectively (Basin and Range – East EMU, see Ganey et al. [2005]). Bar-M Canyon area was dominated by ponderosa pine-Gambel oak forest. The Sacramento Mountains – xeric study area also was dominated by dry forest types, whereas all other study areas either were dominated by (SFP, WM, SM-mesic) or contained significant amounts of (WC) mixed-conifer forest.

³ Number of owl years = (number of owls radio-marked x number of years marked owls were monitored). This figure is approximate.

Table B.9. Numbers of radio-marked Mexican spotted owls observed to migrate during the winter in various studies (from Ganey and Block [2005a]).

Study area	Years	Number of owls radio-marked	Number of owls migrating ¹	Source
San Francisco Peaks	1986-1987	4	2	Ganey and Balda (1989b)
Walnut Canyon	1986-1987	2	2	Ganey and Balda (1989b)
Sacramento Mtns.	1989-1990	8	4	Skaggs (1990)
	1990-1991	9	0	Zwank et al. (1994)
	1992-1995	15	0	Ganey et al. (2005)
Colorado	1992-1996	5	3	Johnson (1997)
Southern Utah	1991-1995	15	2	Willey (1998a)
Bar-M Canyon	1990-1993	13	3	Ganey et al. (1999)

¹ Migration was defined as movement >2 km from the center of the breeding-season home range.

Table B.10. Distance moved, movement duration, elevation change, and habitats used by migrating adult or subadult Mexican spotted owls (from Ganey and Block [2005a]).

Study area	Years	Sex	Distance moved (km)	Duration	Elevation change (m) ¹	Cover type ²	Source ³
San Francisco Peaks	1986-87	F	Unknown ⁴	Nov-Apr	Unknown	Unknown	1
San Francisco Peaks	1986-87	M	Unknown ⁴	Nov-Apr	Unknown	Unknown	1
Walnut Canyon	1986-87	F	10	Dec-Jan	100	MC, PP, P/O/J, R	1
Walnut Canyon	1986-87	M	10	Dec-Jan	100	MC, PP, P/O/J, R	1
Sacramento Mtns.	1989-90	F	10-24	Unknown	Unknown	PJW, SDS	2
Sacramento Mtns.	1989-90	M	10-24	Unknown	Unknown	PJW, SDS	2
Sacramento Mtns.	1989-90	M	~5	Unknown	Unknown	MC	2
Sacramento Mtns.	1989-90	M	~11	Unknown	Unknown	MC	2
Bar-M Canyon	1990-91	M	10	Dec-Jan	0	PO	3
Bar-M Canyon	1990-91	M	50	Dec-Apr	920	PJW	3
Bar-M Canyon ⁵	1991-92	F	50	Dec-Apr	920	PJW	3
Bar-M Canyon ⁵	1992-93	F	50	Dec-Apr	920	PJW	3
Colorado	1992	M	6.7	Nov-Apr	407	PJW, PP	4
Colorado	1995	F	16.5	Nov-Feb	335	PJW, PP	4
Colorado	1995	M	6.7	Dec-Jan	182	PJW, PP	4
Utah	Unknown	F	25	Unknown	+913	SF	5
Utah	Unknown	M	20	Unknown	685	MS	5

¹ Elevation changes are negative unless otherwise indicated.

² Cover types: MC = mixed-conifer forest, MS = mountain shrub, PJW = pinyon-juniper woodland, PO = ponderosa pine-Gambel oak forest, PP = ponderosa pine forest, P/O/J = ponderosa pine/oak/juniper, R = riparian, SDS = semi-desert scrub, SF = Spruce-fir forest.

³ Sources: 1 = Ganey and Balda (1989b); 2 = Skaggs 1990; 3 = J. L. Ganey and W. M. Block (unpublished data); 4 = Johnson (1997: Table 5); 5 = Willey (1998a:54-55).

⁴ Wintering areas not located despite an aerial search covering thousands of square kilometers.

⁵ These two records represent one female owl that migrated to the same area in two consecutive winters. This owl did not migrate in the winter of 1990-1991 (but her mate did).



Figure B.3. Range map of three subspecies of spotted owls.



Figure B.4. Appearance of adult spotted (top left) and barred (top right) owls. Note spotting on the breast of the spotted owl versus vertical barring on the breast of the barred owl.

Barred owl photo downloaded from:

http://www.fws.gov/southeastlouisiana/images/habitat_mgt_images/barred_owl.jpg.

Center photo shows a juvenile (young of the year) with downy body plumage. Compare to head of female adult behind the juvenile.

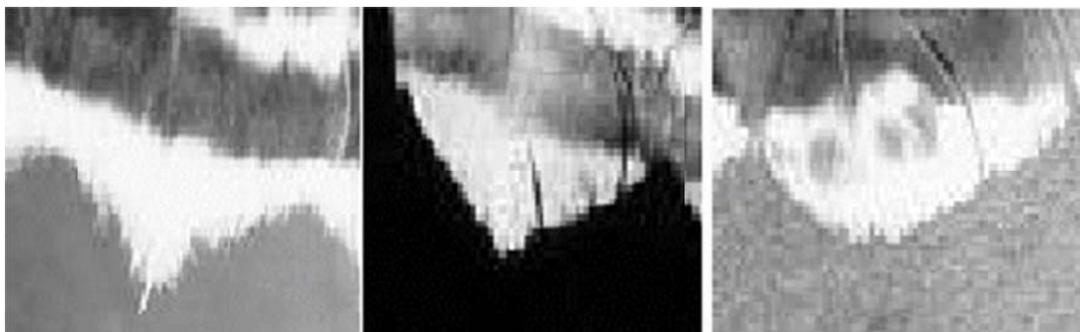


Figure B.5. These three photos show tips of tail feathers of three age classes of spotted owls with non-downy body or head plumage (photos from Moen et al. 1991). From left to right are: first-year subadult (note tips are pointed and tufted, and terminal band is pure white); second-year subadult (note tips are pointed and retain the pure white terminal band, but tufts have worn away); and adult (note rounded tip, and mottled brown spots in white terminal band). Young of the year also have pointed and tufted tips but also have downy body or head plumage.



Figure B.6. General areas occupied by Mexican spotted owls within five Ecological Management Units within their range in the United States.

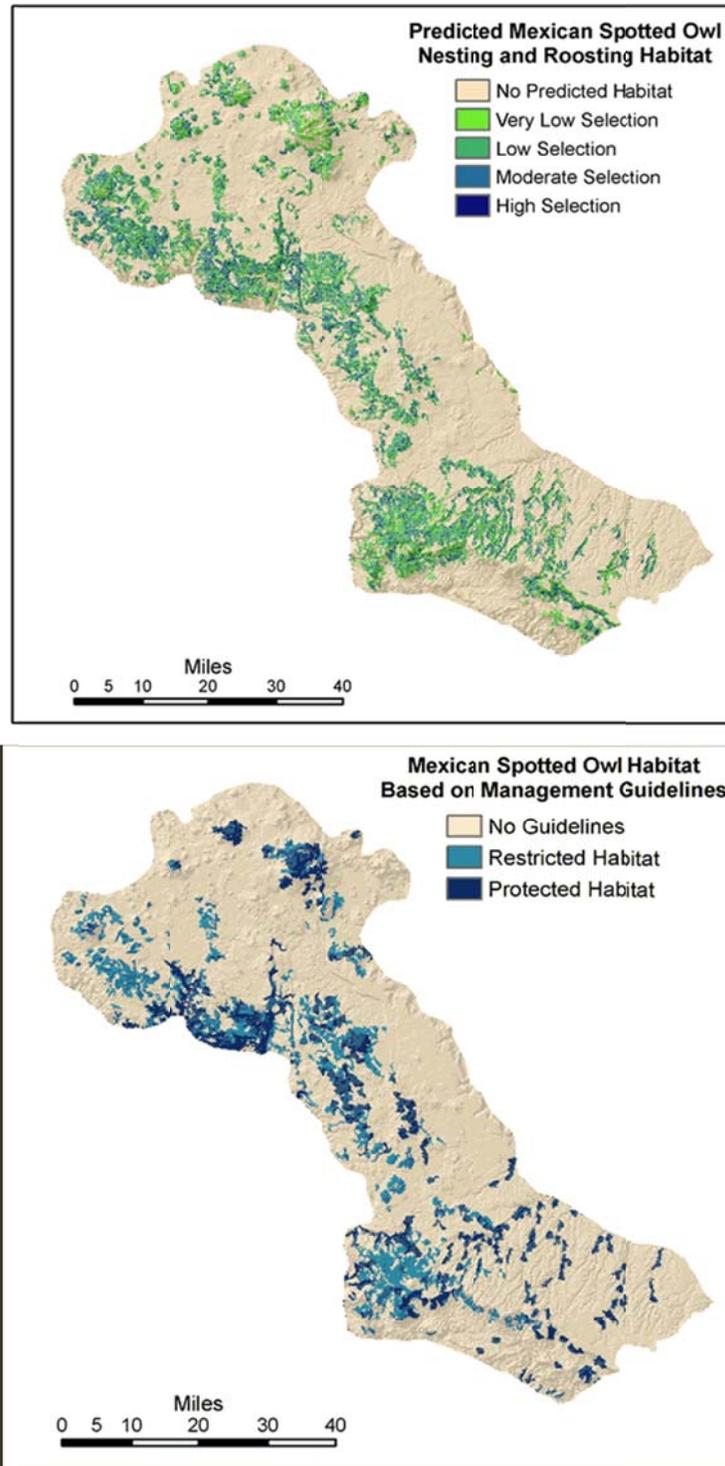


Figure B.7. Maps of predicted spotted owl nesting and roosting habitat (top) and management guidelines (bottom) for Mexican spotted owls under USDI FWS (1995). Source: Forest ERA 2005.

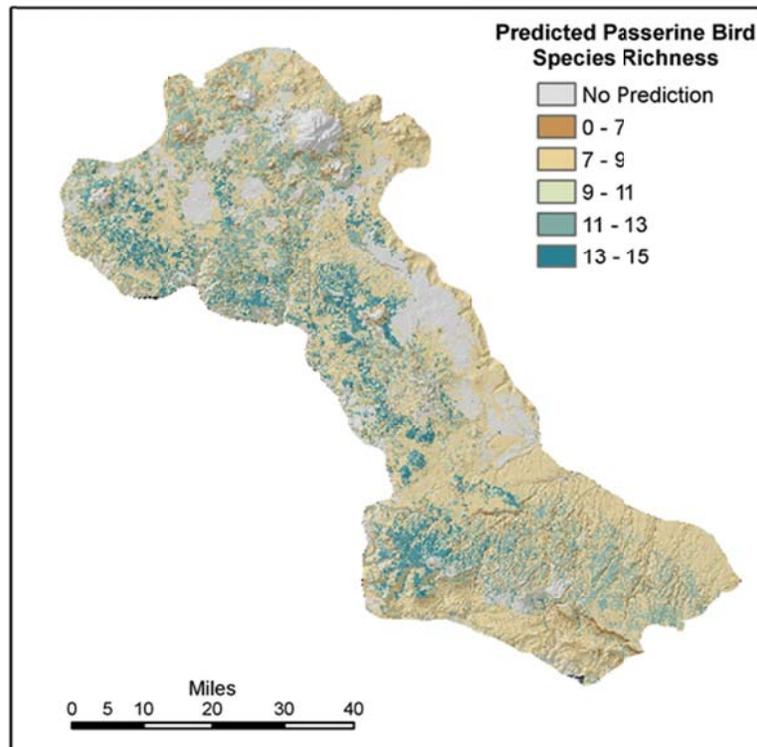
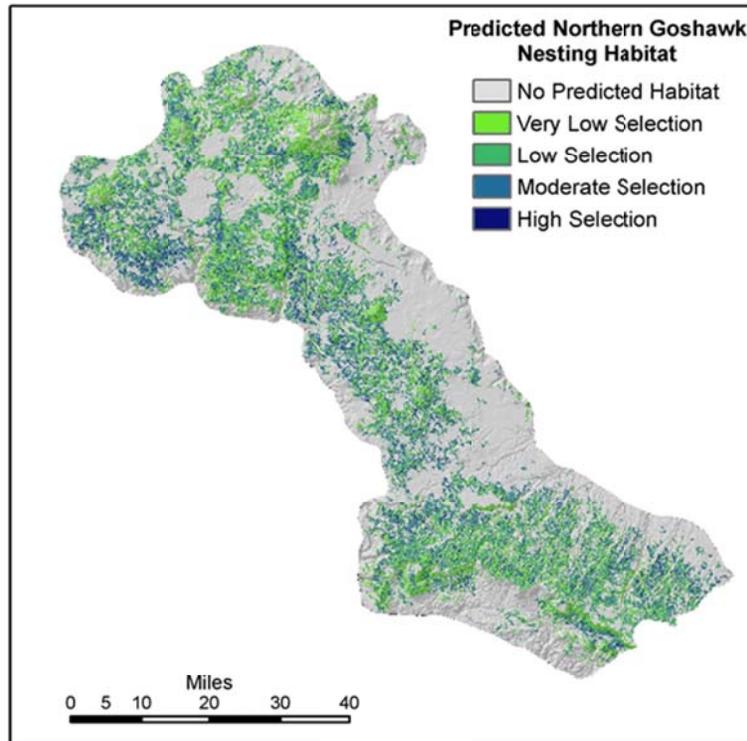


Figure B.8. Maps of predicted nesting and roosting habitat for the northern goshawk (top) and species diversity of breeding birds (bottom). Source: Forest ERA 2005. Compare these maps to maps of predicted habitat for Mexican spotted owls and management guidelines for Mexican spotted owls (Figure II.A.4).

APPENDIX C

MANAGEMENT RECOMMENDATIONS: GENERAL MANAGEMENT RECOMMENDATIONS

1. Assumptions and Guiding Principles

The recommendations proposed in this revised Recovery Plan are based on several key assumptions about habitat requirements of the Mexican spotted owl and a number of guiding principles. These are enumerated below.

- Spotted owl distribution in forested and rocky-canyon environments is limited primarily by the availability of habitat used for nesting and/or roosting. Owl distribution may also be limited by effects of climate on prey abundance and competition for nest habitat among raptors.
- Habitat used for nesting/roosting also provides adequate conditions for foraging and dispersal activities. Thus, sustaining nesting/roosting habitat meets other survival requirements. Some habitats not used for nesting/roosting may provide conditions for other activities such as foraging and dispersal. In forests, these habitats include forest types that do not typically support nesting/roosting and forest stands in seral stages younger than typical nesting/roosting habitat. In rocky canyons, these habitats include riparian vegetation, canyon rims and/or adjacent plateau highlands.
- Nesting/roosting habitat typically occurs either in well-structured forests or in steep and narrow rocky canyons. Nesting/roosting habitat in forest environments is typified by certain structural features, including high canopy cover, large trees, and other late seral characteristics that are common in, but not restricted to, late-successional forests. Nesting/roosting habitat within rocky canyons is dominated by relatively narrow vertical-walled canyons formed by parallel cliffs with numerous caves and/or ledges within specific geologic formations. Mature trees and late-seral features that are common in, but not restricted to, riparian and mixed-conifer forests are present in some rocky canyon habitats; however, steep cliffs may provide adequate nest and roost structures in the absence of late-seral forest.
- Forested nesting/roosting habitat is typically found in mixed-conifer, pine-oak, and riparian forests, with some other types locally important (e.g., encinal oak woodlands). Other habitats are used primarily for foraging, dispersal, or wintering. Because of ecological conditions (e.g., mesic north facing slopes) and processes (e.g., fire) that tend to limit denser forest stands to particular locations on the landscape, the distribution of nesting/roosting habitat is naturally discontinuous and limited in some areas.
- Disturbance events leading to forest canopy gaps are important for maintaining a diversity of tree and understory species, particularly in mixed-conifer spotted owl nest/roost stands. Both shade-tolerant and shade-intolerant species contribute important diversity to both dry and wet mixed-conifer forests.
- Existing forested habitat used by Mexican spotted owls for nesting/roosting generally has not been developed through planned silvicultural treatments. That is, although owls may be found in managed stands, these stands were not treated specifically to enhance spotted owl habitat.

- Forest restoration and fuels-reduction treatments must be evaluated over time using appropriate modeling, rigorous monitoring, management experiments, and/or research to assess their effectiveness in maintaining or creating owl habitat and/or their effectiveness in reducing the threat of high severity or stand-replacing wildfire.
- Recruitment of large trees in both forested and rocky-canyon habitats is a function of both time and ecological site-specific factors affecting productivity. Similarly, many late-seral characteristics typical of owl habitat, such as large snags and broken-topped trees, high canopy cover, large downed logs, and the sharing of growing space among multiple shade-tolerant and -intolerant species, are attained primarily through time and the operation of ecological processes such as fire and forest pathogens.
- This revised Recovery Plan represents a short-term (10 year) strategy, but management actions recommended herein will have long-term consequences. Therefore, care should be taken to preserve future options while designing management prescriptions.
- Ongoing climate change will result in unpredictable changes in habitat distribution and quality, and this creates considerable uncertainty in developing strategies to recover the owl. Again, this argues for preserving options where possible, as well as for attempting to account for potential changes in habitat distribution and quality.
- In general, management should strive to sustain and develop desired future conditions for the owl (Table C.1 in Appendix C) where appropriate.

2. Management Recommendations

Here, we provide general management recommendations for the Mexican spotted owl. These recommendations apply throughout the range of the owl, although specific recommendations will be more applicable to some locations than others. We provide additional management recommendations specific to particular threats in sections regarding those potential threats (see Appendix D) and emphasize management priorities in sections on individual EMUs (see Part II.3 of Recovery Plan), when warranted by differences among EMUs.

General management recommendations focus on three categories relative to land management: Protected Activity Centers (PACs), Recovery Habitat, and Other Forest and Woodland Types. These categories are discussed below.

PACs are established around owl sites (defined below) and are intended to protect and maintain occupied owl habitat. Given our lack of experience and demonstrated expertise in purposely creating the forest structure used by owls, the recommendations for PACs focus on minimizing management. We recognize that these areas cannot be set aside and protected indefinitely, but we regard this as an appropriate interim strategy.

Recovery Habitat occurs in forest types and in rocky canyons used by owls for roosting, foraging, dispersal, and other life history needs, but outside of PACs. Recovery Habitat is intended to (1) provide protection for areas that may be used by owls, (2) foster creation of replacement roost/nest habitat, and (3) simultaneously provide managers with greater management flexibility than is allowed in PACs.

Areas not classified as either PACs or Recovery Habitats are classified as “Other Forest and Woodland Types” for purposes of this plan. These generally include forest, woodland, or other habitat types that appear to be little used by nesting owls but are likely used for foraging and dispersal. Given their apparent lack of importance to nesting owls, we propose no owl-specific recommendations in these types. Figure C.1 provides a general framework to guide implementation of the management recommendations.

Thus, management recommendations proposed here are both hierarchical and tightly targeted, with relatively strict guidelines proposed for occupied roost/nest habitat, flexible guidelines proposed for other areas with potential for use by owls, and no owl-specific guidelines proposed for large portions of the landscape little used by owls. Our intent is to protect the owl and its habitat while simultaneously minimizing conflicts with management for other resource objectives. PACs and Recovery Habitat under this plan comprise only a portion of the landscape (Box II.E.1).

3. Protected Activity Centers (PACs)

PACs are intended to sustain and enhance areas that are presently, recently, or historically occupied by breeding Mexican spotted owls. Minimum PAC area is 243 ha (600 ac; see below) and is based on the median size of the adaptive kernel contour enclosing 75% of the foraging locations for 14 pairs of radio-marked owls (241 ha [595 ac]); Ganey and Dick 1995). Thus, PACs protect activity centers used by owls rather than entire home ranges. Consequently, there is no upper limit for PAC sizes; managers may create larger PACs if it is deemed appropriate.

All PACs should contain a designated 40-ha (100 ac) nest/roost core area, designed to offer additional protection to the nest or primary roost areas (see below). We emphasize protection of habitat used for nesting and roosting within PACs because the owls are most selective for such habitat (Ganey and Dick 1995; Appendix B) and these forest conditions are most limited across the landscape. These areas also provide resources to meet other life-history needs of the owl.

Protection of owl habitat does not always mean a hands-off approach. In some situations, protection of PACs may require active management in forested habitat to reduce fuel loads and fuel continuity in areas adjacent to and within these areas to reduce potential for high severity and stand-replacement fires. Treatments should be located strategically and informed by fire behavior modeling across the greater landscape. Results of such modeling will allow managers to optimize placement of treatments, thus ensuring maximum reduction in risk of severe fires while simultaneously minimizing area treated in PACs. In many cases, strategic treatments on surrounding and/or adjoining lands will reduce fire risk sufficiently so that, in the short term, treatments are not needed within PACs (Ager et al. 2007, Finney et al. 2007, Ager et al. 2010). Where fuels treatments are deemed necessary within PACs, managers must balance fuels reduction goals with short- and long-term conservation of owl habitat, recognizing that drastic alterations to PACs may render them of lesser value for Mexican spotted owls, at least in the short term.

The following guidelines pertain to the designation and management of PACs and supersede all other guidelines within the 1995 Recovery Plan:

A. Where Should PACs Be Established?

Inventory any area that could be occupied by nesting spotted owls (i.e., mixed-conifer, pine-oak, or riparian forest and/or rocky canyons) using the established survey protocol (Appendix E) before implementing any management action that will alter habitat structure or influence owl behavior. Establish PACs at all Mexican spotted owl sites (see Box II.E.2 for site definition) through the life of the Recovery Plan. Exceptions to PAC establishment or continuance are possible; we discuss these situations below. PACs also should be established at historical sites (i.e., sites documented by professional wildlife biologists) that meet our definition of an owl site. Historical sites that do not meet our definition of an owl site may not require a PAC (see below: f. Can PACs Be Decommissioned?).

A long-pending question has been whether high-elevation forest (>2,440 m [8,000 ft]) in CP and SRM EMUs should be surveyed or treated as potential habitat (see Box II.E.3). We evaluated what is known about use by owls of high-elevation, mixed-conifer forest in the CP and SRM EMUs. Given information provided from the North Kaibab Ranger District, Dixie National Forest, Carson National Forest, and SRM-CO Working Team, it appears that use of high elevation forest varies by longitude. We know of few records of breeding owls above 2,740 m (9,000 ft) west of US Highway 191 in Arizona and Utah. Those found in CP tended to be on the Cibola National Forest in New Mexico, which is east of US Highway 191, but very few owls were found in the high-elevation forests of Utah. Records exist of owls breeding at elevations above 2,740 m (9,000 ft) in SRM EMU. Based on this information, surveys are not recommended for forested habitat above 2,740 m (9,000 ft) occurring west of US Highway 191. Surveys in this region would still be required for forests below 2,740 m (9,000 ft). These areas should still be managed as Recovery Habitat (see discussion below) anticipating that owls and their habitat might shift both north and upwards in elevation as climate changes. Range-wide management recommendations (including the need to survey for owls) for mixed-conifer forest should remain in place for CP east of US Highway 191 and for SRM EMU.

B. How Should PACs and Core Areas Within PACs Be Established?

- a. Identify an activity center around which to designate a PAC.
The activity center is defined here as a nest site or a roost grove or cliff area commonly used during the breeding season in absence of a verified nest site, or as the best potential roosting/nesting habitat if both nesting and roosting information are lacking. Site identification should be based on the best judgment of a biologist familiar with the area. Lacking radio-marked birds, spotted owl surveys conducted to locate nests, pairs, or young generally provide the best information for defining activity centers (Ward and Salas 2000).
- b. Delineate a PAC at least 243 ha (600 ac) in area configured around the activity center.
In areas that are mostly forested, construct PACs as compactly as possible to include the best owl habitat roughly centered on the activity center. Boundaries of the PAC should correspond to habitat polygons and/or topographic features, such as ridgelines or canyon rims, as appropriate. The PAC should include as much roost/nest habitat as is necessary to buffer the activity center, supplemented by potential foraging habitat. For example, in a forested area containing mixed conifer on north-facing slopes and ponderosa pine on south-facing slopes, it may be prudent to include some south-facing slopes as potential foraging

habitat rather than 243 ha (600 ac) of north-slope habitat. In many rocky-canyon environments, more complex or linear PACs along the canyon axis will better represent owl habitat than creating circular PACs. The PAC polygons should include opposing canyon slopes and may include some habitat along canyon rims as well (e.g., Bowden 2008), but most PAC area should consist of area below the canyon rim where owls spend approximately 88% of their time (Willey and Van Riper 2007).

- c. Within the PAC, designate 40 ha (100 ac) arranged around the activity center. This is identified in paragraph a. above. This nest-roost core area should include habitat that resembles the structural and/or floristic characteristics of the nest and/or roost sites as much as possible. The intent of the core area is to define parts of the PAC that should receive maximum protection by limiting activities that have a high likelihood of disturbing owls or causing abandonment (primarily habitat alteration and certain forms of mechanical noise). The boundary of the core area should be drawn to include features commonly used by these owls for roosting and nesting (e.g., areas with concentration of conifers or oaks >46 cm [18 inches] diameter, or cliffs with ledges and caves or riparian vegetation, first or second order drainage basins [Ward and Salas 2000]). Cores should be one contiguous polygon unless site-specific information indicates that two or more areas would better meet the intent of core areas. In such cases, coordination with the appropriate FWS office is recommended. If a nest cannot be found, other evidence can be used to designate the core area (see Box C.4).
- d. In general, boundaries of adjacent PACs may abut but not overlap. In some local areas of high owl density, this may be difficult to accomplish. In such cases, exceptions to this guideline can be negotiated in consultation with FWS.
- e. PACs may be larger than 243 ha (600 ac) if deemed appropriate. Larger PACs may be needed to protect owls that shift activity centers across years or in other special situations. Over time, occupants of a PAC may be replaced by new owls, and the new owls may use different nest or roost groves or canyon sections. If the new owls are found outside of a nearby PAC and the former occupants are not located, the biologist must decide whether to establish a new PAC or enlarge the old one. Where owls are found outside of an unoccupied PAC but within 400 m (0.25 mi) of its boundary, the original PAC should be enlarged to include the new owls unless surveys verify that two PACs are needed for two different owls or pairs. If an owl or pair is found roosting beyond 400 m (0.25 mi) of an existing PAC boundary, a new PAC should be established. In this case, the former PAC should be retained as well, unless it meets criteria described in e, below.

C. What Activities Are Allowed in PACs Outside of Core Areas?

- a. All habitat-altering activities within PACs should be coordinated with the appropriate FWS office.
- b. No mechanical or prescribed fire treatments should occur within PACs during the breeding season unless it has been determined that the PAC is unoccupied or the owls are not nesting that year as inferred from results of surveys conducted according to protocol (Appendix E).
- c. Fuelwood harvest within PACs should be avoided.
- d. Road or trail maintenance, repair, and building in PACs should be undertaken only if pressing management reasons can be demonstrated. Activities should occur during the non-breeding season (1 Sep - 28 Feb) to minimize disturbance to owls during the breeding season

unless non-breeding is inferred or confirmed that year per the accepted survey protocol (Appendix E).

- e. Maintaining habitat structure for owls while managing fuels and fire risk is one of the greatest challenges facing land managers within the range of the owl. However, forest management may be needed to reduce fire risk to owl nest/roost habitats as well as larger landscapes, and in some cases may enhance habitat for the owl. As a general guide, forest management programs in PACs should be structured as follows:

Strategic Placement of Treatments. Conduct a landscape-level risk assessment to strategically locate and prioritize mechanical treatment units to mitigate the risk of large wildland fires while minimizing impact to PACs. Treatments should also strive to mimic natural mosaic patterns.

Designate Nest-roost Core. Within each PAC identified for treatment, designate a 40-ha (100-ac) nest-roost core area as described above.

Area Limitations. Mechanically treat as needed up to 20% of the non-core PAC area within an EMU identified through the landscape-level assessment. This landscape proportion may be allocated flexibly. That is, this does not mean that 20% of each PAC should be treated, or that only 20% of any PAC can be treated. Treatment placement and extent should be guided by fire modeling as discussed above.

Types of Treatments. Within the remaining PAC acreage (202+ ha [500+ ac]), combinations of mechanical and prescribed fire treatments may be used to reduce fire hazard while striving to maintain or improve habitat conditions for the owl and its prey (see desired future conditions in Table C.1).

Seasonal Restrictions. Treatments should occur during the non-breeding season (1 Sep - 28 Feb) to minimize disturbance to resident owls during the breeding season, unless non-breeding is inferred or confirmed that year per the accepted survey protocol (Appendix E).

Monitoring. Monitoring should be designed and implemented to evaluate effects of treatments on owls and retention of or movement towards desired future conditions. Box II.E.5 provides a framework for development of monitoring studies.

- f. Within all PACs, light burning of surface and low-lying fuels may be allowed following careful review by biologists and fuel-management specialists on a case-specific basis. Generally, burns should be done during the non-breeding season (1 Sep - 28 Feb) unless non-breeding is inferred or confirmed that year per the accepted protocol (Appendix E).

D. What Activities Are Allowed Within Nest-roost Core Areas in PACs?

- a. All activities within the core area should undergo consultation with the appropriate FWS office.
- b. Management activities should be deferred from the nest-roost core during the breeding season (1 Mar - 31 Aug), except where non-breeding is confirmed or inferred that year per the accepted survey protocol (Appendix E).
- c. Planned or unplanned fires should be allowed to enter cores only if they are expected to burn with low fire severity and intensity. Fire lines, check-lines, backfiring, and similar fire management tactics can be used to reduce fire effects and to maintain key habitat elements (e.g., large downed logs, snags, and large trees) to the extent practicable considering safety

concerns, and as deemed necessary by biologists and fire managers.

- d. Other activities should be conducted outside of the breeding season unless pressing reasons dictate otherwise. These activities include trail maintenance, road repair, removal of hazard trees, and utility-line maintenance. If the activity is conducted during the breeding season with owls present, owl locations should be known and documented during the conduct of the management action. Management actions should not be conducted in the vicinity of nesting owls, where vicinity is defined by the intensity of disturbance (see Appendix D).
- e. Research projects that evaluate effects of a specific activity on owl behavior or life history are allowed and in fact encouraged (see Part V.6 of Recovery Plan). For example, determining the influence of noise disturbance would require that the activity is done close to roosting or nesting owls. These activities will require scientific permits from FWS and state or tribal wildlife agencies.

E. Should Salvage Logging Occur in PACs Impacted by Disturbance?

If a stand-replacing fire, windthrow event, or large-scale mortality due to insects or disease occurs within a PAC, timber salvage plans should be evaluated on a case-specific basis in consultation with the FWS. Salvage logging in PACs should be allowed only if sound ecological justification is provided and if the proposed actions meet the intent of this Recovery Plan, specifically to protect existing nest/roost habitat and accelerate the development of replacement nest/roost habitat. Management actions that do not protect soil integrity, that impede recovery of disturbed systems, or that fail to maintain and enhance native species and natural recovery processes should not be implemented (Betchta et al. 2004, Karr et al. 2004).

Fires within PACs are not always detrimental to owls. Patchy fires result in habitat heterogeneity and may benefit the owl and its prey (Bond et al. 2009). In such cases, adjustments to PAC boundaries are probably unnecessary and salvage should not be done. Salvage and boundary adjustments should be considered in PACs only when the disturbance is extensive in size and tree mortality is extensive and substantial. We make the following recommendations:

- a. In all cases where salvage logging is being considered, the PAC and a buffer extending 400 m (433 yd) from the PAC boundary should be surveyed for owls before non-occupancy is inferred. This survey should occur during the breeding season following the fire or other large-scale mortality events and should adhere to the accepted protocol (Appendix E) except that it could be completed with four visits in a single season.
- b. If owls are located within the PAC or within 400 m (433 yd) of the PAC boundary, then managers should evaluate the extent and severity of the disturbance and consider reconfiguring of PAC boundaries and potential modification of the proposed action in consultation with FWS.
- c. If no owls are detected, Section 7 consultation should be used to evaluate the proposed salvage plans.
- d. Salvage prescriptions should be designed to maintain or enhance the desired future conditions described in Table C.1 in Appendix C and to minimize the spread of exotic invasive species.
- e. New road construction should be avoided whenever possible, and temporary road and skid trail construction should be designed to minimize impacts on soil integrity and natural

recovery processes. All new and temporary roads and skid trails should be decommissioned and obliterated after use.

F. Can PACs Be Decommissioned?

In general, PACs should not be decommissioned. Once a PAC has been established it should remain in place, with a few exceptions discussed below. Site occupancy by Mexican spotted owls is related to owl density, and owl density changes over time (e.g., Seamans et al. 1999). As a result, a territory may be occupied during periods of high owl density and vacant during periods of lower density. Therefore, failure to detect owls in one or even a few years does not necessarily indicate that an area no longer provides useful habitat, or that protecting such habitat is inappropriate. Some circumstances may warrant removing areas from being managed as PACs, however. Examples include:

- a. Situations where PACs were established or converted from previously established management territories using less stringent criteria than the criteria we recommend for defining owl sites (Box II.E.2) and surveys conducted post-establishment have failed to detect owls.
- b. Situations where vegetation within a PAC was altered substantially by wildfire, insect kill, windthrow, or similar natural disturbances to the extent that they would not be expected to support breeding owls, and non-occupancy is documented through surveys conducted to protocol (Appendix E).

G. How Can PACs Be Decommissioned?

When PACs were designated based on information that does not meet the Recovery Plan definition for an owl site, then:

- a. Coordinate with the appropriate FWS office when considering removing PAC status.
- b. If surveys were conducted according to the accepted protocol (Appendix E) and owl-site criteria were not met, then no PAC is necessary. For historical locations that have not been surveyed according to the accepted protocol, surveys should be conducted following the accepted protocol.

Retaining PAC Designation. If owls are detected and these detections meet Recovery Plan criteria for an owl site, PAC status should remain in place. In this situation, if new survey information supports adjusting PAC boundaries, adjustments should be made.

Removing PAC Designation. If no owls are detected during these surveys, PAC designation can be removed. Once the PAC is removed, the area should be managed according to other designations, namely Recovery Habitat or Other Forest and Woodland Types, as appropriate.

- c. In areas that have undergone extensive vegetation change to the point that land managers question the ability of the area to function as a PAC, then:

Contact FWS. Coordinate with the appropriate FWS office when considering removing PAC status.

Survey for Owls. The area should be resurveyed for owls using the accepted survey protocol (Appendix E). If no owls are located, then changes in PAC designation should be considered on a case-specific basis. If owls are found, the PAC should remain,

although adjustments to the boundaries can be considered where appropriate based on survey results and landscape configuration.

Accelerate Surveys. In situations of stand-replacement fire where timber salvage is being considered, accelerated surveys can be conducted as outlined under salvage logging guidelines above.

H. Rationale Underlying PAC Guidelines

We recognize that landscapes are dynamic. The intent of these guidelines is not to preserve designated PACs forever, but to protect them until it can be demonstrated that replacement habitat can be created through active management and/or the owl is delisted. In the following section (Recovery Habitat) we describe one approach for managing to create replacement nest/roost habitat. Once that approach or other approaches have been shown to be effective in creating or enhancing the types of habitat structure used by owls, the PAC concept could be abandoned in favor of a long-term management plan based on maintaining owl habitat well-distributed across a dynamic landscape. Until such an approach has been tested and such a plan is in place, however, we believe it wise to continue to protect occupied owl habitat using the current approach.

We recognize that protection status carries some risk with respect to probabilities of stand-replacing fire. We believe that PACs can be afforded substantial protection by emphasizing fuels reduction and forest restoration in surrounding areas outside of PACs and nest/roost habitat. However, we recognize that in some cases protection of nest/roost habitat and human communities requires reduction of fuels loads and disruption of fuel continuity within PACs. We provide guidance for such treatments above, and urge a deliberate and cautious approach to such activities within PACs emphasizing monitoring and feedback loops to allow management to be adaptive.

4. Recovery Habitat

The PAC guidelines discussed above are intended to protect the core use or activity centers of resident owls. In focusing on activity centers, however, those guidelines do not provide protection to all areas within owl home ranges; most owl home ranges are considerably larger than 243 ha (600 ac; see Appendix E). Further, owls may use areas outside of their usual home ranges at times. Examples include seasonal migration or adult and juvenile dispersal. Finally, it seems logical to strive to provide additional habitat in planning for recovery of a threatened species, as increasing population size is a logical goal of recovery efforts and providing additional habitat is one way to accomplish this. This is particularly true given uncertainty over the effects of climate change on habitat quantity, quality, and distribution. Additional habitat well-distributed across the landscape may be needed to offset unpredictable changes in quantity, quality, and distribution of owl habitat. Consequently, here we provide additional guidelines focused on what we term Recovery Habitat. These guidelines are intended to maintain and develop replacement nesting and roosting habitat now and into the future, and are stratified by two broad categories: Forested Recovery Habitat and Riparian Recovery Habitat.

A. Forested Recovery Habitat

Forested Recovery Habitat occurs in mixed-conifer and pine-oak forests (see definitions in Part II.4 of Recovery Plan) that are not included in PACs. Our primary intent here is to maintain and create replacement owl habitat where appropriate, while providing for both diversity in ecological conditions across the landscape and flexibility for managers. As noted earlier, we assume that the primary limiting factor for Mexican spotted owls in forests is the amount and distribution of nesting and roosting habitat, but we also assume that these habitats also provide key foraging habitat as well. A logical conclusion from this premise is that the landscape should be managed to sustain owl nesting/roosting habitat that is well-distributed spatially. This does not mean that all forests should be managed as replacement habitat. Rather, we recommend that a portion of the landscape should be managed for conditions suitable for nesting and roosting, and that portion differs among EMUs (see Table C.2 and Box C.6 in Appendix C). We recognize that nest/roost habitat cannot be sustained in perpetuity at specific sites, and that nest/roost habitat will continue to be lost to senescence and human and natural disturbance. We assume that providing a dynamic supply of nesting and roosting habitat requires that various parts of the landscape be in various stages of ecological succession. Our goal is to allocate those stages so as to create a landscape mosaic that ensures adequate nesting, roosting, and foraging habitat for the owl, as well as providing habitats for its major prey.

Managing forested Recovery Habitat requires knowledge of both existing and desired future conditions. Ideally, existing conditions should be assessed at multiple spatial scales (Kaufmann et al. 1994). We recognize that information needed to conduct assessments at larger spatial scales frequently is lacking. We encourage agencies to develop the types of information needed for such large-scale assessments, however, and note that such information will be necessary to move from recovery guidelines based on protecting habitat to guidelines based on managing dynamic landscapes.

In reality, most short-term assessments will focus on evaluating forest structure at the scale of individual forest stands. In particular, existing vegetative conditions within mature-old stands must be assessed to determine the treatment potentials within those stands. Given the relatively high frequency of recent stand-altering disturbances, many areas likely are deficient in mature to old-growth forests. Thus, any treatments to these stands should be applied judiciously.

a. Reference Conditions: Nesting and Roosting Conditions in Forested Environments

We defined reference conditions for management in Forested Recovery Habitat based on current knowledge of forests used by spotted owls. Forest stands used by spotted owls for nesting and roosting have certain structural features in common. These typically include relatively high tree basal area, large trees, multi-storied canopy, multi-aged trees, high canopy cover, and decadence in the form of downed logs and snags (Ganey and Dick 1995). Many stands also contain a prominent hardwood component. This is generally provided by Gambel oak in ponderosa pine-Gambel oak forests, by a variety of evergreen oaks and madrone in Madrean pine-oak forests, and by various species (e.g., oaks, maples, box elder, aspen) in mixed-conifer and montane riparian forests.

We used tree basal area and large tree (>46 cm [18 inches] dbh) density to describe minimum conditions for owl nesting/roosting habitat (Table C.2 in Appendix C). Other structures such as canopy cover, snags, and downed logs are important as well. However, we assume that when tree basal area and density approach the levels given in Table C.2, then adequate amounts of canopy cover, snags, and downed logs either exist already or will develop over time. See Box C.6 in Appendix C for a description of how Table C.2 parameters were developed.

b. Recovery Habitat Guidelines for Forest Habitats: General Approach

For planning purposes in Forested Recovery Habitat, there are two types of stands with respect to desired nest/roost conditions: those that meet or exceed the conditions and those that do not. The overriding goal is to manage a specified portion of the landscape (see Table C.2 in Appendix C) as replacement nest/roost habitat. Thus, managers should identify and protect stands that meet or exceed nest/roost conditions and then assess whether or not these stands satisfy the area requirements in Table II.E.2. If these stands are not sufficient to meet the area requirements in Table II.E.2, managers should identify those stands in the planning area that come closest to meeting nest/roost conditions and manage those stands to develop nest/roost conditions as rapidly as reasonably possible to meet recommended percentages. Managers have wide latitude in developing prescriptions that will expedite attainment of nest/roost conditions; prescriptions may include thinning to promote growth of large trees. Stands that do not meet nest/roost conditions and are not designated for development of such can be managed to meet other resource objectives.

Because most project planning occurs at limited spatial scales, the percentages of area in Table C.2 should be regarded as a **minimum** level for a given planning area. If a deficit occurs within the planning area, additional stands should be identified and managed as described above. Even if the proportion of the planning area that meets nest/roost conditions is greater than the percentages in Table C.2, we recommend that no stands be lowered below these conditions until ecosystem assessments at larger spatial scales (e.g., landscape, subregion, and region) demonstrate that desired conditions occur in recommended amounts at these larger scales. Using third-order watersheds in allocating percentages of area to manage for nest/roost conditions should reduce the potential for creating excessively fragmented replacement nesting habitat.

c. Guidelines for Forested Recovery Habitat Managed as Replacement Nest/Roost Habitat

Treatments are allowed within Recovery Habitat stands identified as meeting nest/roost conditions, as long as stand conditions remain at or above the values given in Table C.2 in Appendix C (but see discussion under “Treatments Within Replacement Stands” below). This approach allows for treatments to reduce fire risks, lessen insect or disease problems, maintain seral species, or meet other ecosystem objectives. Management activities that influence the owl and its habitat should be conducted according to the following guidelines:

Manage for Replacement Habitat. Manage mixed-conifer and pine-oak forest types in the designated proportions of Table C.2 to provide continuous replacement nest/roost habitat over space and time. Management of particular stands should be based on their capability to attain the desired stand conditions (Table C.2).

Treatments Within Replacement Stands. No stand that meets Table C.2 conditions should be treated in such a way as to lower that stand below those conditions until ecosystem assessments can document that a surplus of these stands exist at larger landscape levels (e.g., no less than the size of a USFS District). This does not preclude use of treatments to reduce fire risks or lessen insect or disease problems, nor does it preclude management to meet other ecosystem objectives, as long as stand-level conditions remain at or above the values given in Table C.2.

Select Appropriate Stands to Manage. Management should emphasize attainment of nest/roost conditions as quickly as reasonably possible. Identify and assign stands that will reach these conditions soonest to satisfy area requirements in Table C.2.

Retain Large Trees. Stand conditions that provide the owl's nesting habitat frequently vary above the minimum values given in Table C.2. Further, important stand conditions cannot be replaced quickly. In particular, removing large trees in a stand identified as habitat could reduce its suitability as nesting habitat or increase the time required to develop suitable nesting habitat. Because it takes many years for trees to reach large size, we recommend that trees ≥ 46 - cm (18 inches) dbh not be removed in stands designated as replacement habitat unless there are compelling safety or management reasons to do so.

Strive for Spatial Heterogeneity. Incorporate natural variation, such as irregular tree spacing and various stand/patch/group/clump sizes, into management prescriptions. Strive for heterogeneity both within and between stands. Owls currently use uneven-aged stands, and we do not know if landscapes composed of even-aged clumps will provide suitable owl habitat; this idea should be evaluated as described in Box C.5 in Appendix C before wide-scale implementation of management based on even-aged clumps. Attempt to mimic natural disturbance patterns and natural landscape heterogeneity. Allow natural canopy gap processes to occur, or mimic those processes through active management, thus producing horizontal variation in stand structure.

Manage for Species Diversity. Maintain all species of native vegetation on the landscape, including early seral species. Allow for variation in existing stand structures and provide for species diversity.

d. Guidelines for Forested Recovery Habitat Not Managed as Replacement Nest/Roost Habitat

The following guidelines are intended to minimize threats to Mexican spotted owls within Forested Recovery Habitat not managed as replacement nest/roost habitat. Although we emphasize fuels and restoration treatments, these guidelines are applicable to other management scenarios as well. Our intent is to manage Recovery Habitat so that important but difficult-to-replace habitat elements are conserved while allowing management flexibility. Management should strive to maintain conditions where multiple components occur in proximity to one another. For example, if a stand contains large trees, logs, and snags, prescriptions should be designed to keep as many of these components as possible while achieving management objectives such as fuels reduction and ecosystem restoration. Such prescriptions can result in the short-term reductions of key habitat components, but they should strive to maintain some of these components within the stand. Unfortunately, specific targets or quantities of these components to maintain cannot be provided because research has not been conducted to address this information need. Ideally, research in the form of management experiments will address this knowledge gap. In the meantime, management should be based on the best judgment of the

professionals involved to balance our intent with the objective(s) of the prescription. We provide the following guidelines for non-replacement habitats:

Emphasize Large Oaks. Within pine-oak types, emphasis should be placed on management that retains existing large oaks and promotes the growth of additional large oaks.

Retain Large Trees. Strive to retain (do not cut) all trees >61 cm (> 24 in) dbh, the average diameter of nest trees, unless overriding management situations require their removal to protect human safety and/or property (e.g., the removal of hazard trees along roads, in campgrounds, and along power lines), or in situations where leaving large trees precludes reducing threats to owl habitat (e.g., creating a fuel break). To the extent practical, fuel breaks should be designed to avoid the removal of larger trees (trees over 18 in [46 cm] dbh). We recognize that prescribed fire is an inexact tool and that applying prescribed fire may result in the loss of large trees. However, we strongly recommend that action agencies take reasonable steps to minimize the loss of trees >61 cm (24 in) dbh. Steps can include using light burn prescriptions and removal of ladder fuels proximal to large trees. Even with such actions, some large trees may be killed. This should not preclude proceeding with necessary treatments. Large trees killed by fire will provide a source for recruitment of large snags and eventual large logs; these snags should be retained unless their removal is necessary for public or worker safety.

Retain Key Owl Habitat Elements. Design and implement management treatments within Forested Recovery Habitat outside of replacement nest/roost stands so that most hardwoods, large downed logs (>46 cm [18 in] diameter at any point), trees (>46 cm [18 in] dbh) are retained, unless this conflicts with forest restoration and/or owl habitat enhancement goals. Treatments adequate to meet fuels and restoration management objectives in Recovery Habitats may result in the short-term loss of some habitat components in areas that could be occupied by spotted owls. We view these losses as acceptable where they result from actions that otherwise further longer-term protection of forests occupied by owls. When implementing this guideline, managers should strive to achieve a balance between retaining a sufficient density and distribution of important features that spotted owls may require and reducing the risk of losing existing roosting and nesting habitat in protected areas from insect epidemics and stand-replacing fires. Previous wording of this guideline (FWS 1995) was interpreted to mean that trees >46 cm (18-in) dbh may not be removed. That is not our intent. However, large trees are a key habitat correlate for owls, and removal of such trees should be done judiciously and only when truly necessary to meet specific resource objectives.

e. Rationale for Recovery Habitat Guidelines

The collective goal of guidelines for Forested Recovery Habitat is to provide spotted owl habitat that is well distributed over space and time. Accomplishing this goal requires maintaining or creating stand structures typical of nesting and roosting habitats, and sustaining them in sufficient amounts and distribution to support a healthy population of Mexican spotted owls. The approach outlined above provides a template for the development of a long-term management strategy that recognizes and incorporates landscape dynamics. If this approach can be validated, it may be possible to replace short-term protection of owl habitat with a longer-term approach that incorporates the dynamic nature of natural landscapes.

B. Riparian Recovery Habitat

Riparian areas are plant communities contiguous to and/or affected by surface and subsurface water. Riparian areas have one or both of these principal characteristics: (1) distinctively different vegetative species than the adjacent areas and/or (2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian vegetation typically creates a transition, an ecotone between inundated and upland areas. This ecotone makes riparian habitats among the most ecologically productive and diverse terrestrial environments in the arid western United States and Mexico (Naiman et al. 1993). Because of their productivity and diversity, because they differ in important ways from other habitats occupied by spotted owls, and because recommendations for riparian habitats in the original recovery plan (1995) were so broad that they caused considerable confusion, we discuss riparian communities separately here. Our primary focus is on forested riparian areas, because these areas are most likely to provide the habitat structure used for nesting, roosting, foraging, and dispersal (e.g., Ganey and Dick 1995, Stacey and Hodgson 1999).

Riparian habitats are threatened by a long list of anthropogenic activities, but our primary focus here is on threats that are mostly likely to affect Riparian Recovery Habitat and fall within the temporal scope of this plan. Therefore, we provide management recommendations pertaining only to those impacts.

a. Threats to Riparian Recovery Habitat

Riparian habitats are threatened by a long list of anthropogenic activities and natural events (see discussion in I.C.2.a.). Our focus is on the influences described in that section and fall within the temporal scope of this plan.

b. Guidelines for Non-replacement Riparian Recovery Habitat

The goals of the guidelines for managing non-replacement Riparian Recovery Habitat are to (1) maintain and/or restore riparian habitats to proper functioning condition (USDI BLM 1993, 1994, 1998), and (2) where ecologically feasible, provide a mix of size and age classes of both trees and shrubs that should include large, mature trees; vertical diversity; and other structural and floristic characteristics that typify riparian systems in proper functioning condition. Specific recommendations to address threats and maintain or restore riparian habitats include:

Manage for Proper Functioning Condition. Manage non-replacement recovery riparian areas for proper functioning condition as defined above to attain the highest ecological status and potential natural community structure (i.e., mid- to late-seral conditions) possible within the capability and potential of the site. Attaining the goals described, dependent on site potential, should benefit habitat for the owl (e.g., regeneration of riparian tree cover) and its prey species (e.g., provide dense ground cover for small mammals).

Manage for Species Diversity. Manage non-replacement riparian recovery areas, particularly canyon-bottom habitats, for a diversity of age and size classes of native riparian trees and shrubs along with a diverse understory of native riparian herbaceous species to provide potential roost/nest sites for owls and cover for owl prey species.

Manage Grazing Effects. Minimize negative impacts of ungulate grazing on riparian vegetation by modifying livestock grazing systems (i.e., changing seasons and duration of use, establishment of riparian pastures, and providing periods of complete rest) where needed, reducing grazing pressure by livestock and wild ungulates through stocking and population management, and/or establishing riparian exclosures (i.e., either livestock or livestock/wildlife ungulate exclosures).

Minimize Construction Activities. Avoid construction activities (e.g., road or trail building) in recovery riparian areas except on a case-specific basis where pressing management needs can be demonstrated.

Remove Trees Judiciously. Minimize effects of tree removal within recovery riparian habitat by eliminating removal where possible or by restricting removal so that habitat components (e.g., large trees, snags, and large downed logs) are conserved. We support the use of vegetation manipulation, especially removal of non-native vegetation, as a tool to restore, enhance, or maintain riparian conditions. Thus, thinning trees and shrubs is encouraged where such thinning restores properly functioning condition and improves the habitat or protects it against stand-replacing fire.

c. Rationale for Riparian Guidelines

Many riparian systems within the range of the Mexican spotted owl are extremely degraded as the result of past land-use practices (Stacey and Hodgson 1999). Our underlying premise is that if riparian systems are restored to properly functioning conditions, they will meet the needs of the owl (and numerous other species). This is particularly true in canyon-bottom situations at middle and lower elevations where little other typical nesting or roosting habitat may be available. Because canyon bottoms are used extensively by the owl (Ganey and Dick 1995, Rinkevich and Gutiérrez 1996, Johnson 1997, Willey 1998a, Stacey and Hodgson 1999), it is important to preserve and increase the quality of such habitat. We anticipate that PACs will include some of the best canyon riparian habitat that still exists, but increasing the quantity and distribution of properly functioning riparian habitats provides the potential for increasing the amount and extent of spotted owl habitat.

5. Other Forest and Woodland Types

We propose no specific guidelines for several forest and woodland community types where they occur outside PACs. These include ponderosa pine, spruce-fir, pinyon-juniper, and aspen as defined in II.C. However, the lack of specific management guidelines within this plan does not imply that these forest and woodland types are unimportant to the Mexican spotted owl.

The lack of specific recommendations in other forest and woodland types is based on extant information on the natural history of the Mexican spotted owl as summarized in Appendix E and detailed in the original recovery plan (USDI FWS 1995). These other forests and woodlands typically are not used for nesting and roosting but do provide habitat for foraging, dispersing, and wintering spotted owls. Although information on habitat features needed for foraging, dispersing, and wintering is limited, it appears that owls use a broad array of conditions to meet these needs. Furthermore, some of the best foraging habitat should be protected in PACs and Recovery Habitat. Consequently, we can be less restrictive in these other forest and woodland

community types without harming the owl or compromising its primary habitat. We assume that existing and planned management for these forest and woodland types will maintain or improve habitat for these needs of the owl. Our assumption is based largely on the premise that existing, late-seral stands will be maintained or restored where necessary across the landscape, silvicultural practices will favor selection over regeneration cuts, and management will be guided by ecosystem approaches that strive to provide sustainable conditions, which fall within the natural range of variation, across the landscape. Guidelines developed for PACs and Recovery Habitat may have useful applications when judiciously administered in these other forest and woodland types. Such guidelines include managing for landscape diversity, mimicking natural disturbance patterns, incorporating natural variation in stand conditions, retaining special features such as snags and large trees, and utilizing fire as appropriate. We also emphasize the need for proactive fuels management where appropriate. Decreasing fire risks within these types, particularly ponderosa-pine forests, also will decrease fire risks to adjoining PACs and Recovery Habitats by reducing the probability of large, landscape-level crown fires that could impinge upon occupied or potential nesting habitat.

Table C.1. Generalized description of key habitat variables comprising Desired Future Conditions (DFCs) in forest and woodland cover types typically used by Mexican spotted owls for nesting and roosting. DFCs should guide management within PACs and recovery habitats. The ecological relevance of each DFC to this owl subspecies and examples of variables that may be useful to quantify desired conditions are also shown.

Desired Future Condition	Relevance to Owl	Potential Variables
Nest/roost habitat: forest and woodland patches >1 ha (2.5 acre) patch size.	These habitat patches are most limiting to the owl.	Size, cumulative acreage, density of patches, % of landscape, amount of edge habitat, average patch canopy cover, average age of dominant overstory component of patch
Horizontal and vertical habitat heterogeneity, including physiognomy and species composition. Patches of all ages and unevenly spaced trees with interlocking crowns and high canopy cover.	Provides roosting options, thermal and hiding cover for the owl, and habitat for a variety of prey species.	Patch size and configuration (shape), juxtaposition (topology of patches), interspersion, edge length; canopy cover by height strata; number of vegetation strata present (herbaceous, shrub, sapling, pole, mature trees); uneven tree spacing and clumpiness.
Tree species diversity, especially with a mixture of hardwoods and shade-tolerant species.	Provides habitat and food sources for a diversity of prey, roosting options, and perches for young owls during early development of flapping flight. Diversity increases probability of some tree species setting seed in a given year.	Species occurrence (presence), Hill Diversity Index (including richness and equitability), basal area by species, density/species.
Diverse composition of vigorous native herbaceous species; healthy levels of residual biomass, seed head production. Shrub species diversity, physiognomy.	Provides sustainable habitat for a variety of prey; fine fuels to carry surface fire.	Cover/plant group; plant height; vertical density profile; diversity measure (richness and equitability); Robel Pole (vertical distribution); maximum height.
Range of patch sizes > 1 ha (2.5 acres).	Enhances spatial heterogeneity; roosting options, thermoregulation habitat options, creates edges for prey species (e.g., <i>Neotoma</i>).	Frequency distribution of patches by size class, total edge, core to edge distance, fractal index of patch (area to edge ratios).

Opening sizes between 0.04-1 ha (1-2 acres).	Openings provide habitat for a variety of prey and can slow or reduce fire severity by breaking the continuity of dense tree canopies and ladder fuels.	Frequency distribution of openings by size class, % of landscape in openings. Grass and herbaceous cover in openings (Daubenmire plots for coverage percent).
5 snags >46 cm dbh/ha (2 snags >18 inches dbh/acre) in pine-oak forest; 12.5 snags >46 cm dbh/ha (5 snags >18 inches dbh/acre) in mixed conifer forest, on average across large landscapes.	Snags provide nests, foraging, and calling perches for spotted owls, while also providing habitat for a variety of prey species.	Frequency distribution of snags by size class. Type of snag (size, type, condition).
Dead and down logs. Emphasize large logs > 30 cm (12 inches) midpoint diameter;	Provides habitat for a variety of prey; moisture retention at site, which may reduce fire ignition or reduce fire severity in roosting-nesting areas.	Frequency distribution of logs by size class and decomposition stage.
Average canopy cover of 60%	Roosting; nesting; prey needs, thermal environment.	Canopy cover (remote sensing; ocular estimation, Canfield Line Intercept).
Diversity of seral stages dominated by large trees >46 cm (18 inches) dbh.	All life history needs; nesting, roosting, foraging.	Patch size/seral stage; vegetation strata; tree species richness and evenness.

Table C.2. Minimum conditions for mixed-conifer and pine-oak forests managed for nesting/roosting within Recovery Habitats. Forest types are defined in Part II.4 of the Recovery Plan. Parameter values are based on averages among plots sampled within forest stands. Numbers of stands included in analysis = 74 for Basin and Range-East (BRE), 27 for mixed-conifer forest in other Ecological Management Units (EMUs), and 47 for pine-oak forest.

EMU(s) Forest Type	% of area ¹	% basal area by size class		Minimum tree basal area ²	Minimum density of large trees ³
		30-46 cm dbh (12-18 in)	>46 cm dbh (>18 in)		
BRE Mixed-conifer	20	>30	>30	13.5 (145)	37 (15)
CP, UGM, SRM, BRW Mixed-conifer	25	>30	>30	11.1 (120)	30 (12)
CP ⁴ , UGM, BRW Pine-oak	10	>30	>30	10.2 (110)	30 (12)

¹ % of area pertains to the percent of the planning area, subregion, and/or region in the specified forest type that should be managed for threshold conditions.

² Basal areas in m²/ha (ft²/acre), and include all trees >1 inch dbh (i.e., any species). We emphasize that values shown are **minimums**, not targets.

³ Trees > 46 cm (18 inches) dbh. Density is tree/ha (trees/acre). Again, values shown are minimums rather than targets. We encourage retention of large trees.

⁴ Pine-oak recommendations apply only to the Mount Taylor and/or Zuni Mountains regions within the CP Ecological Management Unit.

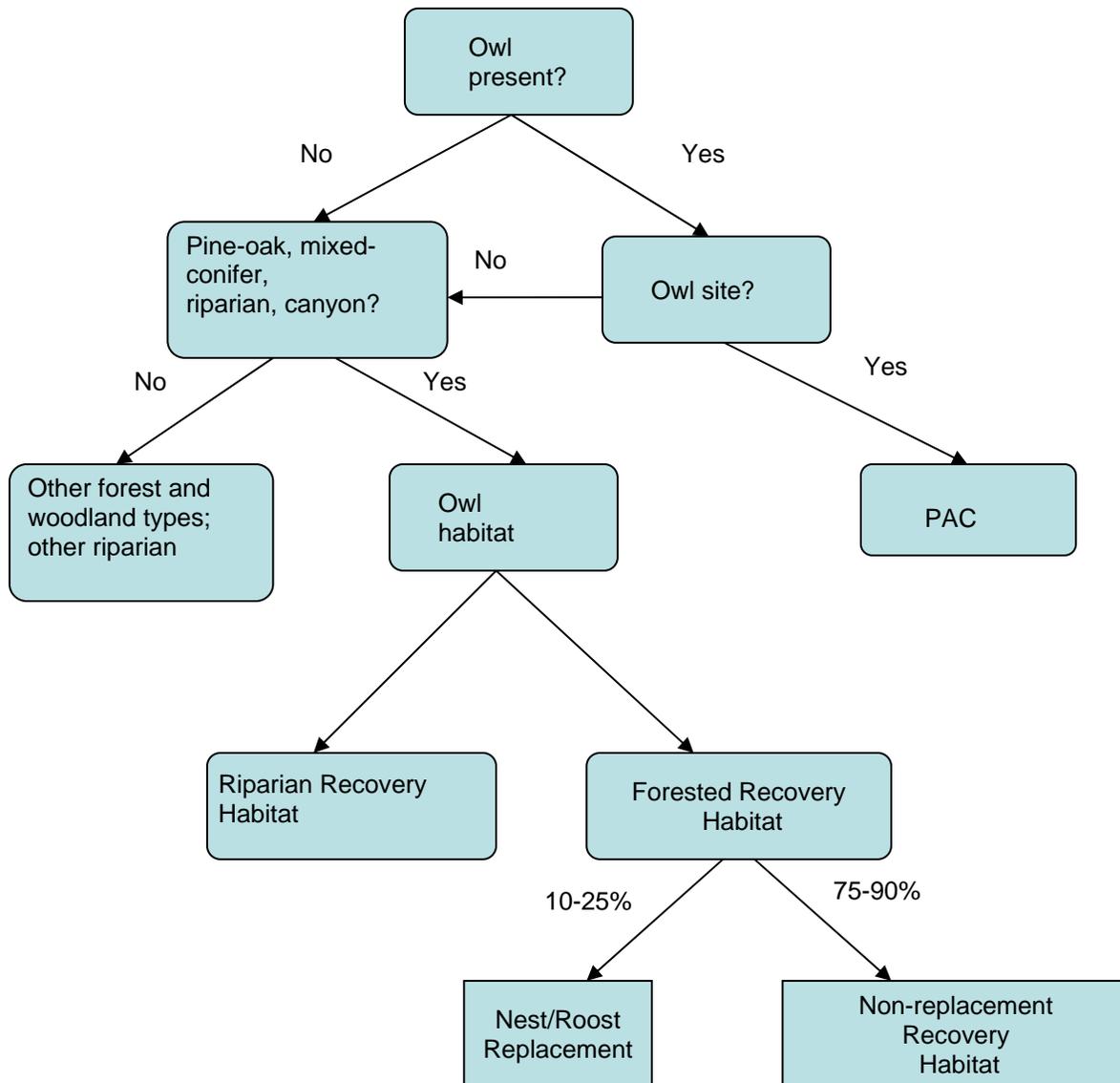


Figure C.1. Conceptual model describing which management guidelines should be followed.

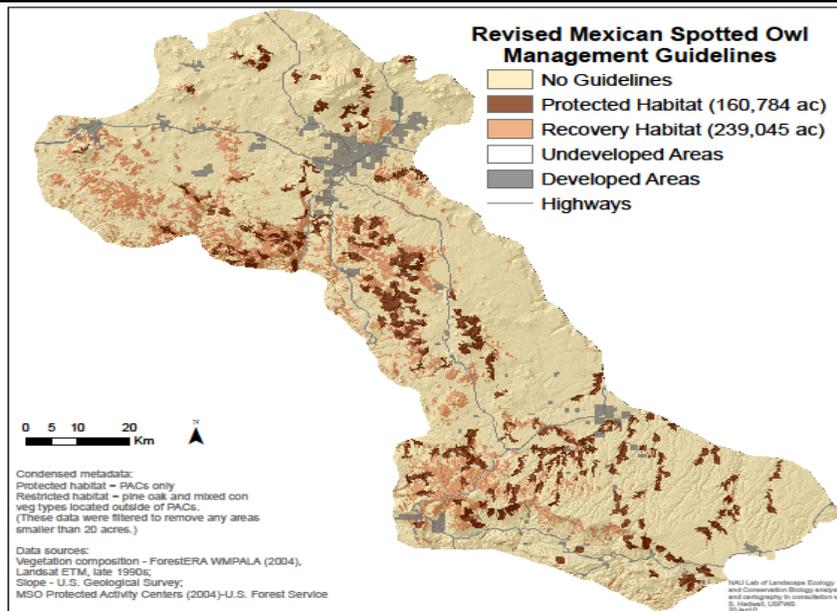
BOX C.1

SPATIAL INTERPRETATION OF MEXICAN SPOTTED OWL MANAGEMENT GUIDELINES BY THE FOREST ECOSYSTEM RESTORATION ANALYSIS PROJECT

Box C.1, Figure 1 shows a spatial interpretation of the current Mexican spotted owl management guidelines (i.e., guidelines in this revised Recovery Plan) across the western Mogollon Plateau, Arizona. This interpretation was created by the Forest Ecosystem Restoration Analysis (ForesterA) project using spatial data layers collected by or created by project members.

The spatial extent of the map includes approximately 812,000 ha (2.04 million ac) within the belt of continuous ponderosa pine forest (and associated vegetation types) extending from north and west of the city of Flagstaff, south along the plateau to the edge of the 2002 Rodeo-Chediski Fire. Approximately 75% of the land within this area is managed by the USFS (Coconino, Kaibab, Apache-Sitgreaves, and Tonto National Forests). The remainder of the land is a patchwork of private, state, and military lands.

Protected habitat includes PACs and replacement Recovery Habitat includes all other areas of pine-oak and mixed-conifer habitat that did not fall within PAC boundaries. Under this interpretation, protected habitat covers approximately 8% (65,067 ha [160,784 ac]) of the region, and replacement Recovery Habitat covers 12% (96,738 ha [239,045 ac]) of the region. Thus, approximately 80% of the land base covered falls in areas not subject to specific Recovery Plan guidelines.



Box C.1: Figure 1. Habitat map produced for the Mexican Spotted Owl Recovery Team by ForesterA Project (see www.forestera.nau.edu) showing the distribution of lands in 2010 within the western portion of the UGM EMU covered by recovery plan designations.

BOX C.2

DEFINING OWL SITES

Our definition of an owl site strives to achieve a balance between being overly inclusive and overly exclusive. An overly inclusive definition could result in PACs where they are not needed; an example might be the detection of a transient owl. In contrast, an overly exclusive definition could result in failure to designate a PAC in an area occupied by ≥ 1 spotted owl. While recognizing the need for balance, we also recognize serious consequences of failing to properly manage occupied owl habitat as the result of an overly exclusive definition. With those considerations in mind, we consider a site to be occupied if any of the following scenarios occur:

5. One daytime location (visual or auditory) of ≥ 1 Mexican spotted owl within the breeding season (Mar-Aug);
6. Two nighttime auditory detections within 500 m (0.31 mi) of each other during the breeding season (Mar-Aug), separated by at least one week;
7. Two owls of different sexes heard on the same night within 500 m (0.31 mi) of each other; or
8. Locating one or more owls born during that breeding season (young-of-the-year) prior to 1 September.

The above criteria assume that daytime detections provide stronger evidence of owl residency than nocturnal detections, and that little dispersal occurs during the survey season. These assumptions are supported in the literature (see Part II in Recovery Plan; Appendix B). The 500 m (0.31 mi) distance seems reasonable based on current knowledge of movement patterns of radio-marked owls and results of demographic studies involving uniquely banded owls (see Part II in Recovery Plan; Appendix B).

PACs are intended to protect the activity center of a single owl territory. Therefore, these criteria should *not* be interpreted to mean that multiple PACs need be drawn in areas where multiple detections may represent a single owl territory. In such cases, biologists should use their professional judgment in determining whether or not additional PACs are necessary or in creating PACs larger than 243 ha (600 ac). If biologists from land-management agencies are unsure how best to proceed, we encourage them to work with the appropriate FWS offices and the state wildlife agency in designating PACs.

BOX C.3

HIGH-ELEVATION, MIXED-CONIFER FOREST

The greater use of canyons and reduced use of upland forests in the northern part of the owl's range has raised questions about whether high-elevation (>2,440 m [8,000 ft]), mixed-conifer forests provide breeding habitat for spotted owls in these areas. This in turn has raised the issue of whether or not these areas should be surveyed and managed for owls. Under the original recovery plan (1995), these areas were subject to the same management guidelines as mixed-conifer forests elsewhere within the owl's range.

Based on past discussions with Working Teams and land-management agencies in these areas, the Recovery Team recommended an amendment to the original recovery plan to deal with this situation. This amendment was approved by the FWS's Regional Director for the Southwestern Region in 1999. This amendment did not provide an elegant solution to this issue and pleased no one, including the recovery team. Consequently, the issue still exists. Therefore, we re-evaluated what is known about owl use of high-elevation, mixed-conifer forest. Specifically, we requested data on extent of surveys within the former Southern Rocky Mountains-Colorado, Southern Rocky Mountains-New Mexico, and CP EMUs. We received useful but not necessarily conclusive information from Southern Rocky Mountains-Colorado EMU, Carson National Forest, Kaibab National Forest, and the Forest Service's Intermountain Region (Region 4).

Data on survey extent and results in Colorado were provided by the working team for that EMU. The Kaibab National Forest provided results of survey data for the North Kaibab Ranger District, the Carson National Forest provided results of survey on that forest, and USFS Region 4 provided information on surveys conducted on multiple forests in that region. T. H. Johnson (Yomi Enterprises) performed the analysis for all EMUs by overlaying known owl records on 7.5 min digital elevation models and determining elevation at these locations (Box C.3, Table 1).

Based on the available data, we conclude that owls in parts of the northeastern extent of the range use high-elevation, mixed-conifer forests. Therefore, blanket exemptions of such forests from range-wide management recommendations are not warranted. Data provided from Colorado recorded owls in high-elevation forests and that several PACs are at elevations >2,440 m (8,000 ft).

Given the use by owls of areas above 2,440 m (8,000 ft) and even 2,740 m (9,000 ft) in the northeastern part of their range, we recommend that range-wide management recommendations for mixed-conifer forest remain in place for these areas. If agencies within these units believe that these high-elevation forests do not provide suitable habitat, they should compile the data to support that contention. Specifically, data provided should include:

1. For all future surveys conducted, action agencies create Geographic Information System (GIS) coverage maps of areas surveyed; these should include forest types, survey points or routes, and survey results (spotted owl locations and associated attribute data).
2. In conjunction with the previous point, interested agencies could work with the working teams to compile currently available information on past survey efforts and results within their EMU. Minimum information required for this assessment includes: (1) total acres of mixed-conifer forest above 2,440 m (8,000 ft) in elevation, (2) acres of the aforementioned mixed-conifer that were surveyed to protocol, (3) how many years areas were surveyed, and (4) owl locations with associated attribute data. It may also be helpful

to provide similar information for other cover types, if possible. For example, if a unit has surveyed 40,080 ha (100,000 ac) of high-elevation, mixed-conifer and 20,040 ha (50,000 ac) of rocky canyons, and found all owls in canyons, that information presented together is more convincing than simply presenting acres of mixed-conifer surveyed.

Box C.3: Table 1. Summary of elevation data based on daytime records of Mexican spotted owls in the database compiled in 1993 by the recovery team, based on agency survey data. Elevation data were compiled by T. H. Johnson (Yomi Enterprises), by overlaying owl locations on 7.5-min digital elevation maps (DEMs).

Ecological Management Unit	N	% above 2,440 m (8,000 ft)	% above 2,743 m (9,000 ft)
Colorado Plateau	69	15.9	7.2 ^a
Southern Rocky Mountains	30	46.6	10

^a Represents detections only on the Cibola NF.

BOX C.4

CRITERIA USEFUL IN DESIGNATING CORE AREAS IN THE ABSENCE OF NEST LOCATIONS

If no nest location is known, the following criteria (after Ward and Salas 2000) may be useful in determining where to locate the core area within a PAC:

- A circle with a 359 m (1,179 ft) radius centered on a location of one young-of-the-year Mexican spotted owl observed during the day prior to 1 August of any year.
- A 40 ha (100 ac) area that surrounds daytime observations of adult or subadult Mexican spotted owls documented over four different breeding seasons.
- Lacking this information, managers should rely on experienced spotted owl biologists to exercise their best professional judgment to identify likely habitat for nest/roost cores and delineate the 40 ha (100 acre) area.

Once designated, cores should remain in place and not be moved without sound biological rationale for making any adjustments.

BOX C.5 - 1

ASSESSING TREATMENT ACTIVITIES WITHIN PACs BUT OUTSIDE OF CORE AREAS

Several types of restoration activities (e.g., various silvicultural prescriptions and burning) are allowed in portions of landscapes that include Mexican spotted owl PACs. The effects of these treatments are not fully known and well-designed monitoring can provide valuable information on the effects of these activities on the owls and their habitat. The following recommendations provide general guidance for monitoring forest and fire management treatments that will occur in PACs but outside of nest-roost core areas. This monitoring should be designed, implemented, and analyzed in cooperation with scientists to ensure adequate sampling procedures and reliable inferences about potential effects of planned treatments on the owls and their habitats.

General Guidance for Monitoring and Estimating Effects of Treatments in PACs

Guiding Questions (these are not a complete list of potential questions; local managers will likely develop additional, site-specific questions of interest):

- Do planned treatments (e.g., thinning, prescribed fire) affect key spotted owl responses (identified below)?
- How do identified effects vary among potential treatment types (e.g., fire intensity and duration, total area affected, thinning acreage and intensity)?

Response Variables:

- Owl occupancy rate (corrected for detection probability; the percent of PACs occupied before and after treatments).
- Owl reproductive output (the number of fledglings observed per adequately checked pair before and after treatments).
- Habitat change (the immediate effect of a treatment type on key variables selected from Table C.1 in Appendix C showing description of desired future conditions [DFCs]) in forest and woodland cover types typically used by Mexican spotted owls for nesting and roosting. Analysis should incorporate what is retained as well as extent of change.

Planned Treatments:

- We assume these will vary by EMU and be agency defined at local scale, but they may also require regional EMU coordination across agencies.
- Treatments will likely be variable in spatial extent and intensity (intensity measured by degree of change in key habitat variables related to DFCs [i.e., Table C.1 in Appendix C]).

General Study Design Approach:

- For each planned treatment(s), monitoring should be designed to robustly contrast a set of reference PACs (with no planned treatments) to a set of treatment PACs.
- PACs may be stratified by treatment type.
- Reference PACs should match the environmental conditions in PACs where treatments are planned, as closely as possible. (Continued below)

BOX C.5 - 2

General Guidance for Monitoring and Estimating Effects of Treatments in PACs

Sampling Considerations:

- Identify set of PACs for a planned type of treatment.
- Identify set of reference PACs for each geographic area and cover type.
- Sample response variables for owls each year, using a design that allows estimation of effects to occupancy, detection probability, reproductive output, and habitat DFCs.
- Sample timing: one year pre-treatment, during treatment year, and one, three, and five years post-treatment.
- Identify DFC variables (Table C.1 in Appendix C) that measure habitat change to calibrate treatment effects.

Potential Analytic Approaches

- Will depend on sample size.
- Possibilities include:
 - Simple treatment effect stratified by treatment type and geographic area/cover type. Two-sample tests, ANOVA, regression-based approaches, power dependent on sample size and variability.
 - Subsequent analyses only if treatment effects are apparent – gradient analysis, AIC based model selection if sample size permits use of treatment/habitat covariates.

Quality Control / Assurance

- A monitoring plan should be written that includes the details for sample selection, treatment specifics, measurement protocols including timing, and planned analyses.
- The monitoring plan should be reviewed as part of the consultation process for treatments planned to occur within PACs.

BOX C.6 - 1

DEFINING AND USING REFERENCE CONDITIONS FOR MEXICAN SPOTTED OWL NEST/ROOST HABITAT

In the original 1995 Recovery Plan, two primary types of information were used to formulate recommendations for habitat management. In one analysis, quantitative descriptions of site- and stand-scale habitat conditions were used to describe characteristics of nesting/roosting habitat. In a second analysis, forest vegetation simulators were used to estimate the proportion of the landscape that could sustain those conditions through time (see USDI FWS 1995). Thus, information developed was used to define both desired forest structure at the scale of individual stands or patches, and the desired proportion of the landscape to manage for that structure.

Much of the information used to describe forest structure in the original 1995 Recovery Plan was derived from samples at relatively fine scales (i.e., sub-stand scales). Forest management typically is focused at larger scales such as forest stands, however, and stands are not entirely homogeneous. Owls locate and use distinct patches within stands, and stand descriptors based on characteristics of those used sites may not be representative of overall stand characteristics. To be most useful, descriptors of stand characteristics should be based on the same type of sampling and data that will be available to land managers faced with assessing stands. Consequently, we revised values in Table C.2 in Appendix C based on an analysis of nest stands used by Mexican spotted owls in Arizona and New Mexico as described by existing USFS stand-exam data.

We queried the USFS Southwest Region's database of common stand exams for data representing identified spotted owl nest stands. We then summarized these data in a two-step process. In step one, we aggregated values across plots *within* individual stands, to estimate average characteristics within individual stands. In step two, we averaged stand parameters *across* nest stands, to estimate mean stand characteristics and 95% confidence intervals around those mean values. We conducted analyses in step two separately for mixed-conifer and pine-oak forests. In addition, we analyzed mixed conifer separately for the BRE vs. other EMUs due to the relatively high density of owls in the Sacramento Mountains (BRE), and thus the high percentage of that landscape protected with existing PACs.

The values provided in Table C.2 define desired future conditions to be achieved with time and management, or to be maintained where they already exist. **These values are based on the lower bound of 95% confidence intervals around estimates of means computed across stands.** Consequently, we view these values as minimum targets for managers. We also stress that values in Table C.2 must be met simultaneously. Management can occur within stands that exceed these minimum conditions, but such activities should not lower stand characteristics below these levels unless large-scale assessments demonstrate that such conditions occur in a surplus across the landscape (see below).

BOX C.6 - 2

DEFINING AND USING REFERENCE CONDITIONS FOR MEXICAN SPOTTED OWL NEST/ROOST HABITAT, continued

We reiterate that we developed the table values from analyses that first averaged stand characteristics across plots within stands. Owl nest stands are not homogeneous. A typical nest stand may contain both pockets of large trees and greater basal area and areas of more open forest. We suspect that this heterogeneity and within-stand diversity is valuable (Ganey and Dick 1995), and we encourage managers to retain that variability. In particular, small areas with high basal area, canopy cover, and densities of large trees appear to be important for providing suitable nest and roost sites (Ganey and Dick 1995, Ganey et al. 2003), and such patches should be retained where they exist.

A frequent criticism levied at the precursor to Table C.2 in the original recovery plan (USDI FWS 1995:Table III.B.1) was that the specified stand conditions could not be sustained on the landscape. The portions of the landscape specified for management in this table were based on simulations using table parameter values and established models of forest succession and stand prognosis conducted by USFS personnel with expertise in the use of such models (USDI FWS 1995). These simulations clearly demonstrated that such conditions are sustainable on the portions of the landscape specified, and to date no empirical data or modeling results have surfaced to support the claim that the specified stand conditions cannot be supported on the landscape in the indicated amounts. A more recent, spatially explicit analysis evaluated possible constraints imposed by the 1995 Recovery Plan on conducting fuels-reduction treatments (Prather et al. 2008). Results indicated that 1995 Recovery Plan guidelines applied to less than one third of an 811,000 ha study region, and that the majority of the forest even in these conflict areas could be managed to reduce fire hazard without eliminating owl habitat (Prather et al. 2008).

We did not repeat the modeling efforts used in the original recovery plan to generate percentages of the landscape capable of sustaining nest/roost conditions. In most cases, we reduced values for describing required stand parameters in the revised Table C.2 relative to values in the original recovery plan. Logically, if it was possible to sustain the conditions in the original recovery plan over a specified portion of the landscape, it should be possible to sustain the revised, and more lenient, conditions over that same portion of the landscape.

As in the original recovery plan, the percentage of landscape area recommended for management for nest/roost conditions is lower in the BRE EMU than it is in other EMUs. This is based on the observed high density of owls in the Sacramento Mountains (BRE), which effectively places a large proportion of that landscape in protected status. Also as before, we do not provide guidance on how to allocate future owl habitat across the landscape. Although this is a critically important issue, we lacked the information and resources to accomplish this allocation.

APPENDIX D

MANAGEMENT RECOMMENDATIONS: THREAT-SPECIFIC MANAGEMENT RECOMMENDATIONS

In this section, we provide recommendations as they relate to specific threats or activities. Some recommendations are similar to those presented in the General Recommendations (Appendix C), but we repeat them here for clarity.

1. Fire Management

Overarching forest management goals should embrace the restoration of ecosystem health, historical and/or natural conditions, and the range of variability in forest structure, composition, and function. In places, these restoration goals may likely include the ecological role of fire and the emulation of past fire regimes and ecological processes. Fortunately, the Southwest has one of the largest compilations of ecological research that documents and reconstructs historical reference conditions such as past stand structure, density, and fire frequencies for many forest types, with research sites throughout the region. These references along with our recommendations should help guide and quantify future restoration activities.

A. Guidelines

The appropriate management of prescribed fire and wildfire outside of PACs to moderate fire severity and the potential for stand-replacing fire may provide most alternatives to mitigate severe fire threats. Mechanical treatments, however, may be necessary in some areas before fire can be effectively and safely applied to meet management objectives. The focus of mechanical thinning will likely be concentrated in the wildland-urban interface (WUI) communities at risk to fire, where fires are a greater threat to people and property and where fire applications have much greater risk and liabilities. Planning and implementing fire risk-reduction activities should balance the intensity and arrangement of treatments needed to reduce the landscape risk of high-severity fire yet maintain owl habitat. Due to the current magnitude of forest fuel accumulations, some preliminary treatments (e.g., thinning combined with pile and low intensity prescription burning) will be required to reduce the severity of wildland fires and to allow for the safer management of prescribed fire and wildfires. Cumulative effects of multiple treatments across the watershed, downstream effects, and effects to spotted owl habitat will need to be evaluated through landscape analyses and modeling, and effects must be moderated to the extent possible.

a. Wildfire Suppression

Protect People and Property. Fire fighter safety and community protection are the utmost priorities during ES and BAR activities.

Emergency Consultation. All wildfire suppression activities with potential to affect PACs should be made in emergency consultation with the appropriate U.S. Fish and Wildlife Service, Ecological Services office.

Wildfire Behavior and Incident Planning. Conduct landscape-level fire behavior assessments to strategically locate and prioritize fire suppression activities/tactics to mitigate the effects of high-severity fire and suppression activities on PACs and recovery habitat. Potential strategies include locating fire-line construction and other suppression activities where possible outside of PACs, and conducting night burning ahead of approaching moderate-high severity wildfire in areas surrounding PACs to reduce wildfire severity within PACs.

Retain Key Habitat Elements. Where possible, wildfire suppression activities should be applied that limit high-severity fire and loss of key habitat elements within PACs and recovery habitats.

Applied Research. Research should be conducted to evaluate the short- and long-term correlates of wildfire severities and their spatial extent on Mexican spotted owls and their habitat.

b. Burned Area Emergency Stabilization (ES) and Burned Area Rehabilitation (BAR).

Protect People and Property. Fire fighter safety and community protection are the utmost priorities during ES and BAR activities.

Consultation. All habitat-altering activities within PACs should be coordinated with the appropriate U.S. Fish and Wildlife Service, Ecological Services office.

Seasonal Restrictions. ES and BAR treatments where deemed necessary within PACs should occur during the non-breeding season (1 Sep - 28 Feb) to minimize disturbance to resident owls during the breeding season, unless non-breeding is inferred or confirmed that year per the accepted survey protocol (Appendix E).

Treatment Priorities. ES and BAR treatments should be limited to areas surrounding PACs, and only when considered critical to stabilize soils, retain key habitat elements, and enhance ecosystem recovery. Soil stabilization should be considered only where crucial and implemented through local biomass mulching or other seed-free mulching materials to minimize risk of introduced exotic species. Seeding is not recommended due to its limited effectiveness, lack of local genetically compatible seed stock, and exotic contaminants found in most seed mixes (Peppin et al. 2010a, 2010b; Dodson et al. 2010; Stella et al. in press).

c. Prescribed Fire, Hazardous Fuels Treatments, and Wildland Urban Interface (WUI).

We propose the following recommendations for prescribed fire and hazardous fuels treatments. Much of the work needed to reduce broad-scale fire risk to owl habitat can be accomplished by first treating areas down-slope from and surrounding PACs. We recognize, however, that other management considerations like WUI may require treatments within PACs. In these situations, treatments should be done with adequate safeguards to minimize loss of key habitat components for owls and their prey.

Protect People and Property. Fire fighter safety and community protection are the utmost priorities during prescribed fire and hazardous fuels treatment activities.

Consultation. All habitat-altering activities within PACs should be coordinated with the appropriate U.S. Fish and Wildlife Service, Ecological Services office.

Area Limitations. Treat as needed up to 20% of the non-core PAC area within an EMU identified through the landscape-level assessment (see Appendix C).

Seasonal Restrictions. Within all PACs, light burning of surface and low-lying fuels may be allowed following careful review by biologists and fuel-management specialists on a case-specific basis. Mechanical or prescribed fire treatments should occur during the non-breeding season (1 Sep - 28 Feb) to minimize disturbance to resident owls, unless non-breeding is inferred or confirmed that year per the accepted survey protocol (Appendix E). Treatments should be planned when environmental conditions provide enhanced opportunities to achieve fuel reduction and forest-restoration objectives. These activities however should be deferred in severe drought years and times of high-to-extreme wildfire risk.

Types of Treatments. Combinations of mechanical and prescribed fire treatments may be used to minimize risk of high-severity fire effects while striving to maintain or improve habitat conditions for the owl and its prey.

Strategic Placement of Treatments. Treatments should be placed strategically to minimize risk of high-severity fire effects to the nest core while mimicking natural mosaic patterns.

Treatment Priorities. Emphasize treatments in other forest and woodland types over those of PACs and recovery habitats to the extent practicable. Treatments in these areas might buffer owl habitat as well as provide fire risk reduction to WUI communities. Where appropriate, areas surrounding PACs could be treated with higher prescribed fire and mechanical treatment intensities to better achieve management objectives (e.g., reduction of hazardous fuels and potential for stand-replacing fires, enhancement of landscape, and forest structural diversity).

Landscape Assessment. A landscape-level assessment should be conducted to strategically locate and prioritize prescribed and hazardous fuels treatments to best mitigate the risk of stand replacing fires and high severity fire effects to current and future spotted owl habitat elements (Table C.1 in Appendix C).

Monitoring. Monitoring should be designed and implemented to evaluate the effects of prescribed fire and hazardous fuel reduction treatments on spotted owl habitat, and to retain or move towards Mexican spotted owl desired future conditions (Table C.1 in Appendix C). Box II.E.5 provides a framework for development of monitoring studies.

Applied Research Experiments. Management experiments should be conducted in places to evaluate the short-term, long-term, cumulative, and watershed effects of these activities on Mexican spotted owls and their habitats (see Part V.6 of Recovery Plan).

These recommendations, when implemented, should help reduce high-severity fire effects across broader forest landscapes and help protect Mexican spotted owl PACs, potential habitats, and suitable nesting/roosting habitat locations from future stand-replacing wildfires and enhance landscape-level forest resiliency to climate variability. Additionally, these recommendations are supported by current research and monitoring on Mexican spotted owl fire effects that show limited, short-term effects from moderate- to high-severity fires (Bond et al. 2002, 2009; Jenness et al. 2004).

2. Insects and Disease

Biotic disturbance agents most influential to forest habitat of the Mexican spotted owl are bark beetles, defoliating insects, dwarf mistletoes, root disease fungi, and rust fungi (USDA FS 2004). Many agents act in concert with abiotic factors; the current aspen decline in northern Arizona is an example of a complex disturbance. The course of an outbreak can be characterized by its rate of increase and spread, duration, and spatial scale. Impacts consider the spatial extent and intensity of tree mortality as well as the values of killed and remaining trees (“value” can be in the sense of ecosystem function).

Although knowledge of forest condition and predisposition allows managers to assess the risk and potential impacts of an insect or disease outbreak, control is difficult (Holling and Meffe 1996). Management has limitations in techniques, resources, and reaction time; social and natural systems are complex and dynamic. Nonetheless, management intervention can be useful to change forest conditions predisposing areas to outbreak and to influence the extent, course, and impact of outbreaks. Effective treatments are generally tailored for a specific insect or pathogen, instituted early, executed in multiple stages, monitored, and modified as needed to achieve objectives (adaptive management).

A. Guidelines

- a. Resource managers should work with forest insect and disease specialists to develop ecological assessments of these kinds of disturbances at various scales. Evaluations should be based on the role these organisms play in directing succession toward, or away from, desired future conditions at different spatial-temporal scales.
- b. Managers, in consultation with specialists, can use these organisms to strategic advantage in creating, enhancing, or maintaining habitats for owls (and associated biota) in accord with landscape goals.

When considered a threat to owl or prey habitat, various tools—prescribed fire, thinning, other silvicultural treatments—can be used to limit the spread of insects or diseases. Management actions include sanitation, thinning, maintenance of mixed species stands (coarse-filter techniques), chemical protection of individual trees, and use of insect-behavior modifying chemicals (fine-filter techniques). Methods used are often specific to the organism and should be done in consultation with owl biologists, insect and disease specialists, fire personnel, and silviculturalists.

3. Grazing

As discussed in I.C.2.a.vii, grazing can adversely affect spotted owls primarily through four indirect effects: (1) diminished prey availability and abundance, (2) increased susceptibility of habitat to destructive fires, and (3) degradation of riparian and meadow plant communities, impairing their ability to recover or develop into spotted owl habitat. These indirect effects flow from the potential direct effects of ineffective livestock management practices that result in long-term alterations in plant species composition, density, vigor, and vegetation structure. Therefore,

in order to provide for recovery of the spotted owl and adequate protection of its habitat, livestock management within the owl habitat should be designed with the following objectives: (1) to maintain or enhance prey availability, (2) to maintain potential for beneficial surface fires while inhibiting potential for destructive stand-replacing fire, and (3) to promote natural and healthy riparian, meadow, and upland plant communities including their functional processes.

Important grazing areas within Mexican spotted owl habitats are primarily in riparian areas, natural meadows, and other forest openings dominated by herbaceous vegetation. Management for an appropriate grazing intensity should be designed to provide a target level of residual vegetation that would attain or sustain good to excellent range conditions, moderate to high similarity to potential natural vegetation, or otherwise favorable habitat characteristics for the spotted owl and its prey within grazed areas. For example, if current vegetation conditions are such that forage plant density, vigor, reproduction, recruitment, and recovery from grazing is lacking, management for extended rest or light to conservative grazing intensity would be needed and appropriate (depending on the degree to which the vegetation condition is degraded) to promote recovery to a more vigorous and ecologically functioning plant community. In the alternative, if indicators of plant vigor and forage species composition and density suggest a robust and ecologically functional system, a target of moderate grazing intensity may be appropriate in upland areas to maintain these desirable habitat conditions (Holechek et al. 2001). In sensitive riparian areas, the season (dormant vs. growing season), duration, and intensity of grazing are key factors of importance for managers to consider when grazing riparian plant communities within owl habitat. Managing grazing to occur during certain times of the year for finite periods (e.g., during plant dormancy periods if possible) may be needed to maintain riparian plant density, composition, vigor, and recruitment to sustain or develop a multi-storied woody vegetation component (i.e., if applicable), including seedlings and saplings that are often highly selected by grazing ungulates, and to maintain or improve stream channel and bank stability (Chaney et. al. 1990, 1993; Leonard et. al. 1997) The goal of attaining these conditions is to improve and maintain habitat features that will benefit owl prey species (e.g., dense grass cover for voles) and owl nest/roost habitat (e.g., regeneration of oak trees, or cottonwood) within protected and recovery habitats.

We strongly advocate for field monitoring and experimental research related to potential impacts of livestock and wild ungulate grazing on the Mexican spotted owl. Only through monitoring and research can we: (1) develop a comprehensive understanding of how grazing affects the habitat of the owl and its prey; (2) determine the effectiveness of current grazing standards and guidelines as they relate to the owl's needs; and (3) devise grazing strategies that can benefit the owl, its prey, and other resources. "Key areas¹," "critical areas²," and "key species³" as defined by the Society for Range Management (1998) should be identified for the purposes of managing grazing and monitoring its effects on herbaceous and woody vegetation. One unpublished study

¹ Key Area - A relatively small portion of a range selected because of its location, use, or grazing value as a monitoring point for grazing use. It is assumed that key areas, if properly selected, will reflect the overall acceptability of current grazing management over the range (SRM 1998).

² Critical Area - An area that must be treated with special consideration because of inherent site factors, size, location, condition, values, or significant potential conflicts among uses (SRM 1998).

³ Key Species - (1) Forage species whose use serves as an indicator to the degree of use of associated species. (2) Those species which must, because of their importance, be considered in the management program. (SRM 1998)

conducted in the Sacramento Mountains of New Mexico found mean herbaceous cover height (grasses and forbs) in key foraging areas during mid-July to mid-August to be a useful indicator of the proportion of voles in the diets of Mexican spotted owls, a common prey species for owls (Ward 2004). Herbaceous cover height means of >11.5 cm (> 4.6 inches) were associated with the maximum proportion of voles in the owl's diet, whereas heights < 4.0 cm (1.6 inches) were associated with near 0 numbers of voles in the environment and the owl's diet. This form of monitoring may also be applicable to owls in other EMUs where voles are often common prey, like in portions of the CP and UGM EMUs (Ward and Block 1995). Monitoring of residual herbaceous cover characteristics in terms of height, density, and patchiness during and following a grazing season along with measuring browsing use of shrubs/trees (e.g., riparian species) where applicable are generally accepted to be informative of ungulate forage use and wildlife habitat conditions. Resource managers should incorporate scientifically valid procedures for evaluating ungulate grazing use into their monitoring programs. The purpose is to evaluate the quantity and quality of residual herbaceous ground cover, shrub/tree component (e.g., riparian), and habitat conditions affected by ungulate grazing as they relate to the habitat needs of important owl prey species, the vegetative biomass needed to restore low intensity ground fire regimes, restoration of key habitats (e.g., riparian), and restoration and maintenance of overall watershed health.

A. Guidelines

The following guidelines are provided for grazing management in all areas of protected and recovery habitats:

- a. Resource managers should conduct site-specific assessments, utilizing pertinent research information and standardized monitoring techniques to identify the appropriate vegetative conditions needed to maintain or improve: (1) habitat conditions for availability of prey species to Mexican spotted owl, (2) conditions of riparian and meadow habitats including their functional processes (USDI BLM 1996*a,b*; Ruyle et. al. 2000), and (3) conditions and processes required for the restoration and maintenance of historical fire regimes and native plant communities where fire has historically influenced habitat structure and plant composition. These assessments should be conducted during both dormant and growing seasons to provide favorable habitat characteristics throughout the year. Assessments should be used to design and modify livestock grazing strategies in Mexican spotted owl habitat.
- b. Resource managers should establish and enforce residual vegetation (e.g., residual leaf length or stubble height) standards during plant growth and dormant periods that are consistent with light to moderate grazing intensity within protected and replacement habitats. Use range management monitoring standards developed for local geographic areas and habitat types (e.g., USFS Region 3, Range Analysis Handbook, Rangeland Analysis Management and Training Guide) based on current vegetation conditions, and establish allowable use and residual vegetation levels that will expedite attaining or maintain desired habitat conditions affected by livestock management. Established standards should be attained at a minimum in at least four out of every five years, should be reviewed by resource managers periodically (every five to seven years) to determine if desired vegetation conditions are being achieved or maintained, and should

be modified appropriately when vegetation conditions indicate the need. Specific protocols should be used where they have been developed to monitor habitat conditions for the owl's prey.

c. Resource managers should implement grazing and other management strategies for livestock and wild ungulates that will improve degraded riparian communities in owl habitats to proper functioning condition (see Appendix C) as soon as possible and implement monitoring programs to evaluate improvement in habitat conditions (USDI FWS 1995, Winward 2000). Sensitive riparian areas such as stream-riparian habitats, wetlands, wet meadows, springs, and seeps may not be able to support high grazing intensity and may require special management as a "critical area" as defined by the Society for Range Management (1998) for short (e.g., a season or year) to indefinite time periods to help promote vegetation conditions suitable for owl prey species and/or recovery of nest/roost habitat provided by riparian vegetation. Management strategies may include (Kennedy 1977, Rickard and Cushing 1982, Clary and Webster 1989, Chaney et al. 1990, 1993, Platts 1990, Krueger 1995, Leonard et al. 1997):

- *Exclusion of Grazing.* Total exclusion of ungulate grazing use (i.e., either livestock or both livestock and wild ungulates) from sensitive riparian areas for extended time periods (e.g., multiple years) through the use of exclusion fencing to improve riparian herbaceous plant cover, promote regeneration of riparian shrub and tree cover, and protect stream banks and channels;
- *Reduce Grazing Pressure.* Reductions in grazing intensity in riparian areas through the use and enforcement of appropriate vegetation utilization or residual vegetation standards and timely livestock removal;
- *Seasonal Grazing.* Changes in seasons of grazing use (e.g., allow livestock grazing in riparian areas only during plant dormancy periods where possible); and
- *Reduce Numbers.* Reduction in numbers of grazing animals (i.e., both livestock and wild ungulates if needed) to attain sufficient residual riparian vegetation levels and improvement in riparian habitat conditions.

Additional strategies may include the use of riparian pastures, management-intensive rotational grazing systems, and other methods that emphasize riparian vegetation and stream bank and channel recovery where degraded riparian conditions exist (Platts 1990, Holechek et al. 2001). Riparian protection and management projects that make use of fence enclosures to either prohibit use by livestock or both livestock and wild ungulates do not necessarily need to exclude the entire riparian area from ungulate grazing at one time. Rather, systematic use of enclosures that protect the most sensitive portions of riparian habitats is a viable approach (Leonard et al. 1997). Placement of enclosures (controls) and areas open to grazing (treatments) should be designed to permit determination of effects on several ecological responses, such as vegetation, erosion, water quality, and prey availability. Vegetation management, restoration, and protection of adjacent upland areas (Bryant 1982) may also be used as part of an effective strategy to enhance recovery of degraded riparian habitats.

4. Energy-Related Development

We provide general recommendations below. However, in most cases, specific recommendations will depend on case-by-case evaluations of the timing and duration of the proposed action. The

timing of an action is pertinent in that a disturbance during the breeding season (1 Mar - 31 Aug) is more likely to impact owls than a disturbance outside the breeding season. Pertaining to length of disturbance, actions should be categorized as temporary or long-term according to the following definitions:

1. *Temporary*: An action that leaves no long-term structure or long-term habitat loss and does not result in persistent noise pollution (e.g., occasional helicopter overflights).
2. *Long-term*: An action that causes a loss of owl habitat, increases the probability of mortality through collision, increases human access to an area, or creates a persistent owl disturbance from noise (i.e., noise above 69 dBA at 50 m [165 ft] from nest or PAC if nest site is not known; e.g., creation of long-term facilities such as mines, pits, well pads, roads, pipelines, compressor stations).

A. Guidelines

The following guidelines pertain to PACs and Recovery Habitats. In most cases, temporary actions that occur outside of the breeding season will require no occupancy surveys and no mitigating actions. If activities will be long-term or take place during the breeding season, conduct occupancy surveys according to the standard protocol approved by FWS. Where owls are found, PACs should be established and the PAC guidelines should be followed. Where owls are not found, temporary actions may be allowed either during or outside of the breeding season. Long-term actions may, on a case-by-case basis, be allowed to proceed in Recovery Habitats outside of PACs, provided that the actions avoid detrimental habitat alteration, minimize the risk of owl mortality from collision, and conform to the recommendations for Recovery Habitats. Collision risk is best minimized through proper siting of structures (e.g., away from likely owl travel corridors).

The following guidelines apply to areas within PACs during the breeding season (1 Mar - 31 Aug) unless otherwise stated. If owls are not detected in a PAC, restrictions on temporary activities may be relaxed depending on the nature and extent of the proposed action.

- a. No seismic activities or construction of new facilities or expansion of existing facilities should take place during the breeding season. Any construction within PACs during the non-breeding season should be considered on a case-specific basis (see item 2 below). Modifications to existing facilities pertaining to public health, safety, and routine maintenance are excepted. However, when implementing such activities, those conducting the work should use all measures possible to avoid potential effects on owls (e.g., use least disruptive machinery, time project to minimize disturbance).
- b. Construction and seismic activities may take place outside of the breeding season or during the breeding season if non-occupancy or non-breeding is inferred through protocol surveys. Long-term activities should avoid loss of habitat through, for example, use of directional or multi-lateral drilling and locating new facilities within existing rights of way. Long-term activities that increase the risk of owl collision with structures (e.g., turbines, power lines) should not be allowed in PACs.

c. The potential for noise disturbance to nesting owls should be assessed on a case-specific basis. Breeding season restrictions should be considered if noise levels are estimated to exceed 69 dBA (~80 dBO) [owl-weighted noise level, cite Delaney et al. 1999a]) consistently (>twice/hour) or for an extended period of time (>1 hr) within 50 m (165 ft) of nesting sites (if known) or within entire PACs if nesting sites are not known. Noise reduction may be accomplished through proper placement of facilities and use of noise dampening equipment (e.g., hospital-grade mufflers, electric pump motors) as well as other techniques.

5. Land Development

The following guidelines are provided to mitigate potential threats to owls due to land development. Guidelines are based on the assumption that most land development threats to Mexican spotted owls are edge effects influencing adjacent federal lands, and that mitigation of threats following guidelines for wildland-urban interface treatments and recreation on applicable lands, combined with implementation of the general recommendations, will maintain current levels of owl habitat.

A. Guidelines

a. Managers are encouraged to pursue voluntary consultation on a case-by-case basis with local governments and developers to encourage development in areas least likely to directly influence habitat use of known owls. When possible, managers should encourage maintenance of existing habitat conditions on private lands (see Appendix C). Development of positive incentive programs may be a feasible approach.

b. Managers should implement recreation-disturbance guidelines (below).

6. Water Development

Water development includes dams, permanent flooding of riparian habitats, bed degradation below dams, stream and spring dewatering, water diversions, altered-flow regimes of streams and springs, and artificial watering ponds (e.g., stock tanks). Effects of water development on spotted owls vary but can range from loss or degradation of habitat to habitat fragmentation, disruption of migration corridors, inhibited gene flow, altered prey habitat, and altered grazing patterns by wild and domestic ungulates. Recommendations for addressing water development vary. In some situations, options are limited for addressing effects of established water developments on spotted owls (e.g., Lake Powell). Greater flexibility exists for addressing developments before they occur or for slightly modifying practices that might reduce effects on the owl.

A. Guidelines

a. Collect materials for genetic analyses to evaluate if large water developments are impeding movements and gene flow. If so, consider lowering water levels to reduce barriers to movement.

- b. Discharge water from dams in such a way to sustain and enhance native riparian vegetation.
- c. Conduct surveys following accepted survey protocol prior to initiating any water development that would modify habitat. If owls are detected, implementation of projects should be done in consultation with U.S. Fish and Wildlife Service.

7. Recreational Exploitation

Recreational exploitation can result in harm, harassment, and even mortality of Mexican spotted owls. Management, education, and/or enforcement actions may be needed to protect spotted owls from this threat.

A. Guidelines

- a. Calling, hooting, or playing of taped recordings to elicit responses from or to locate owls is prohibited without a section 10(a)(1)(A) recovery permit from the FWS. Where recreational exploitation is known to be a problem, managers should report continued issues to the appropriate FWS Law Enforcement Office.

8. Recreation Disturbance

The following guidelines apply to areas within PACs during the breeding season, (1 Mar - 31 Aug) unless otherwise stated. If protocol surveys indicate that the PAC is not occupied or owls are not breeding, restrictions on non-habitat-altering recreation can be relaxed depending on the nature and extent of the proposed disturbance. Recommendations are based in part on Swarthout and Steidl (2001, 2003). Guidelines for noise management related to recreation are provided below in the noise management recommendations.

A. Guidelines

- a. No construction of new facilities (e.g., trailheads, OHV trails) or expansion of existing facilities should take place in PACs during the breeding season. Any construction within PACs during the non-breeding season should be considered on a case-specific basis. Modifications to existing facilities pertaining to public health, safety, and routine maintenance are excepted (e.g., removal of dangerous trees in a campground; replacement of road culverts within campgrounds, etc.). However, when implementing such activities, those conducting the work should use all measures possible to avoid potential effects on owls (e.g., use least disruptive machinery; timing of the project to minimize disturbance).
- b. Managers should, on a case-specific basis, assess the presence and intensity of currently allowed (permitted and non-permitted) recreational activities. The assessment should include distance, frequency, duration, and source of the disturbance. If recreation is determined to be a problem (e.g., increased OHV or hiking use), limit human activities during the breeding season in areas occupied by owls (timing will depend on local nest chronology) to two or fewer disturbances per hour averaged over a 24-hour period. Disturbance here is defined simply as the

presence of ≥ 1 person. In areas where nest and roost sites are not identified, reduce human disturbances to ≤ 2 per hour throughout the PAC. Where nest and roost sites are known, restrict human disturbance ≤ 2 disturbances per hour within line of sight of the nest/roost sites. In some cases, disturbances may be avoided by routing trails and recreational uses (e.g., OHV use) outside of PACs through signing in order to designate zones free from human disturbances during critical periods.

- c. Seasonal closures of specifically designated recreational activities (e.g., OHV use, rock climbing, or biking) should be considered where disturbance to breeding owls seems likely.
- d. Conduct education through signing, interpretation events, access permitting, or other information sources to inform the public of proper and legal behaviors when encountering owls. In some areas, land managers are maintaining permanent, all-weather signs that inform the public that the area is home to a sensitive species; visitors should stay on the trail and be as quiet and unobtrusive as possible; and group sizes are limited to 12 or less from March 1 to August 31.
- e. If owls are not detected in a PAC during the breeding season, restrictions on non-habitat-altering recreation can be relaxed depending on the nature and extent of the proposed disturbance.

9. Scientific Exploitation

Although we do not view research and monitoring activities as a significant threat to the Mexican spotted owl (see Part II.9.D.b.iii of Recovery Plan), such activities may on occasion alter owl habitat, influence owl behavior, or harm or kill owls. Whereas long-term benefits to owls from these activities can be substantial, safeguards are needed to ensure that any negative short-term effects are acceptable.

A. Guidelines

- a. Quality assurance and quality control procedures should be applied to all scientific studies that may directly or indirectly affect owls or owl habitat. Quality assurance requires that study plans undergo appropriate levels of review, revision, and approval. Quality control means that methods of data collection adhere to prescribed standards.
- b. All scientific activities that have potential to harm owls or owl habitat should undergo FWS review and concurrence. Concurrence is demonstrated by granting appropriate permits. Applications for these permits routinely requires a review of the techniques to be used and a finding that those techniques are generally acceptable and have a low risk of causing harm or death.
- c. Contingency plans (e.g., how an injured owl will be treated or transported and where an injured owl will be taken) for dealing with injured owls should be included as part of the study proposal submitted with the permit application. In addition, many researchers must undergo approval of animal care and use by their employing institutions.

- d. Annual reports are required from all permit holders.
- e. All owl mortalities are reported to FWS within 48 hours of being discovered. If a particular study or a particular activity results in an undue number of mortalities, FWS will convene an independent expert panel to evaluate the situation and propose recommendations to continue, adjust, or cease the activity resulting in mortalities.
- f. Radio-marking spotted owls likely poses the highest risk among typical research activities. This risk may be alleviated partially by adhering to marking requirements issued by the Bird Banding Lab. For example, these guidelines restrict transmitter packages (includes the transmitter, antenna, and attachment materials) to $\leq 3\%$ of body weight. We endorse that restriction but also note that past studies have demonstrated that spotted owl body mass can fluctuate by up to 5% between years and/or seasons. Therefore, we recommend that transmitter packages used on Mexican spotted owls not exceed 16 g for female owls and 14 g for male owls. These guidelines should ensure that transmitter packages are light enough to be tolerated even if owls undergo significant loss of body mass.
- g. Radio transmitters have been attached to spotted owls successfully using both backpack and tailmount attachments. Any other attachment methods should be viewed as experimental and should be tested on captive spotted owls before deployment in the field, if possible. If captive spotted owls are not available, experimental attachment methods should be tested on captive barred owls, with transmitter weight adjusted to account for increased body mass of barred owls. If neither of the above options are possible, then experimental attachments should be tested on a very small sample of wild spotted owls, and results should be monitored before allowing widescale use of the method.
- h. All radios should be attached by researchers with demonstrated expertise in handling raptors and attaching transmitter packages to raptors. Experience with spotted owls and the specific attachment method in use is preferable here.

10. Noise

The following guideline applies to areas within PACs during the breeding season (1 Mar - 31 Aug). If owls are not detected or non-breeding owls are inferred during approved-protocol surveys in a PAC during the breeding season, restrictions on noise disturbances should be relaxed depending on the nature and extent of the proposed disturbance. The recommendation is based in part on Delaney et al. (1999a,b), Delaney and Grubb (2003), and Pater et al. (2009).

A. Guidelines

- a. Managers should, on a case-specific basis, assess the potential for noise disturbance to nesting owls.
- b. Breeding-season restrictions should be considered if noise levels are estimated to exceed 69 dBA (A-weighted noise level) (~80 dBO [owl-weighted noise level, Delaney et al. 1999a])

consistently (i.e., >twice/hour) or for an extended period of time (>1 hr) within 50 m (165 ft) of nesting sites (if known) or within entire PAC if nesting sites are not known.

c. If owls are not detected during approved-protocol surveys in a PAC during the breeding season, restrictions on noise disturbances should be relaxed depending on the nature and extent of the proposed disturbance.

11. Climate Change

Given mounting empirical evidence and model-based predictions for effects of climate change in the United States, a central dictum, under an uncertain future, is that no single management approach for intervention will fit all situations (Spittlehouse and Stewart 2003, Hobbs et al. 2006). A toolbox approach, from which various treatments and practices can be selected and combined to fit unique local settings, will be most useful (Millar et al. 2007). Our recommendations for addressing the effects of climate change on the owl are primarily based on the Intergovernmental Panel on Climate Change's *Climate Change and Biodiversity* technical paper (Gitay et al. 2002), Mawdsley et al. (2009) adaptation strategies for wildlife management, and the Millar et al. (2007) conceptual framework for managing forested ecosystems. Our recommendations include mitigation strategies (i.e., actions that reduce causes of stress) and adaptation strategies (i.e., actions that help forested ecosystems accommodate change). Our recommendations for climate change are consistent with all other guidelines and recommendations for the owl within this plan.

A. Mitigation Strategies

a. *Reduce Non-Climate Stressors.* Reduce or remove other non-climate stressors, including: scientific exploitation, noise disturbance, recreation disturbance, negative effects from grazing, and land development (see specific recommendations). Ameliorating non-climate stressors will provide the owl sufficient time to respond to local effects of climate change, including, for example, future range shifts or modifications in home range boundaries.

b. *Prioritize Forest Management.* Increased fire severity and incidence of stand replacing wildfire, and extensive tree mortality as a result of insect and disease, are predicted to be primary sources of unintentional carbon emissions from forests in the western United States (Stephens 2005). We support management strategies that will decrease release of carbon from forests and increase forest resistance to fire, drought, and disease. Priority-setting approaches (e.g., triage) will be necessary for rapidly changing conditions, for example, reducing the density of small trees (see our recommendations for thinning in PACs), increasing basal area of large trees, and protecting old-growth stands following Table C.2 in Appendix C.

B. Adaptation Strategies

a. *Promote Forest Resistance.* Resistance strategies forestall impacts and protect highly valued resources. Resistance practices are recommended because they have potential to improve forest defense against direct and indirect effects of rapid environmental changes. An obvious strategy

to promote resistance that will benefit the owl would include reducing undesirable or extreme effects of fires, insects, and disease through active forest management (see our recommendations and guidelines regarding fire management, wildland-urban interface, and insect and disease).

b. *Promote Forest Resilience.* Resilience strategies improve the capacity of ecosystems to return to desired conditions after disturbance. Promoting resilience is the most commonly suggested adaptive option discussed in a climate-change context. Resilient forests are those that not only accommodate gradual changes related to climate but tend to return toward a prior condition after disturbance either naturally or with management assistance. This strategy intentionally accommodates change rather than resisting it but has the goal of enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue. The strategic goal is to encourage gradual adaptation and transition to inevitable change, and thereby to avoid rapid threshold or catastrophic conversion that may occur otherwise. One way to achieve resilience is to promote diverse age classes and species mixes both within-stand and across landscapes and reduce stressors to forest habitat (i.e., by thinning overstocked stands and restoring fire-adapted ecosystems). Treatments implemented should mimic, assist, or enable ongoing adaptive processes such as owl dispersal and range expansion, for example promoting connected landscapes and minimizing physical and biotic impediments to movements (see our recommendations for Recovery Areas).

c. *Anticipate Surprises.* Evidence is accumulating that species interactions and competitive responses under changing climates can be complex and unexpected. Abrupt invasions, changes in population dynamics, and long-distance movements of native and nonnative species are expected in response to changing climates. Managers should strive to anticipate events outside the range of conditions in recent history. For example, changes in barred owl distribution and abundance should be monitored for potential effects on spotted owls.

d. *Use Adaptive Management and Monitor.* Given long-term uncertainty, it is imperative to “learn-as-you-go,” following an adaptive management strategy. Although general principles will hopefully emerge, the best preparation is for managers and planners to remain informed about emerging climate science as well as land-use changes in the Southwest, and to use that knowledge to shape effective management decisions for owl habitat. Following our General Management Recommendations, we recommend that vegetation manipulations be designed within an adaptive management framework. Rigorous monitoring systems will provide information that managers can use to adjust or modify objectives and activities. Long-term monitoring of owl site occupancy, extinction, and recolonization rates using appropriate designs will be imperative in light of climate change and evaluating efficacy of management objectives.

12. West Nile Virus

The recovery team does not currently view West Nile virus as a threat to Mexican spotted owls, as the virus has never been detected in this subspecies to our knowledge. However, given the fact that the virus occurs within the range of the Mexican spotted owl and that spotted owls have shown vulnerability to it, we believe the following measures are prudent.

A. Guidelines

- a. As suggested by Hull et al. (2010) in reference to their work on California spotted owls in the Sierra Nevada, estimating spotted owl survival rates and identifying causes of death would help determine whether West Nile virus is a significant threat to the population. We recommend that well-distributed demographic studies be carried out and that populations exhibiting significant downward population trends, especially in absence of other identifiable causes, be investigated for the possibility of West Nile virus-caused epizootics.
- b. Similarly, if routine spotted owl surveillance indicates the disappearance of birds from a given area, the possibility of West Nile virus should be investigated.
- c. Local biologists should monitor reports of avian mortality on the Centers for Disease Control and Prevention (CDC) website (www.cdc.gov) as well as those of state and county health departments.
- d. If any of the above situations lead to suspicion of a West Nile virus epizootic, conduct surveillance for the disease using standard arbovirus surveillance techniques. The CDC website contains a wealth of information on this subject, and state and county public health agencies can also be of assistance.
- e. Finally, although we do not recommend that spotted owls be captured and sampled specifically for West Nile virus absent the exigent circumstances described above, biologists who become aware of spotted owl captures for other purposes should look into asking researchers to collect saliva swabs or other minimally invasive samples. If researchers are also collecting blood or other tissue samples, testing of those for West Nile virus antibodies is advised. Again, state and county health departments can provide information on this process.

APPENDIX E

MEXICAN SPOTTED OWL SURVEY PROTOCOL U.S. FISH AND WILDLIFE SERVICE, 2011

INTRODUCTION

The following field survey protocol is designed for detecting Mexican spotted owls (hereafter, “owl”; *Strix occidentalis lucida*) and for surveying areas where human activities might remove or modify owl habitat, or otherwise adversely affect the species. The owl was federally listed as threatened on March 16, 1993 (58 FR 14248). Federal agencies are not required to conduct surveys for listed species prior to preparing a biological assessment under the Endangered Species Act [“Act”; see 50 CFR 402.12(f)]. However, Federal agencies are required to provide the best scientific information available when assessing the effects of their actions to listed species and critical habitat [50 CFR 402.14(d)]. In the absence of necessary information, the U.S. Fish and Wildlife Service (FWS) gives the benefit of the doubt to the listed species [H.R. Conf. Rep. No. 697, 96th Cong., 2nd Sess. 12 (1979)].

This survey protocol expresses the FWS’s scientific opinion on adequate owl survey methods and includes guidance and recommendations. It does not constitute law, rules, regulations, or absolute requirements. Our knowledge is continuously developing and changing; therefore, this protocol, which is based upon the best scientific data available, is a work in progress. This protocol will be modified as new information becomes available. The public will be notified of changes to the protocol through postings to the FWS’s Arizona Ecological Services Field Office (<http://www.fws.gov/southwest/es/arizona/>). We encourage submissions to us (email submissions to Shaula_Hedwall@fws.gov) at any time of any information that can add to our understanding of what is needed to provide for long-term conservation of this species and its ecosystem. Persons conducting owl surveys must be covered under a research and recovery permit under Section 10(a)(1)(A) of the Act in order to avoid unauthorized harassment of owls, which could violate the prohibitions of Section 9 of the Act. However, no other Federal permitting requirements are implied, though individual states might have their own permitting requirements. Circumstances dictate how owl surveys are implemented. If surveys cannot be accomplished pursuant to this protocol, we recommend contacting the nearest FWS Ecological Services Field Office for guidance on additional survey methods before proceeding.

The FWS endorses the use of this protocol for obtaining information on owl occupancy within and adjacent to proposed project areas. This protocol helps the public and agency personnel determine whether proposed activities will have an impact on owls and/or owl habitat. A properly conducted survey will help agencies determine whether or not further consultation with the FWS is necessary before proceeding with a project. Any information on owl presence within and/or adjacent to the proposed planning or activity areas is important, even if it does not meet the guidelines described below. However, if the only owl location information available for a proposed project was acquired through surveys not conducted in accordance with this protocol, the FWS may conservatively assess the impacts of the proposed management activity on owls, (e.g.) assume the species is present in or near the action area if the best available information

makes such an assumption reasonable. This survey protocol is not designed for monitoring owl population trends or for research applications.

The generally accepted protocol for inventorying owls was developed by the Southwestern Region of the U.S. Forest Service in 1988. The protocol was revised in 1989 and in 1990 it was appended to the Forest Service Manual. The protocol, as an element of Interim Directive No. 2, had an official duration of 18 months but has served as the guidance accepted by most agencies and individuals conducting surveys for owls on public lands throughout Arizona, New Mexico, Utah, and Colorado through 2003. The U.S. Forest Service reissued the inventory protocol in 1994, again in 1995, and then issued the latest version in February 1996. The U.S. Forest Service incorporated recommendations from the draft and subsequent final Recovery Plan for the Mexican Spotted Owl (1995 Recovery Plan) (USDI FWS 1995) regarding the designation of protected activity centers (PACs) around owl locations but did not modify the overall survey design.

Through application of and the use of the data gathered by the existing protocol under informal and formal consultations under Section 7 of the Act, the FWS has found instances where the refinement of the protocol would benefit both the species and those working with it. On January 26, 1998, the FWS met with a group of experts to review the U.S. Forest Service protocol and available literature and to improve and update the document. The following draft document is the result of those discussions and subsequent review by FWS biologists and Mexican Spotted Owl Recovery Team members.

This protocol provides a FWS-endorsed method to: (1) make inferences regarding the presence or absence of owls in a defined area; (2) assess occupancy and nesting status, and locate nests, in areas where habitat alterations or disturbances to owls are likely to occur; and (3) provide information to allow designation of PACs.

The primary objective of conducting surveys using this protocol should be to locate and observe the nest of a Mexican spotted owl or young. These observations provide the most reliable and efficient information for documenting presence and delineating potential nest core areas or roost sites (Ward and Salas 2000). Because spotted owls do not nest every year, the alternative, and often default outcome, is to observe adult or subadult spotted owls at daytime roosts. However, it can take up to four years of roost location data to effectively delineate owl core activity areas (Ward and Salas 2000). Locating a resident owl's nest or young may be accomplished most effectively using the mousing technique described in the protocol below (and see Forsman 1983). The mousing technique requires that personnel are trained in proper care and handling of live animals for research, and that, when conducting daytime follow-up surveys, they procure and carry "feeder" mice into the field (American Society of Mammalogists 1998, National Academy of Sciences 1996).

Individuals surveying for owls should meet certain training standards. Experience will be reviewed and approved during a surveyor's application for an FWS issued Section 10(a)(1)(a) recovery permit. These standards strongly encourage surveyors to have knowledge of this protocol and the ability to identify owls visually and vocally, determine sex and age of owls,

imitate vocal calls of the owls if not utilizing a tape recording of the calls, and identify other local raptor species. Orienteering skills, including use of map, compass, and/or GPS units, are essential. Surveyor safety should be of primary importance. Those surveying for owls who do not meet these training standards could “take” owls by harming or harassing them, resulting in criminal or civil penalties.

MEXICAN SPOTTED OWL SURVEY PROTOCOL

The most efficient way to locate owls is to imitate their calls (Forsman 1983). The owl is territorial and responds to imitations of its common vocalizations. Night calling is used to elicit responses from owls and locate the general areas occupied by them. Daytime follow-up visits are used to locate roosting and/or nesting owls and to further pinpoint the activity centers of individual owls. If owls are located, mice are offered to them to locate mates, nests, and young. The information collected from nighttime calling surveys and daytime follow-up surveys assist biologists and land managers to determine whether areas are occupied or unoccupied by owls and to determine the owl’s reproductive status.

Throughout this protocol, all bold-faced terms are included in the glossary. Only the first use of the term is bold-faced. An outline summarizing the primary steps for implementing the protocol appear below.

1. Survey Design

The survey design uses designated **calling routes** and **calling stations** to locate owls. The intent of establishing calling routes and calling stations is to obtain **complete coverage** of the survey area so that owls will be able to hear a surveyor calling and a surveyor will be able to hear the owl(s) responding.

- A. The survey area should include all areas where owls or their habitat might be affected by management actions. If an area is relatively large, it can be subdivided into manageable subunits in order to achieve the best survey results. In general, the survey area should include the survey area and an 800-meter (0.5-mile) area from its exterior boundaries. Within the project area, all areas that contain forested **recovery habitat**, riparian forest, and canyon habitat, or might support owls, are surveyed as defined in this revised Recovery Plan. Descriptions of owl habitat for different areas and physiographic provinces should be available from various state and Federal wildlife agencies.

Where known **protected activity centers (PACs)** exist within the survey area, calling routes can be adjusted to lessen disturbance to established PACs.

- B. Owl surveyors should establish calling routes and calling stations to ensure complete coverage of the survey area. The number of calling routes and calling stations will depend upon the size of the area, topography, vegetation, and access. Calling stations should be spaced from approximately 400 meters (0.25 mile) to no more than 800 meters (0.5 mile) apart depending upon topography and background noise levels. Nighttime calling routes and

calling stations should be delineated on a map, reviewed in the field, and then relocated, as necessary, to improve the survey effectiveness.

2. Survey Methods

Owls are usually located using nocturnal calling surveys where a surveyor imitates the territorial calls of an owl (Forsman 1983). Upon hearing a suspected intruder within their territories at night, most owls respond by calling to and/or approaching the intruder.

A. CALLING

1. Owls call during all hours of the night. However, optimal survey times include two hours following sunset and two hours prior to sunrise, and surveys should be concentrated around these periods.
2. Surveys should use nighttime surveys for all calling routes in the survey area unless safety concerns dictate that a daytime survey is necessary.
3. Calls can be imitated by the surveyor or by playing recordings of owl vocalizations. If a tape recorder is used, both the tape and tape deck used should be of high quality. Tape decks should have a minimum output of 5 watts (Forsman 1983).
4. The vocal repertoire of owls consists of a variety of hooting, barking, and whistling calls (Ganey 1990). Three call types accounted for 86 percent of calling bouts heard in Arizona: four-note location call, contact call, and bark series. The four-note call appears to be used the most frequently by owls defending a territory. It is suggested that surveyors use all three of these calls during surveys, with the four-note call as the primary call.
5. Surveyors should discontinue calling when a potential owl **predator** is detected, and should move on to another calling station out of earshot of the predator before resuming calling. Surveyors should return at a later time to the station(s) skipped to complete the calling route.
6. Surveyors should avoid calling for owls during periods of rain or snow, unless there is only a light misting of rain or snow that would not affect the surveyor's ability to detect owls. Surveying during inclement weather could prevent a surveyor from hearing owl responses and reduce the quality of the overall survey effort. Negative results collected under inclement weather conditions are not adequate for evaluating owl presence/**absence**. There is also the added risk of inducing a female owl to leave the **nest** during inclement weather and potentially jeopardizing nesting success.
7. Calling should not be conducted when the wind is stronger than approximately 15 miles per hour or when the surveyor feels that the wind is limiting their ability to hear an owl. Consider using the Beaufort Wind Strength Scale. Level 4 describes winds 13-18 miles

per hour as a moderate breeze capable of moving thin branches, raising dust, and raising paper.

B. SURVEYS

In order to ensure complete coverage of the survey area, surveyors should select the best survey method for the situation and/or terrain. An owl survey might require a combination of methods, which are defined below, including: (1) calling stations; (2) continuous calling routes to obtain complete coverage of an area; and (3) leapfrog techniques. Each of these methods is designed for nighttime calling and involves calling for owls and listening for their responses. All surveys where occupancy status is unknown should include nighttime calling.

It is imperative that, whatever method is used, surveyors actively listen during owl surveys. Owls may respond only once; therefore, surveyors must concentrate on listening at all times during surveys. In addition to active listening, surveyors should watch for owls that might be drawn in but do not respond vocally.

1. CALLING STATIONS

- a. **Spacing** - Calling stations should be spaced approximately 400 meters (0.25 mile) to no more than 800 meters (0.5 mile) apart depending on topography and background noise. In some situations (i.e., complex topography, etc.), establishing calling stations <400 meters apart and more calling stations increases the likelihood of detecting owls. In canyon habitat, if surveying from the canyon bottom, stations should be placed at canyon intersections. If surveying canyons from the rims, calling stations at points and canyon heads should be included.
- b. **Timing** - Surveyors should spend at least 15 minutes at each calling station: 10 minutes calling and listening in an alternating fashion, and the last 5 minutes listening. Owl response time varies, most likely due to individual behavior. Some owls will respond immediately, some respond following a delay, and some do not respond. In canyon habitat, it is recommended that surveyors spend a minimum of 20 minutes (30 minutes, if possible) at each station.
- c. **Visitation** - Vary the sequence of visitation to calling stations, if possible, during subsequent visits to the area. For example, the order of the calling stations can be reversed. Varying the order of calling stations avoids potential bias related to time of night or other factors.
- d. **Intermediate calling stations** should be used when weather or other factors decrease the probability of achieving complete coverage using the originally designated stations, or as triangulation points for determining nighttime owl locations. Use of intermediate calling stations can increase the likelihood of detecting owls and, thus, allow for stronger inference regarding the absence of an owl within the area.

2. CONTINUOUS CALLING METHOD

In some cases, using continuous calling is appropriate. Continuous calling involves imitating owl calls at irregular intervals while walking slowly along a route and stopping regularly to listen for owl responses. Because of the sounds produced by walking (e.g., snapping twigs, pinecones, etc.), surveyors utilizing this calling method must concentrate on active listening. In canyon habitat, the continuous calling method is only recommended when combined with calling stations.

- a. The surveyor should walk slowly so as to minimize the possibility that an owl responds after surveyors are out of hearing range (i.e., allow time for owls to respond)
- b. The surveyor must stop regularly along the route to listen for owl responses.

3. LEAPFROG METHOD

The leapfrog method is very useful when there are roads that allow for coverage of all or a portion of the survey area. This method requires two people and a vehicle.

- a. One surveyor is dropped off and begins calling while the other person drives the vehicle ahead at least 800 meters (0.5 mile). The second person then leaves the vehicle for the first person and proceeds ahead while calling.
- b. Each surveyor should follow the continuous calling method. The first person continuously calls as he or she walks towards the vehicle, drives the truck at least 800 meters (0.5 mile) past the second person (i.e., “leapfrogs”), leaves the vehicle there and resumes calling along the survey route.
- c. Surveyors should repeat this procedure until complete coverage of the survey area is accomplished.

3. Number and Timing of Surveys

Owl detection rates change with season, owl activity, and habitat. Ganey (1990) found that calling activity was highest during the nesting season (March-June). Information from past survey efforts indicate that owl response can also vary with habitat type and/or reproductive chronology (Figure E.1 in Appendix E). Generally, late March through late June is the optimal time period to detect owls. Surveys conducted during March-June will increase the likelihood of detecting owls. Additionally, if owls are not detected when surveys are conducted properly and at these peak times, then inferences about absence of owls in a given area will be stronger. It should be noted that responses in September can be used only to document presence. Surveys in September are not reliable for locating nests, delineating PACS, and/or inferring absence.

Specific criteria on number and timing of surveys are used to determine whether a **complete inventory** has been accomplished. A complete inventory requires that at least four properly scheduled complete surveys be accomplished annually for two years. Additional years of surveys strengthen any inferences made in cases where owls are not detected. If habitat-modifying or potentially disruptive activities are scheduled for a particular year, the second year of surveys should be conducted either the year before or the year of (but prior to) project implementation. In other words, no more than one year should intervene between the completion of surveys and project implementation. If more than five years have elapsed between the last survey year and the initiation of the proposed action, then one additional year of survey is recommended prior to project implementation.

- A. In compliance with the guidelines in B through G below, surveyors should conduct four **complete surveys** during each breeding season. A complete survey can be a combination of a pre-call (daytime reconnaissance of habitat to be night called), a nighttime calling survey, and, if owls are detected, a **daytime follow-up survey**. If owls are not detected during daytime calling, night calling must be completed. However, if owls are located during a pre-call, night calling of the survey area is not required. Surveyors might want to conduct additional surveys if there is evidence that additional owls remain undetected in the area.
- B. The four complete surveys must be spread out over the breeding season (1 March - 31 August) by following one of three recommended scheduling scenarios:
 1. Conducting two to four surveys during 1 March - 30 June, with no more than one survey in March. Owl calling activity tends to increase from March through May (Ganey 1990), so this time period is optimal for locating owls.
 2. Completing all surveys by 31 August, with no more than one of the four required surveys conducted during each of the months of July and August. Owl response rates tend to decrease by July (Ganey 1990). By September, juveniles have usually dispersed and adults are not necessarily on their territories. If additional surveys are added (e.g., more than the recommended four surveys), more than one complete survey could be completed in August.
 3. Allowing at least five full days between surveys. For example, assume a visit ends on 30 April. Using a proper five-day spacing (1-5 May), the next possible survey date would be 6 May (see section 3.D below for an exception to this rule).
- C. A complete survey of the area should be conducted within seven consecutive days. If the area is too large to be surveyed in seven consecutive days, it should be divided into smaller subunits based on available owl habitat, topography, and other important factors.
- D. In **remote areas**, surveyors can conduct two complete surveys during one trip into the area, so long as surveyors allow a minimum of two days between complete surveys. Conduct all field outings required for a complete survey prior to repeating any route for the second survey. Wait a minimum of 10 days before starting the next two surveys. Areas defined as

remote should be cleared with the FWS prior to proceeding with this deviation from the survey protocol.

- E. The two- to three-hour periods following sunset and preceding sunrise are the peak owl calling periods and the best times to locate owls in or near day **roosts** or nests.
- F. Surveys can be discontinued in a given area when data indicate that the entire survey area is designated as PACs.
- G. Vocal or visual locations of owls outside the breeding season (1 September - 28 February) as extra information can be of assistance in locating nesting owls in the upcoming breeding season.

4. Methods After Detecting a Mexican Spotted Owl

Once an owl has been detected, the following should be done:

- A. Record the time the owl(s) was first detected, the type(s) of call(s) heard (if any), the owl's sex, and whether **juveniles** were detected.
- B. Record a compass bearing from the surveyor's location to the location where the owl was heard and/or visually observed. If possible, triangulate the owl's location, taking compass bearings from two to three locations and estimate the distance to the owl. Record both the location where the owl responded from and the surveyor's calling location and triangulation locations on a map or photo attached to the survey form. The surveyor should know her/his location at all times. Triangulating provides an accurate means to map the owl's location. Attempt to confirm the presence of the owl(s) with a daytime follow-up visit (see section 5 below). Daytime owl locations, particularly of nests and young of the year, are very important in determining activity centers.
- C. If the owl is heard clearly, and the call type and direction are confirmed, there is no need to continue calling. If, however, there is some doubt as to whether a response was detected, or from which direction, the surveyor should listen carefully for a few minutes, as an owl may call again if given the opportunity. If the owl does not respond after two to five minutes, the surveyor should continue calling in order to confirm owl presence and better assess the direction of the call. Do not call any more than is necessary. By stimulating the owl(s) to move you may harass a female owl off a nest or increase an owl's risk of predation.
- D. Owls may move before or after they begin calling. Every effort should be made to estimate the location of the owl when the first response was heard. After you have determined the owl's location (see section 4.B above), move approximately 800 to 1,200 meters (0.5 to 0.75 mile) away (depending upon topography) before continuing surveys to avoid response by the same owl. If the owl responds from the original detection area, then move farther away before continuing to call.

- E. Record the approximate location (bearing and distance), sex, age, and species of all other raptors heard in the survey area.
- F. Conduct a daytime follow-up survey as soon as possible (see section 5 below).

5. Conducting Daytime Follow-up Surveys

As with nighttime surveys, follow-up daytime searches ensure quality of results and standardization of effort. Calling to elicit territorial responses is also used during daytime follow-up visits. A daytime follow-up survey helps locate owl roosts, nest sites, and young of the year (during 1 Jun - 1 Aug) by conducting an intensive search within the general vicinity of the original night response location. Owls tend to be more active in the early morning and late evening. During the day, owls are sleepy and do not always readily respond to calling, especially on warm days. Therefore, it is critical that surveyors conduct a thorough daytime search of the response area. Surveyors should spend enough time within the response area to cover all habitats within at least an 800-meter (0.5 mile) radius of the response location. This involves walking throughout the area, calling, listening, and watching for owl sign (e.g., whitewash, pellets, etc.). The FWS recommends that a minimum of one hour be spent searching for owls (regardless of the number of people surveying).

- A. Complete a daytime follow-up survey as soon as possible, but within a maximum of 48 hours after owls are detected during nighttime surveys. The optimum daytime follow-up time is the morning following the nighttime detection. In general, the longer the time delay between the nighttime response and daytime follow-up survey, the smaller the probability of locating the bird and finding its roost or nest location. This is especially true if the owl(s) are not nesting. If the daytime follow-up survey is performed longer than 48 hours after the nighttime detection and no owls are found, the survey is considered incomplete and the survey must be re-done.
- B. Conduct daytime follow-up surveys in the early morning or late afternoon/early evening. The optimal dawn period is 0.5 hour before sunrise to two hours after sunrise and the optimal dusk period is two hours prior to sunset; each daytime follow-up visit should include one of these time periods. Investing time in searching for the owl during these times will provide a more reliable inference of absence in the case where the owl cannot be located. For areas where spotted owls have been observed during the daytime during previous years, an initial survey in late April through mid-May can often elicit a response. However, non-responses are not that meaningful in documenting absence without nighttime surveys because owls could have moved to another nesting or roosting grove. However, initial daytime surveys can be an efficient way to start each survey season where owls have been found in the past. If the initial daytime survey is unsuccessful (i.e., no response is heard), then nighttime surveys should be used to locate owls before attempting additional daytime surveys.
- C. The search area for a daytime follow-up survey is a specific, smaller area within the broader survey area in which an owl was detected.

1. Minimum search area is all forested recovery, riparian forest, and canyon habitat within at least an 800-meter (0.5 mile) radius of a nighttime owl response.
 2. The search area should center on the location of the owl or owls that were heard during the nighttime survey. If there is some uncertainty, focus the search on the best nesting and roosting habitats (e.g. see Ward and Salas 2000).
 3. Aerial photos and maps of the area should be studied to identify habitat patches and topographic features, such as canyons or drainages, to prioritize daytime survey locations. In forested areas, spotted owls often roost in first- and second-order tributaries (Ward and Salas 2000).
- D. To conduct a thorough search for owls, the surveyor should systematically walk and call all forested recovery, riparian forest, and canyon habitats within the search area. As with nighttime surveys, be aware that owls often fly into the area to investigate; thus, surveyors must also attentively watch for owls. Surveyors should also search for signs of owls such as pellets, white wash, or molted feathers. However, pellets and whitewash alone are not sufficient to document owls. Mobbing jays or other birds can also be a sign that an owl is present.
- E. If a daytime follow-up visit is not completed for any reason, or the search effort was not thorough because of the presence of predators or weather, a second follow-up visit should be conducted as soon as possible.
- F. If no owl(s) are located during complete daytime follow-up visits, the surveyor should return to conduct nighttime surveys. Four complete surveys to an area are recommended by the survey protocol, but surveyors should assess the confidence of the nighttime and daytime responses and determine if additional nighttime surveys are needed to more accurately determine the location of the responding owl(s). Field personnel conducting surveys need to be given the flexibility to return as many times as necessary to find the owl(s).
- G. As with nighttime surveys, daytime follow-up surveys should not be conducted in inclement weather and surveyors should avoid calling when potential owl predators are present.
- H. Surveyors should minimize the amount of incidental disturbance to owls. For example, surveyors must not linger in nest sites or over-call in an area.

6. Methods If Mexican Spotted Owls Are Located on a Daytime Follow-up Visit

Mousing is the primary tool to locate an owl's mate, young, and/or nest. Mousing entails feeding live mice to **adult/subadult** owl(s) and observing the owl's subsequent behavior. Surveyors should be prepared to offer four mice (one at a time) to at least one member of the pair or to a single owl located on the daytime follow-up visit. For surveyors to draw conclusions about reproductive status, the owl must take at least two mice before refusing them. A mouse is considered "refused" if, after 30 minutes, it has not been taken by an owl.

If an owl takes a mouse and flies away, the surveyor should follow it as closely as possible to determine where it takes the mouse. If the surveyor is unable to follow the owl, and doesn't know if it took the mouse to a mate, nest, or fledged young, then the fate of that mouse cannot be counted toward the four-mouse minimum described above. Surveyors should be ready to rapidly pursue owls that take mice, as owls sometimes fly with mice several hundred yards to reach their nests or young. It is not necessary to complete the four mice minimum after a mouse has unequivocally been taken to a nest.

Owl pairs are determined to be non-nesting if a single owl eats and/or caches all four mice or eats and/or caches two mice and refuses to take a third. A mouse is cached when the owl puts the mouse in a tree or on the ground and then leaves the mouse or the owl perches with the mouse for at least one hour and gives no sign of further activity. Do not feed any more mice than necessary to determine pair status, nest location, and/or reproductive status (i.e., if all observed juveniles have received a mouse then number of young produced is determined and there is no need to continue mousing). Dropped mice or mice whose fates are unknown do not count toward the total of four mice needed to complete the protocol.

Ancillary notes on an owl's behavior during the mousing attempts are also very important to record. These observations can help clarify situations in which incomplete information was collected. For example, if a male is given a mouse and begins to make single-note contact calls while looking in a specific direction in April-June, that is often a good clue that a mate, nest, and/or young may be present. Sometimes observers are too close to other owls or the nest for the "true" mouse fate to be observed. Such observations should trigger another daytime follow-up to secure the location of a mate, nest, or young of the year. For these types of additional follow-up surveys, nighttime calling is usually not necessary.

7. Determining Status from Nighttime Surveys and Daytime Follow-up Visits

A. "Pair status" is established by any of the following:

1. A male and female owl are heard and/or observed in proximity (500 meters or 0.31 mile apart) to each other on the same visit.
2. A male takes a mouse to a female (see section 6 mousing guidelines).
3. A female is observed or heard on a nest.
4. One or both adults are observed with young.
5. At least one young of the year is observed.

B. "Single status" is inferred from:

1. A daytime observation on a single occasion or nighttime responses of a single owl within the same general area (within 500 meters or 0.31 mile) on two or more occasions, with no response by an owl of the opposite sex after two complete inventories (two years of survey); or

2. Multiple responses over several years from a bird of the same sex (i.e., two responses in first year of surveys and one response in the second year of surveys, from the same general area).

Determining if the responses occur within the same general area should be based on topography and the location of any other known owls in the surrounding area.

- C. “Two birds, pair status unknown” is inferred from:

The presence or response of two owls of the opposite sex where pair status cannot be determined.

- D. “Status unknown” is inferred by:

The response of a male and/or female spotted owl that does not meet any of the above criteria. We recommend additional years of survey if this is the site status following a complete inventory of the site.

- E. “Absence” is inferred:

If a complete inventory has been conducted according to this protocol, or an alternative protocol approved by the FWS, and no owls are heard. However, absence does not necessarily indicate that owls never occupy the area.

- F. Separate territories are inferred by:

When two responses are recorded from owls that are more than 800 meters (0.5 mile) apart. These responses should be considered from individuals in separate territories unless daytime follow-up visits indicate otherwise. Ideally, surveyors on two or more crews should coordinate efforts to begin calling simultaneously near each suspected activity area to rule out the existence of multiple territories. If more than one survey crew elicits responses from owls of the same sex at roughly the same time, then two or more territories probably exist. However, if responses vary from those above, the results are considered inconclusive and additional attempts to determine status should continue. However, keep in mind that some spotted owls shift their use of an area after failing to nest in a given season. Hence, responses heard in July that are 800 meters (0.5 mile) from a pair that was nesting in April or early May could be from the same individuals.

8. Determining Nesting Status and Reproductive Success

Determining reproductive success is not required if breeding season restrictions that protect owl reproduction are applied to all management projects in any given year. However, reproduction surveys are always valuable as they can provide information on nest tree locations, which provide the best data for determining 100-acre **nest buffers** (Ward and Salas 2000) and

delineating PAC boundaries as recommended in this revised Recovery Plan. If the exact location of the nest is not determined, but juveniles are seen prior to August, the area where the juveniles are seen can be referenced as the **nest stand**. There are two stages of reproduction surveys: nesting status and reproductive success.

A. Determining Nesting Status:

1. Nesting-status surveys should be conducted between 1 April and 1 June. The start date is based on nesting initiation dates. Young identified after 1 June would still confirm that nesting occurred but would not allow identification of the exact location of the nest. However, young observed prior to August are usually within 400 meters (0.2 miles) of the nest of that year (Ward and Salas 2000) and this information can be useful in delineating a 100-acre nest buffer.
2. Mousing should be used to determine nesting status. The site is classified as nesting, non-nesting, or unknown nesting status based on the surveyor's observations.
3. Two observations at least one week apart are necessary to determine nesting status if the first observation occurs before 1 May. This is necessary because the owls may show signs of initiating nesting early in the season without actually laying eggs and their behavior could be mistaken for nesting behavior. After 1 May, a single observation of nesting behavior is sufficient.
4. The owls are classified as nesting if, on two visits prior to 1 May, or one visit after 1 May:
 - a. The female is seen on the nest;
 - b. Either the male or female member of a pair carries a mouse to a nest; or
 - c. Young-of-the-year are detected.
5. The owls will be classified as non-nesting if any of the following behaviors are observed. Two observations, minimum three weeks apart, are required during the nest survey period (1 April - 1 June) in order to infer non-nesting status. Because nesting attempts might fail before surveys are conducted, the non-nesting status includes owls that did not attempt to nest as well as those that had a failed nesting attempt. Non-nesting status is inferred during a daytime follow-up visit if:
 - a. The female is observed roosting for a full 60 minutes (1-30 April) during the time she should be on a nest. The female should not be in an agitated state and should be given every opportunity to return to the nest. Surveyors should attempt to mouse the female.

- b. The surveyor offers prey to one or both members of the pair and they cache the prey, sit with the prey for an extended period of time (30-60 minutes), or refuse to take additional prey beyond the minimum of two prey items. To be considered a valid nesting survey, one owl must take at least two prey items.
 - c. All pairs considered to be non-nesting should receive at least one daytime follow-up visit between 15 May and 15 July to confirm that no young were produced.
6. Nesting status is unknown if:
- a. Owls are found after 1 June without young-of-the-year; or
 - b. No adult or young owls are found after 1 June at those sites where adult owls were present prior to 1 June.

B. Determining Reproductive Status:

1. Once a pair is classified as nesting, reproductive success surveys should be conducted after the time the young-of-the-year leave the nest (fledge), usually in early to mid-June. For pairs whose nesting status was not determined, reproductive success surveys should be conducted between 15 May and 15 July.
2. At least two visits to the site spaced at least one week apart should be conducted to locate and count fledged young, and the timing of the visits should be scheduled so that the fledged young are observed as soon after leaving the nest as possible.
3. Visual searches and/or mousing should be used to determine reproductive success. The mousing protocol is the same as for determining non-nesting. If young are present, the adults should take at least some of the prey to the young. The sight of an adult with prey can stimulate the young to beg, revealing their number and location.
4. If the owls take at least two prey items and eventually cache, sit with, or refuse further prey without ever taking prey to fledged young during the proper time period and no other indicative behaviors like contact calls or searching are observed, then zero young are recorded. If one individual adult or subadult owl takes and eats four mice on one visit during the proper time period, then zero young are recorded. If, however, other behaviors indicate young may be in the area, another follow-up survey is recommended to verify that zero young were produced, particularly if the pair had been observed nesting earlier that year.

9. Annual Reporting

An annual report of the activities conducted (including field data forms, if appropriate) should be submitted to the FWS Permits Office in Albuquerque, New Mexico, as well as the appropriate state Ecological Services Field Office. If applicable, hard copies of any unpublished or published reports generated by the study and other data that would be useful for the conservation or recovery of the owl should be submitted to the appropriate Ecological Services Field Office(s).

10. Disposition of Dead, Injured, or Sick Mexican Spotted Owls

Upon locating a dead, injured, or sick owl, initial notification should be made to the FWS's Law Enforcement Office in Arizona (telephone: 480-967-7900), Colorado (telephone: 303-274-3560), New Mexico (telephone: 505-346-7828), or Utah (telephone: 801-625-5570) within two working days (48 hours) of its finding. Written notification should be made within five calendar days and should include information on when (date, time) and where (exact location) the owl was found, photographs of the owl and/or area, if possible, and any other pertinent information. The notification should be sent to the Law Enforcement Office with a copy to the appropriate FWS Ecological Services Field Office. Sick and injured owls should be transported by an authorized biologist to a licensed and permitted wildlife rehabilitator or veterinarian, and care must be taken during handling to ensure effective treatment. Should the treated owl(s) survive, the FWS should be contacted regarding the final disposition of the animal. Salvaged specimens or owls that did not survive rehabilitation should be handled with care to preserve the biological material, and the remains of intact owl(s) should be provided to the appropriate FWS Ecological Services Field Office. If the remains of the owl(s) are not intact or are not collected, the information noted above should be obtained.

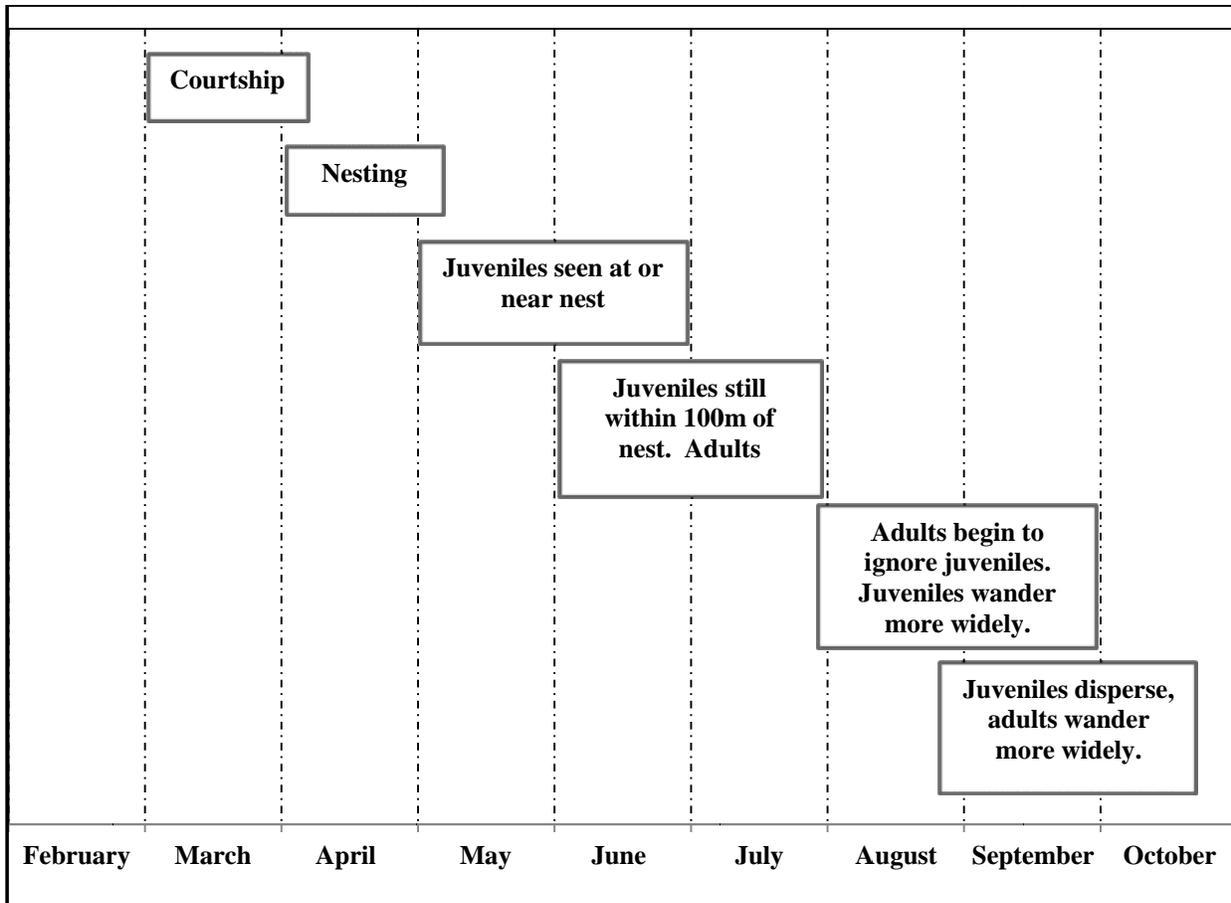


Figure E.1. Generalized reproductive chronology for the Mexican spotted owl. The area between the arrows at the bottom of the table indicates periods of high probability of detecting owls. Chronology may vary slightly with area, elevation, and/or in response to weather.

GLOSSARY FOR APPENDIX E, SURVEY PROTOCOL

Absence	Absence of Mexican spotted owls can be inferred when no response is recorded after a complete inventory has been completed in a defined area. Absence does not necessarily indicate that Mexican spotted owls never occupy the area.
Adult	A Mexican spotted owl ≥ 3 years old. Tips of retrices (tail feathers) will be rounded with white and mottled color. Subadults will have triangular all white tips on tail feathers. For more information on identifying adult and first and second-year subadult Mexican spotted owls, see Moen et al. (1991).
Breeding Season	The time period from 1 March through 31 August that includes courtship, nesting, and nestling- and fledgling-dependency periods. This is the period of time in which surveys should be conducted. This time period will vary by geographic locale.
Calling Route	An established route within a survey area where vocal imitations or recorded calls of Mexican spotted owls are used to elicit a response.
Calling Stations	Point locations used to conduct surveys, distributed throughout an area so as to attain complete coverage of the survey area.
Complete Coverage	Complete coverage is obtained when the calling stations have been located within a survey area so that a Mexican spotted owl anywhere in the survey area would be able to hear surveyors and vice-versa.
Complete Inventory	When the following are met: (1) four complete surveys have been conducted in one year; (2) consecutive surveys have been conducted a minimum of five days apart; (3) no more than one survey has been conducted in March; (4) a minimum of two surveys have been conducted by 30 June; (5) all surveys were completed by 31 August, with no more than one survey conducted in the months of July and August; and (6) two years of survey have been completed.
Complete Survey	A survey is complete when all calling stations or calling routes within a survey area are called within a seven-day period, including daytime follow-up visits for all Mexican spotted owl responses. If every reasonable effort has been made to cover the survey area in one outing but this is not accomplished, then additional outings will be scheduled to cover the remaining area. The entire survey area must be covered within seven consecutive days in order to be considered one complete survey. Although adverse weather conditions may present problems, an effort should be made to complete survey visits on consecutive days. If the survey area is

too large to be completely surveyed in seven days, it may be divided into smaller areas based on available habitat, topography, drainages, etc.

Daytime Follow-up
Visit

A daytime follow-up visit is conducted around Mexican spotted owl responses. The objective of a daytime follow-up visit is to locate Mexican spotted owl(s), their nests and their young by conducting an intensive search within an 800-meter (0.5-mile) radius of the original nighttime or last known response location. The follow-up visit is conducted during daylight hours and should be completed as soon as possible following the initial detection, but no later than 48 hours after detection. If Mexican spotted owls are located during the daytime follow-up visit, the surveyors use the mousing technique to determine nesting and reproductive status.

Intermediate Calling
Stations

Calling locations between identified calling stations or routes used to triangulate a Mexican spotted owl's location or used to improve calling coverage of an area when weather or other conditions require. Not required to be established prior to the field outing in which they are used.

Juvenile

A Mexican spotted owl is considered a juvenile in its first five months after hatching. Juveniles one to three months old are very white and have downy plumage over all of the body or evident on breast and head; at four to five months old, juveniles begin losing downy plumage but retain white triangular tips on their tail feathers (Moen et al. 1991).

Mousing

Mousing is a term used to describe the act of offering prey items to owls or other birds of prey. The purpose of mousing Mexican spotted owls is to find mates and determine the reproductive status of the owl(s) (i.e., pair, nesting, non-nesting). In some instances, a male Mexican spotted owl will take a prey item to an unseen female or an adult owl will take prey items to unseen young.

Nest

Mexican spotted owls use broken-topped trees, old raptor nests, witches brooms, caves, cliff ledges, and tree cavities for nests. A Mexican spotted owl must be observed using the structure in order to designate a nest site.

Nest Buffer

A 100-acre area within designated protected activity centers (PACs) circumscribed around the nest site. The nest area should include habitat that resembles the structural and floristic characteristics of the nest site. These 100-acre areas will be deferred from mechanical treatment. For additional details on delineation, see Ward and Salas (2000).

Nest Stand

An area of vegetation that contains a Mexican spotted owl nest and that is homogeneous in terms of tree size, forest structure, and species composition.

Nestling	A young owl that is still in the nest; may also be called a hatchling.
Predator	Potential predators of Mexican spotted owl eggs and young include the following: great-horned owl (<i>Bubo virginianus</i>), northern goshawk (<i>Accipiter gentilis</i>), red-tailed hawk (<i>Buteo jamaicensis</i>), golden eagle (<i>Aquila chrysaetos</i>), common ravens (<i>Corvus corax</i>) and procyonid mammals (e.g., coati [<i>Nasua nasua</i>] and ringtail [<i>Bassariscus astutus</i>]).
Protected Activity Center (PAC)	An area of at least 600 acres (240 ha) surrounding the “activity center,” which is the nest site, a roost grove commonly used during the breeding season in absence of a verified nest site, or the best roosting/nesting habitat if both nesting and roosting information are lacking. The 600 acres (minimum size) is delineated around the activity center using boundaries of known habitat polygons and/or topographic boundaries, such as ridgelines, as appropriate. The boundary should enclose the best possible Mexican spotted owl habitat, configured into as compact a unit as possible, with the nest or activity center located near the center. This should include as much roost/nest habitat as is reasonable, supplemented by foraging habitat where appropriate. For example, in a canyon containing mixed-conifer on north-facing slopes and ponderosa pine on south-facing slopes, it may be more desirable to include some of the south-facing slopes as foraging habitat than to attempt to include 600 acres of north-slope habitat. In many canyon situations, oval PACs may make more sense than, for example, circular PACs; but oval PACs could still include opposing canyon slopes as described above. All PACs should be retained until this subspecies is delisted, even if Mexican spotted owls are not located there in subsequent years.
Remote Area	Generally, any survey area that requires more than four hours of travel time by vehicle and/or foot during good road, trail, and weather conditions (good for the road or trail in question) to reach. All remote areas should be agreed upon by the FWS on a case-by-case basis prior to using the survey protocol to clear a project.
Recovery Habitat	Mixed-conifer and pine-oak forest types, and riparian forests as described in this revised Recovery Plan. These areas are not managed as strictly as PACs, but specific guidelines for management activities and developing nest/roost replacement conditions are specified in this revised Recovery Plan.
Roost	Tree, cliff ledge, rock, or log used by a Mexican spotted owl for extended daytime rest periods. A roost site consists of the roost itself and the immediate vicinity. Roost areas are identified by observations of the Mexican spotted owls and/or the presence of pellets, whitewash, and other evidence.

Subadult

Mexican spotted owls in their second and third summers. Identified by characteristic tail feathers with white tips tapering to sharp points (i.e., triangular shaped). For more information on identifying subadult Mexican spotted owls, please see Moen et al. (1991).

LITERATURE CITED FOR APPENDIX E - SURVEY PROTOCOL

- American Society of Mammalogists. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. *Journal of Mammalogy* 79:1416–1431.
- 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..
- Ganey, J.L. 1990. Calling behavior of spotted owls in northern Arizona. *Condor* 92:485-490.
- Moen, C.A., A.B. Franklin, and R.J. Gutierrez. 1991. Age determination of subadult northern spotted owls in northwest California. *Wildlife Society Bulletin* 19:489-493.
- National Academy of Sciences. 1996. Guide for the care and use of laboratory animals. Institute for Laboratory Animal Resources. Commission on Life Sciences, National Research Council, Washington, D.C, USA.
- U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1995. Recovery plan for the Mexican spotted owl. Albuquerque, New Mexico. .
- Ward, J. P., Jr., and D. Salas. 2000. Adequacy of roost locations for defining buffers around Mexican spotted owl nests. *Wildlife Society Bulletin* 28:688-698.

SUGGESTED READING FOR APPENDIX E – SURVEY PROTOCOL

- Ganey, J.L. and J. L. Dick, Jr. 1995. Chapter 4. Habitat relationships of the Mexican spotted owl: current knowledge. Pp. 1-42 *in* USDI Fish and Wildlife Service. Recovery plan for the Mexican spotted owl: volume II. Albuquerque, New Mexico, USA.
- Gutiérrez, R. J., A. B. Franklin, and W. S. LaHaye. 1995. Spotted owl. The birds of North America 179:1-28.
- Moen, C.A., A.B. Franklin, and R.J. Gutierrez. 1991. Age determination of subadult northern spotted owls in northwest California. Wildlife Society Bulletin 19:489-493.
- Rinkevich, S.E., and R.J. Gutierrez. 1996. Mexican spotted owl habitat characteristics in Zion National Park. Journal of Raptor Research 30:74-78.
- Seamans, M.E., and R.J. Gutierrez. 1997. Breeding habitat of the Mexican spotted owl in the Tularosa Mountains, New Mexico. Condor 97:944-951.
- USDI Fish and Wildlife Service. 1993. Final rule to list the Mexican spotted owl as threatened. Federal Register 14248. Albuquerque, New Mexico, USA.
- USDI Fish and Wildlife Service. 1995. Recovery plan for the Mexican spotted owl: volume I. Albuquerque, New Mexico, USA. 172 p.
- Ward, J.P., and D. Salas. 2000. Adequacy of roost locations for defining buffers around Mexican spotted owl nests. Wildlife Society Bulletin 28(3):688-698.
- White, G. C., A. B. Franklin, and J. P. Ward, Jr. 1995. Chapter 2. Population Biology Pp. 1-25 *in* USDI Fish and Wildlife Service. Recovery plan for the Mexican spotted owl: volume II. Albuquerque, New Mexico, USA.
- Zwank, P.J., K.W. Kroel, D.M. Levin, G.M. Southward, and R.C. Romme. 1994. Habitat characteristics of Mexican spotted owls in southwestern New Mexico. Journal of Field Ornithology 65:324-334.

Mexican Spotted Owl Survey Protocol Outline

Complete Inventory Four complete surveys each year (minimum five days apart)

No more than one survey in March

Minimum of two surveys prior to June 30th

No more than one survey in each of July and August

All surveys completed by 31 August

Two years of complete surveys

1. Owl(s) Detected, go to 3
2. No Owls Detected, Absence inferred for survey area
3. PRESENCE - Conduct a daytime follow-up visit
 - A. No owl(s) found on daytime follow-up visit:

Status unknown, SINGLE STATUS inferred, return to night calling
 - B. Single owl located on daytime follow-up visit:

Feed maximum 4 mice to owl to determine status; if no other owl located, RESIDENT SINGLE CONFIRMED
 - C. Pair of owls located on daytime follow-up visit:

PAIR CONFIRMED for site, go to 4B
4. NESTING STATUS SURVEYS (1 April - 1 June)
 - A. Pair not detected, non-nesting, non-reproduction inferred (for that survey)
 - B. Pair located, mouse owls (1 of owl pair fed 4 mice)
 1. If one of the following occurs, nesting confirmed, reproduction unknown, go to 5B:
 - a. Female on nest
 - b. Owl takes prey to nest
 - c. Young in nest with adult present
 2. If one of the following occurs, non-nesting inferred, non reproduction inferred (two visits to infer non-nesting, minimum three weeks apart):

- a. One of owl pair fed four mice (know fate of all four mice)
- b. Female refuses mouse and/or roosts for minimum one hour (1 April - 30 April)
- 3. Pair (but no young) located after 1 June:
 - a. NESTING STATUS UNKNOWN
 - b. Conduct reproductive visit, go to 5A
- 5. REPRODUCTIVE SUCCESS VISITS
 - A. NESTING STATUS UNKNOWN
 - 1. Recommend two visits, one week apart, feed four mice to locate juveniles
 - B. NESTING STATUS KNOWN
 - 1. One visit to look for juveniles (this may take more than one visit to locate all juveniles produced)
 - 2. If surveyor does not find juveniles, mouse adults to locate juveniles

APPENDIX F

MONITORING PROCEDURES

In developing the original Recovery Plan (FWS 1995), the Team assimilated, reviewed, and analyzed data generated by the Mexican Spotted Owl Monitoring Program of the Forest Service (FS) Southwestern Region. The Team also compiled and reviewed data from the Bureau of Land Management (BLM) and the Intermountain and Rocky Mountain Regions, USFS. In addition, the Team evaluated results of a pilot study (Ganey et al. 2004) conducted to test the population-monitoring procedures proposed in FWS (1995) and more recent studies that have estimated the probability of site occupancy by Mexican spotted owls (Lavier 2006, Mullet 2008). Based on lessons learned from these efforts, we offer an alternative design for monitoring the Mexican spotted owl population within the United States. This approach would measure the critical variables – changes in owl site occupancy rates and changes in habitat – needed for delisting the species (see Part III.5 of the Recovery Plan).

Our proposed approach uses occupancy monitoring to evaluate trends in the owl population. Occupancy monitoring is based on mark-recapture theory (MacKenzie et al. 2002, 2003, see also Mackenzie et al. 2006) and allows for estimating detection probabilities and correcting directly observed estimates of occupancy rates. This detail is critical, because it is likely that not all resident owls will be detected in a given year and because detection probabilities may change over time. Such changes in detectability of owls could result in erroneous trend estimates and misguided conservation efforts.

Accurate and efficient protocols for occupancy monitoring require pilot studies to estimate detection probabilities and to estimate variances associated with detection probabilities, occupancy rates, and important habitat variables. For occupancy monitoring, these estimates then can be used to determine the number of call stations per survey plot and to refine the number of visits per plot. Most importantly, the numbers of plots required within predefined strata and EMU can be determined more precisely.

Habitat monitoring should entail remote sensing of habitat across the range of the bird and estimates of desired future conditions (DFCs, Table C.1 in Appendix C), some of which are best measured on the ground. Although we do not advocate a specific methodology for ground measures, the USFS Forest Inventory and Analysis (FIA) program offers some promise. We describe some relevant details of this program below.

1. OCCUPANCY MONITORING

Monitoring habitat as a singular effort will not adequately reveal the true status of the owl population because numerous factors besides habitat can influence population levels. Thus, it is desirable to simultaneously monitor trends in both habitat and owl abundance (or an acceptable surrogate index).

A limitation of the monitoring scheme proposed here (and all known approaches) is that it monitors primarily territorial birds. The population of non-territorial “floaters” (Franklin 1992) is

difficult to detect reliably. Evidence for Mexican spotted owls suggests that a large population of floaters does not exist, however. Specifically, the proportion of subadult owls successfully holding territories is relatively high, suggesting that surplus older birds do not exist. For example, the proportion of the territorial population comprised of subadult females ranged as high as approximately 30–33% in two demographic study areas in Arizona and New Mexico over a seven-year period (Seamans et al. 1999: Fig. 1). Further, density of territorial owls in these study areas tracked reproduction with a short lag period (Seamans et al. 1999: Fig. 5; Gutiérrez et al. 2003), again suggesting that there were not substantial numbers of floaters available to fill territory vacancies. This evidence supports the use of trends in site occupancy as a reasonably sensitive measure of population trend.

In the following sections, we outline a framework and statistical estimation approach for monitoring owl populations via directly estimating the site occupancy rate of territorial owls. Critical design and sampling details were developed from a pilot study (Ganey et al. 2004). To illustrate the potential utility of FIA, we incorporated FIA into the occupancy monitoring plan so that microhabitat variables can be related to owl occupancy rates. Managers can consider other habitat monitoring programs in lieu of FIA if available or developed.

Monitoring Site Occupancy

Although we support the idea of estimating population size directly and collecting associated demographic data as described in FWS (1995), the results of the pilot study suggest that the costs for such a monitoring program are daunting. Therefore, we propose this alternative monitoring program based on monitoring occupancy rates as an index of population size.

Occupancy

We define occupancy for Mexican spotted owls as the proportion of plots occupied by the species. Plots sampled will be square 1-km² (0.36-mi²) blocks (Universal Transverse Mercator [UTM]) blocks of 100 ha (247 ac) that can be easily mapped using GIS, located using GPS, and surveyed to detect Mexican spotted owls. The population of plots from which samples are to be drawn will be defined based on FIA Phase 2 state-wide maps. The number of occupied plots divided by the total number of plots sampled (n) provides an estimate of the proportion of sites occupied (O), referred to as occupancy rate.

We suggest that the owl monitoring plots be defined based on overlaying 16 of the 250-m (273-yd) raster cells of the FIA state-wide maps. The advantage of combining FIA plots and occupancy plots is that the FIA data can be used to determine which, if any, habitat variables sampled by FIA are associated with owl occupancy rates. This would allow for estimation of trends in those variables from the full FIA database and from repeated samples over time.

Statistical Model

The proportion of occupied plots (occupancy rate) in year i is taken as $O_i = \mu_o + \delta_i$, where δ_i is distributed with mean zero and variance σ^2 , and μ_o is the mean of occupancy across years. The

variance σ^2 is the temporal variation in the occupancy rate (i.e., the year-to-year variation in the proportion of sites occupied).

Because not all sites can be surveyed each time an estimate of occupancy is desired, a sample of plots is selected to estimate occupancy. The estimate obtained is $\hat{O}_i = O_i + \varepsilon_i$, where ε_i is distributed with mean zero and sampling variance $\text{Var}(\hat{O}_i | O_i)$. In actuality, the occupancy rate will be estimated through a stratified simple random sample without replacement.

Sampling Plan to Estimate O_i

Occupancy will be estimated by sampling occupancy sampling units (plots), consisting of square 1-km² areas. A plot size of 1 km² was selected to keep sampling units small and for operational simplicity. Small sampling units are desirable in this monitoring scheme because the response variable is basically owl presence-absence, and so it varies only from zero to one. As the number of owls present in a sample block increases above one, the occupancy index becomes less sensitive as an index of actual population change (i.e., as long as one owl remains, one or more birds could disappear with no change detected). Thus, it is desirable to minimize the probability that a sample unit overlays >1 owl territory. In addition, spacing constraints should be applied so that sampled blocks are separated by >4 km (2.5 mi), to minimize the probability of detecting the same owl(s) on >1 sampled unit. For example, mean nearest-neighbor distances between territorial owls in two study areas in Arizona (2.4 km [1.4 mi], $n = 42$ pairs, May and Gutiérrez 2002) and New Mexico (2.1 km [1.3 mi], $n = 31$ pairs, Peery et al. 1999), suggested that a separation of 4 km (2.4 mi) is appropriate. Both of these constraints (size and spacing) should help ensure that occupancy rate actually tracks abundance (i.e., no sampled unit should contain large numbers of owls and no owls should be sampled on >1 unit). We envision drawing a random sample of plots and sampling these same plots each year to minimize the variation between years. Drawing a new sample of plots each year has some advantages (see below) but would increase year-to-year variation over our proposed design.

Each of the Mexican spotted owl Ecological Management Units (EMUs) to be included in monitoring must be partitioned into occupancy sampling units consisting of existing FIA Phase 2 plots. This partitioning must be done before a sample is drawn so that a random sample can be drawn from the entire population of occupancy sampling units. Habitat characteristics of all sampling units must be known to estimate and implement a ratio estimator based on the estimated probability of occupancy for each potential plot (Cochran 1977, Bowden et al. 2003) and to estimate occupancy rate for all the plots in the sampling frame.

The sampling scheme will be a stratified simple random sample without replacement, with stratification consisting of at least the EMUs. Additional stratification should be based at least on elevation, as was done for the previous quadrat sampling scheme (Ganey et al. 2004), on topographic indices (see Bowden et al. 2003), and/or on FIA habitat maps. We expect that one stratum in each EMU will consist of non-habitat for owls, defined as low elevation, unforested areas lacking canyons or other topographic relief. Delineation of non-habitat will be based on validated owl habitat models and through Phase 1 FIA data and Phase 2 FIA state-wide maps. One important aspect of classifying owl habitat is that non-forested areas must be included in

some locales, particularly owl habitat that occurs in non-forested canyons. Stratification variables such as forest type also should be used where available, and clearly the FIA Phase 1 and Phase 2 data can be used to provide stratification information. Likely, three forest types should be defined within each of the five EMUs: mixed conifer, ponderosa pine-Gambel oak, and Madrean pine-oak. In addition, some plots should be placed in a canyon stratum in each EMU. The canyon stratum should be defined based on topographic roughness and lack of forested habitat. Thus, we envision up to five strata in each of the five EMUs, for a potential total of 25 strata.

Stratification serves two purposes here. First, and most importantly, stratification distributes the sample across the sampling frame (and thus provides an argument for stratifying by EMU). With a simple random sample, there is a risk that all or most of the sampled plots are in one localized area. As a result, the sample is not considered representative of the sampling frame (even though such a sample has the same probability of being selected as a sample where the plots are more evenly distributed). Second, stratification provides improved estimates because proper stratification reduces the variability among plots, and thus results in more precise estimates. There is a need to make inferences from individual stratum estimates for the four core EMUs because each of these units must demonstrate a stable or increasing occupancy rate (see Part III.5 of the Recovery Plan). When inferences are stratum-specific, then each stratum must be considered a separate sampling frame. In the monitoring scheme we describe, the stratum-specific estimates are viewed as essential information, and it is thus necessary to obtain precise estimates of occupancy for each stratum. As we describe below, data from all the plots where owls are detected, regardless of which stratum a plot occupies, will be used to generate models of owl detection probabilities. Therefore, the effect of combining data across strata will improve the precision of the estimates across strata, but it will also result in a sampling covariance across strata that must be handled with the methods presented by Bowden et al. (2003).

Estimation of occupancy for each sampling unit will be made from two or more visits, because detection rate can be estimated only when plots are visited >1 time. Based on at least two visits, estimates of the detection rate of owls on an occupancy sampling unit and occupancy rate for the sample can be estimated using the maximum likelihood approach of MacKenzie et al. (2002, 2003). Parameters estimated are the occupancy probability for the sampling unit (ψ) and probability of detection given owls are present (p) for the sample. To determine the proportion of false negative plots (i.e., proportion of plots that are occupied but on which owls are not detected), the modeling approach requires at least two visits to a sample of plots to be able to estimate p and then ψ .

Several examples will now be given to explain this estimator. First, assume one or more owls are detected on occupancy sampling unit j on each of the $t = 2$ visits, and assume that the probability of detection is not occasion-specific. The probability of this series of events is $\psi_j p_j p_j$. If owls are detected only on the first visit, then the probability is $\psi_j p_j (1 - p_j)$. If they are only detected on the last visit, then the probability is $\psi_j (1 - p_j) p_j$. If owls are never detected, then the probability is $\psi_j (1 - p_j)(1 - p_j) + \psi_j$. These four probabilities sum to one because they are the only possible observations. Thus, these probabilities can be modeled in a maximum likelihood

estimation (MLE) framework (using numerical optimization of the log likelihood) based on observed histories of owl detections on sampled units.

We expect that habitat information provided by FIA Phase 2 state-wide maps will provide useful predictors of owl occupancy rates. We envision two separate analyses of the occupancy data that incorporate habitat information. The first analysis would link FIA variables to occupancy rates, specifically the key variables listed above. Models that incorporate multiple covariates and possibly their interactions should be developed to identify habitat variables important for further analysis. That is, the trends in the identified variables will be examined with the FIA data base. These habitat variables will be constructed from the means or sums of variables provided by the 16 250-m (273-yd) cells of the FIA state-wide maps that underlie each of the 1-km² (0.36-mi²) occupancy plots.

The FIA covariates may not prove useful as predictors of owl occupancy. If so, this should not necessarily be interpreted as evidence that owl occupancy is not related to habitat conditions. Several alternative explanations may better explain this outcome. For example, the variables included in the analysis may not relate directly to owls, or spatial scale issues may mask any existing relationship.

The second analysis will be to identify functions of the FIA variables that can be used in a ratio estimator sampling model (Cochran 1977). Typically, ratio estimators use a single variable to improve the precision of the desired estimate. For example, Ganey et al. (2004) found that the triangulated irregular network (TIN) ratio was an important variable for use as a ratio estimator, and the TIN ratio reduced the variance of the estimate by nearly a factor of four. We hope to identify ratio covariates that will be useful in improving precision of the occupancy estimates, although these models will likely need to be stratum-specific to accommodate the differences in the strata identified.

If plot-specific covariates from Phase 2 FIA state-wide maps do not improve the estimation of occupancy rate within a strata, then the estimate of ψ obtained without covariates for the plots would be an appropriate estimate of O , or model averaging might be used to average $\hat{\psi}$ from multiple models but still providing an estimate of O . However, plot-specific covariates would be expected to improve the estimate of occupancy probability for each plot, and also of p (see Bowden et al. 2003). The occupancy estimator has been implemented in Program MARK (White and Burnham 1999) so that the use of individual covariates, AICc model selection, and variance components capabilities already available in this software package (White et al. 2001) can be used with this model. In addition, Bayesian estimation methods were added to MARK in 2004, allowing estimation of process variances through the use of hyper-distributions. Plot-specific covariates can be used to build a model from the data on the sampled plots to estimate the probability of occupancy of a plot. The resulting model on a logit scale then could be used in a ratio (or regression) estimator to estimate the number of occupied plots for the sampling frame as we describe above. Thus the occupancy rate (O_i) for a stratum for year i would be estimated based on the covariate values for each of the plots in the strata. If the model (and associated covariates) predicting the probability of occupancy of a sampling unit is poor, in the sense that the model does not improve the predictions of the probability of occupancy, then the occupancy

estimate from the sample is still a valid estimator of the occupancy rate of the stratum. However, if the model is a good predictor, then using the covariate information from each potential sampling unit in the stratum will improve the estimate for the stratum. That is, the additional information available for each unsampled plot in the stratum is used, resulting in a less biased and more precise stratum-level estimate.

Multiple strata might be pooled in a MARK analysis to obtain better estimates of detection probabilities and the functional relationship between a covariate and probability of occupancy, but estimates of occupancy rate would still be specific to each stratum. However, if multiple strata are pooled to estimate occupancy, then a sampling covariance is induced between the strata estimates, necessitating the use of a ratio estimator incorporating this sampling covariance (Bowden et al. 2003).

Another possibility that could be explored is to use cluster sampling to sample plots (but see above concern about spacing of sample units). Biologists conducting the surveys could decrease travel time between plots, increasing the number of plots that could be surveyed on one occasion. The difficulty with cluster sampling is how to handle the lack of independence of plots within the same cluster and the effect of this lack of independence on estimation of ψ . Further, cluster sampling improves efficiency of the sampling design when the variance among cluster totals is small and, conversely, variance within the cluster is large (Scheaffer et al. 1986). Likely exactly the opposite is the case for clusters of 1-km² (0.36-mi²) plots because of a high spatial autocorrelation between plots. Clusters would have to be quite large to make cluster sampling more efficient than random sampling. However, cluster sampling should still be an option that is considered to decrease travel time.

One fundamental part of the field methodology is yet to be resolved fully. We lean toward basing occupancy estimates on whether or not a bird was detected from a call point in a sample plot, for operational simplicity. That is, if a surveyor calls from within the plot and hears a response, the plot is considered occupied, regardless of whether the owl was physically on the plot. The alternative approach is to require the surveyor to verify that the owl responding is physically on the plot being sampled, which is a time-intensive (and often dangerous) nighttime activity. However, not requiring the owl to physically exist on the plot at the time of the survey will cause detection probabilities to be lower because of the heterogeneity caused by owl responses from varying distances off the plot. Peripheral birds may be detected on some occasions and not others. In contrast, birds residing on the plot would generally be detected with higher probability. As a result, there is a tradeoff here – if keeping detection probabilities high is a priority, only plots where owls are detected on the plot should be considered occupied. However, because of the objectivity of monitoring when the detections are not limited to just the plot being sampled, we tend to prefer this simpler approach.

Based on data from the pilot study on population monitoring (Ganey et al. 2004), detection probabilities for two occasions were sufficiently high when six to seven call points were visited within the 1-km² plot (Figure F.1 in Appendix F). The population monitoring pilot study was not intended to provide call points well-spaced to cover 1-km² plots, however, so this figure may present a worst-case scenario. It is suspected that five call points would be adequate for most UTM blocks. Further, because a site is classified as occupied if an owl is detected, the number of

call points that a surveyor must actually visit will depend on when an owl is first detected (i.e., if an owl is detected from the first call point, the remaining call points need not be visited).

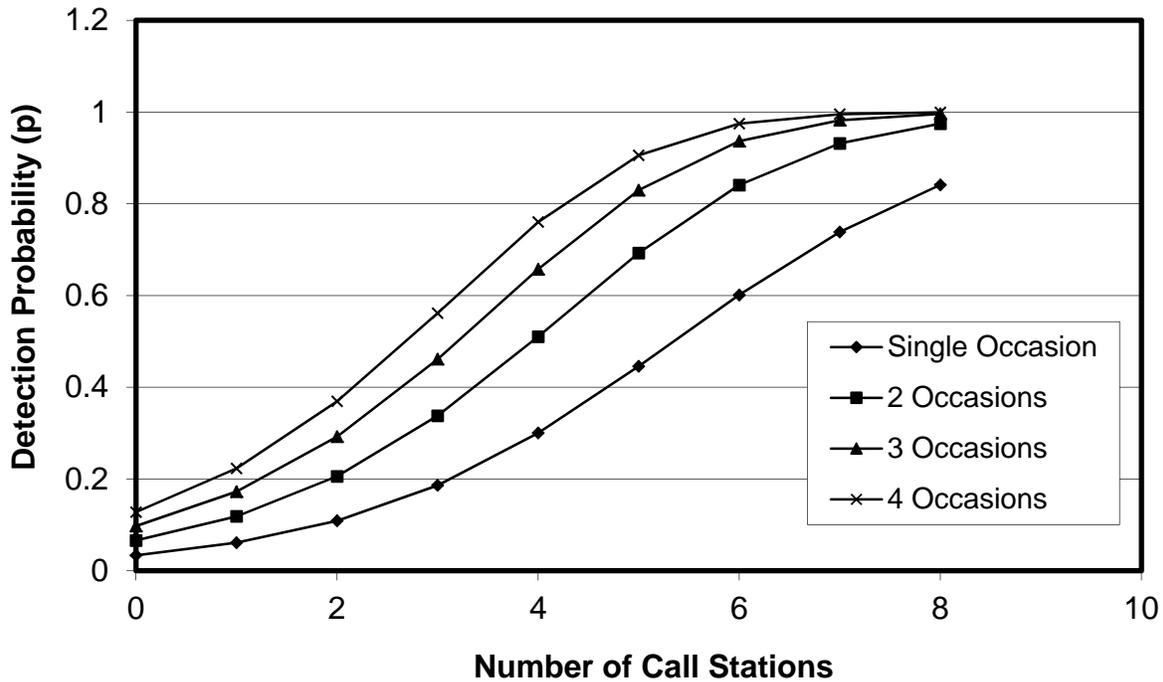


Figure F.1 Probability of detection for a 1-km² (0.36-mi²) plot for the number of points on the plot from which owls are called and the number of occasions on which the plot is visited. For example, a plot with two visits and six points called would have a detection probability of >0.8 that an owl was detected on at least one of the visits. Note, however, that even though detection probabilities are provided for a single visit, a sample of plots must be visited twice to be able to estimate the probability of detection (p) and hence the probability of occupancy, ψ .

The results in Figure F.1 above also demonstrate that increasing the number of visits to the plot from two to three or more provides only small increases in probability of detection. Thus, we suggest visiting more plots two times rather than fewer plots three or more times.

Statistical Estimation of Trend in Occupancy

The sequence of years for which occupancy rates are measured can be viewed as either a sample of all years, or as a fixed interval in time about which we desire to make inferences. Different statistical models are appropriate for these different sets of assumptions. A random effects model assumes that the sequence of years is a representative sample from a sampling frame of years. As a result, inferences are being made to the entire sampling frame. In contrast, the fixed effects model is only making inferences to the sequence of years measured.

Random Effects Model. Changes in occupancy across years are assumed to be a stochastic process, as we describe above. When the mean of the process (μ_o) is assumed to be constant in

the stochastic model described above, changes in occupancy are strictly random. However, trends in occupancy may still be present, although the process generating these trends is purely random. That is, by chance alone, a set of realized temporal observations may show a trend, even though the mean of the underlying process is not changing. The hypothesis examined with a random effects model is that a trend in the occupancy process is taking place (i.e., that there is a trend in μ_o through time). The random effects estimator is supposed to detect a change only in the process. Therefore, potentially important trends in occupancy may be missed with the random effects estimator because these trends are only from variation due to δ_i , not from changes in μ_o . In addition, to detect trends in μ_o , a long time span of data is required. That is, the random effects model will not have much power to detect trends in relatively short spans (i.e., ≤ 10 years).

An important assumption of the random effects model is that the sample of \hat{O}_i across years is a random sample from all possible years to which inferences are being made. In reality, this assumption is unobtainable because the years sampled are not randomly selected from a population of years.

Fixed Effects Model. The fixed effects model evaluates the trend in the realized sequence of occupancy estimates. That is, the process generating the occupancy rates may not be changing (i.e., μ_o is constant across time), but by chance alone, a realized sequence may show a trend. The fixed effects model will detect this trend, whereas the random effects model we describe above should not detect such “random” trends. Realistically, the statistical procedure used to detect such random trends is desired because the interest is in providing management action as soon as possible given a downward trend in occupancy rates. In such a situation, management actions will not have an impact because the process has not changed. However, this is the price paid to achieve a more sensitive monitoring system.

Therefore, we suggest that the sequence of occupancy estimates, \hat{O}_i , be analyzed with a fixed effects model. It is recognizing that the years sampled were not drawn at random from a population of years and that the interest is in detecting downward trends in occupancy, even if the underlying process has not changed, because management actions require some lead time to have an impact on the Mexican spotted owl population.

Expected Precision of Occupancy Estimates

We conducted simulations with Program MARK to determine the precision of the estimate of occupancy without individual covariates. We simulated a factorial design of $N = 200, 400, 800,$ and $1,600$ occupancy sampling units, $p = 0.6, 0.7, 0.8,$ and $\psi = 0.2$. For each scenario, we conducted 1,000 simulations to estimate the expected precision. We based the detection probabilities of $p = 0.6, 0.7,$ and 0.8 on the probability of detection from the quadrat sample (Ganey et al. 2004), where detection of an *individual* owl was ~ 0.5 in roadless areas, and ~ 0.9 in roaded areas. We also based the occupancy rate of 0.2 on results of the pilot study (Ganey et al. 2004), where $>50\%$ of the high elevation quadrats were occupied. However, because the

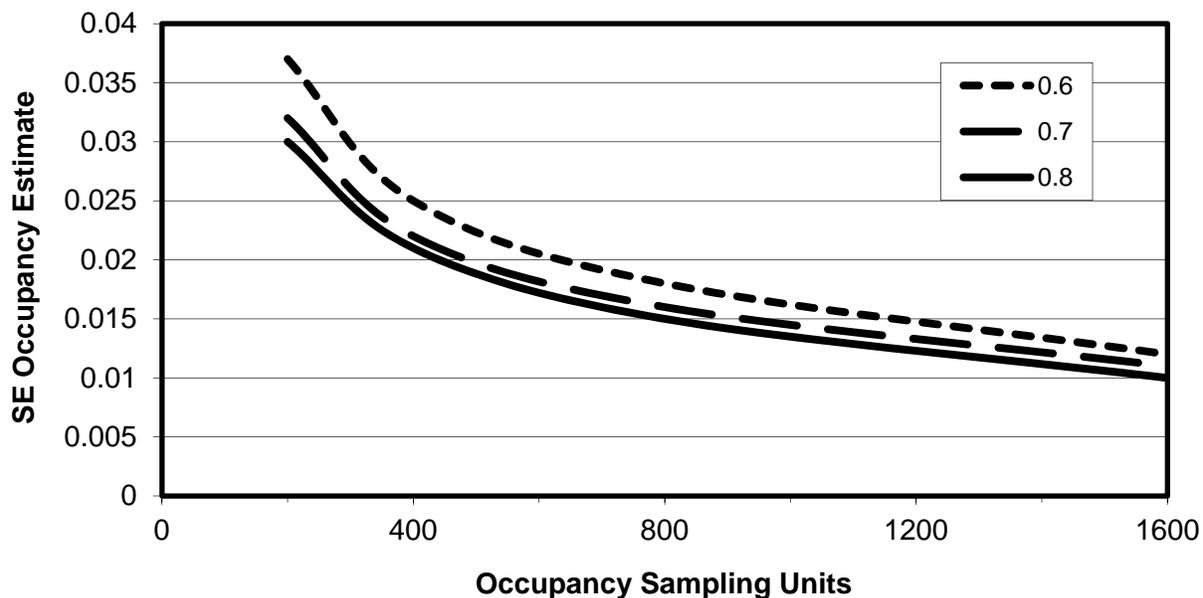


Figure F.2. Standard error of the estimate of site occupancy rate for three levels of the detection probability, p , and two visits per site, as a function of the number of occupancy sites sampled.

quadrats were much larger than the occupancy sampling units, the expected occupancy rate of the occupancy sampling units will be considerably less, so we chose 0.2 as a reasonable value. Simulation results for the standard error of $\hat{\psi}$ are shown in Figure F.2 above for three values of p and a range of sample sizes.

These results (Figure F.2) suggest that a large number of occupancy sampling units must be measured in each stratum (or within an EMU) to obtain reasonable precision for \hat{O} . For example, sampling 1,600 occupancy sampling units in one stratum using a stratified random sample design would result in a standard error of 0.011 for $p = 0.7$. If three strata in an EMU with this same standard error were combined, the overall estimate would have a standard error of $0.011/\sqrt{3} = 0.00635$, or approximately a $\pm 6\%$ confidence interval. With this sampling precision, two consecutive year's estimates with a 10% decline between years would likely be considered statistically different. However, if only 200 occupancy sampling units were sampled in one stratum, giving a standard error of 0.032, a $\pm 18\%$ confidence interval would result. This level of precision would be adequate to detect a 25% decline between consecutive years. What this result suggests is that any occupancy monitoring scheme implemented will only be able to detect changes over a large geographic area. That is, multiple strata must be combined in order to obtain precise estimates of occupancy that will be useful in detecting changes.

Power of Fixed Effects Analysis of Occupancy Estimates

We conducted simulations using Program MARK and SAS to estimate the power of occupancy monitoring to detect trends in percent occupancy. We simulated all combinations of the following models: a linear trend in $\psi = 0.00, -0.01, -0.02, \text{ and } -0.03$ each year; ψ values in year zero of 0.10, 0.15, and 0.20; process standard deviation of ψ of 0, 0.05, 0.10, 0.15, and 0.20; $p = 0.6, 0.7, 0.8, \text{ and } 0.9$; years of sampling 10, 15, ..., 30; and 200, 400, 800, and 1600 sampling units. Note that annual declines of 1, 2, and 3% result in declines of 10, 18, and 26% over 10 years, respectively.

For 10 years of sampling, power of >90% was generally found for 1,600 sampling units and for 800 sampling units with a process standard deviation of zero and a trend in ψ of -0.03. Thus, this power analysis confirms that large sample sizes will be required to detect changes in occupancy. However, this power analysis does not incorporate plot-specific covariates that might greatly improve the precision of the annual occupancy estimates. For example, plot-specific covariates reduced the variance by half in the pilot population monitoring survey (Bowden et al. 2003, Ganey et al. 2004). Hence, the sample sizes we determine here to provide adequate power may be more than needed to achieve the same power with a ratio estimator. Without a pilot study to determine these relationships (i.e., the degree of correlation between occupancy and plot-specific covariates) and to provide some idea of the temporal process variation in site occupancy rate, inadequate information is available to estimate the necessary sample sizes and/or power of a site occupancy monitoring design at this time.

Relationship Between Occupancy Estimates and Population Abundance

In theory and practice, there is some relationship between occupancy rate and population abundance. Further, Royle and Nichols (2003) describe an approach for estimating occupancy rate or the proportion of an area occupied when heterogeneity in detection probability exists as a result of variation in abundance of the organism under study. Variation in abundance induces variation in detection probability so that heterogeneity in abundance can be modeled as heterogeneity in detection probability. Their method allows estimation of abundance from repeated observations of the presence or absence of animals without having to uniquely mark individuals in the population. Depending on the amount of heterogeneity in detection probabilities observed when the proposed sampling scheme is implemented, the method of Royle and Nichols (2003) may be useful in quantifying population abundance.

2. POTENTIAL EXPERIMENTS

Many habitat variables important to Mexican spotted owls cannot be monitored by remote sensing. Further, it is important to ensure that adequate habitat is provided for key prey as well. Thus, we propose some potential experiments to relate habitat conditions to owl population dynamics where key habitat characteristics would be measured on the ground. On-the-ground monitoring of relevant habitat characteristics would quantify their change at a local (i.e., within plot) scale and relate them to owl population dynamics.

Monitoring of owl population size based on randomly selected quadrats (as proposed in FWS 1995) provides the opportunity to conduct experiments to extend our knowledge of the impact of habitat manipulation on Mexican spotted owl population dynamics. These experiments are proposed to produce credible, defensible, and reliable results (*sensu* Murphy and Noon 1991). Quadrats within the population monitoring design would serve as experimental units for examining the effects of future management such as fires, grazing, timber harvest, and recreation.

Given that a treatment is identified prior to its occurrence, vegetation measurements can take place on the site of the expected treatment and on a second, control quadrat that is selected based on its similarity to the expected treatment quadrat. This experimental design is not a true experiment because the treatment is not randomly allocated to one of the pair of quadrats. However, this quasi-experiment is still more powerful in developing cause-and-effect relationships between habitat manipulations and owl population dynamics than the more common correlative designs used by past researchers. Further, the capability to replicate the treatment exists because of the extensive number of quadrats that would be required for measuring changes in population size.

Areas where planned treatments result in some form of habitat alteration provide excellent opportunities for quasi-experiments. Vegetation measures should be taken immediately before and after the habitat-modifying event and thereafter at 5-year intervals. Vegetation measurements that seem especially important to examine are tree size-class distribution, log size-class distribution, canopy cover, and shrub cover. Results from these experiments, coupled with results of population monitoring, provide the basis for a predictive model of spotted owl habitat quality (assuming that owl occupancy reflects habitat quality).

Unfortunately, for logistic reasons we describe above, this revision of the Recovery Plan shifts from direct monitoring of population size to monitoring site occupancy. This modification in monitoring approach reduces our ability to detect impacts of management on owl populations because occupancy is not as sensitive a measure of the response of the owl population to manipulations as is the measurement of population change.

3. ALTERNATIVE DESIGNS FOR OCCUPANCY MONITORING

In developing the monitoring scheme proposed here, we considered many alternative schemes. Some of these are discussed here, simply to illustrate some of the alternatives considered and why they were rejected.

Drawing a New Sample of Plots Each Year

Instead of the proposed scheme of drawing an initial sample of plots from the sampling frame and monitoring these same plots through time, an alternative approach would be to draw a completely new random sample of plots each year. For repeated sampling of a set of plots to be legitimate, normal activities that occur in spotted owl habitat should continue during the monitoring program, provided these activities meet the requirements of Section 7(a)(2) of the Act by not likely jeopardizing the continued existence of the Mexican spotted owl. Because this

Recovery Plan requires that Protected Activity Centers (PACs) be placed around locations occupied by owls, management activities may be modified if an occupied site is found during the occupancy sampling. Thus, the monitoring process affects the management of occupied sites, an undesirable situation. The main advantage of a new sample each year is that it guards against the potential for land managers to manage areas within the plots differently than the remainder of the landscape. Such differences in management will likely occur because of the establishment of PACs. The price of this protection is relatively great, as illustrated by these three points: (1) the logistics of conducting the surveys each year would increase because of the new plots; (2) quasi-experiments to detect the relationship between habitat manipulations and owl occupancy rates would not be possible; and (3) higher sampling intensities would be required because this design is less efficient (i.e., less precise) for estimating change. Our proposed design is to draw an initial sample of plots and monitor those same plots each year. Because the plots are small and randomly distributed, management activities probably cannot avoid them, even though PACs are established. As a result, a fixed sample of plots likely is appropriate, so we do not deem it necessary to draw a new sample of plots each year.

Conducting Surveys Less Often Than Yearly

Instead of surveying plots each year, effort and cost could be saved by conducting the surveys at longer intervals, such as every five years. An advantage of this approach is that costs will be lowered, and more precise estimates of population size could possibly be obtained by pooling money to conduct a few very good surveys instead of more frequent surveys with lower effort per survey. The main disadvantage of this approach is that funding would not be allocated each year, which would likely make procuring funding for intense efforts every five years difficult. Finally, the ability to detect relationships between habitat manipulations and occupancy would be greatly decreased because this approach is more sensitive to variability introduced by the years chosen for sampling. That is, less information is provided on temporal variation when samples are only taken every five years. Therefore, we recommend sampling each year as the most effective approach to occupancy monitoring.

PACs as Sampling Units for Monitoring Occupancy

The PACs would seem to be a natural sampling unit to monitor occupancy. The difficulty with this scenario is that PACs are not a representative sample of available owl habitat. The PACs can only be established by the presence of an owl. As a result, the occupancy rate of PACs can only decline, since each PAC is initially occupied. Additionally, PAC boundaries may change as neighboring sites are found to be occupied, creating a non-static sampling frame. Therefore, we recommend that the sampling frame consist of 1-km² plots rather than PACs.

One important use of PACs would be to improve stratification of the proposed sampling plan, since the presence of a PAC suggests the area is likely occupied, and a large number of PACs would suggest that much of an area is occupied.

4. HABITAT MONITORING

The primary objective of habitat monitoring is to validate results of occupancy monitoring. For example, if occupancy monitoring indicates stable (or increasing) occupancy rates, habitat monitoring will provide a general measure of whether there will be sufficient nest and roost habitat for occupancy rates to remain stable. We advocate no specific method for habitat monitoring and leave it up to management agencies to determine the best method(s) to use. One possible approach is to use data from Forest Inventory and Analysis (FIA). We provide a brief overview of that program below.

Introduction to the Forest Inventory and Analysis (FIA) Program

Habitat monitoring depends on remote-sensing and stand-level vegetation data of habitat across the owl's range, using vegetation measures from the FIA program. The FIA has been in continuous operation since 1930 with a mission to "...make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the U.S..."

The core design of FIA consists of three phases (<http://fia.fs.fed.us/about.htm>). Phase 1 is a remote sensing phase aimed at classifying the land into forest and non-forest and taking spatial measurements such as fragmentation, urbanization, and distance variables. This phase has historically been conducted using aerial photography, but it is changing to a system based on satellite imagery. Data from this phase will be useful for monitoring macrohabitat changes in the range of the Mexican spotted owl.

Phase 2 consists of field samples distributed across the landscape, based on a permanent grid system with an FIA plot approximately every 2430 ha (6,000 ac). Field plots are located systematically on a 5-km (3.1-mi) grid regardless of whether they are forest or non-forest, and regardless of land ownership. Permanent plots are installed on all land ownerships (after permission is granted by the landowner), but the actual locations are kept secret to prevent tampering with the site and to prevent the knowledge of plot presence to influence decisions. Plot locations that are in forested vegetation are visited by field crews who collect a variety of forest ecosystem data. Data are collected at the forested plots regardless of the landowner's intended use or specific management actions. Non-forest locations are also visited as necessary to quantify rates of land use change. The following data are collected at FIA plots:

- i.* The general land use that was projected in Phase 1 is verified;
- ii.* On forested plots, general stand characteristics are collected, such as forest type, stand age, and evidence of disturbance;
- iii.* Individual tree measures such as diameter, height, damage, cull, and grade are recorded;
- iv.* Tree regeneration is documented.

The FIA Phase 3 program is based on a subset of the Phase 2 plots (located on a 22-km [13.7-mi] grid, sampling approximately 0.0405 ha every 38,881 ha [1 ac for every 96,000 ac]), from which an extended suite of ecological data (see list below) are collected. These measures relate to forest ecosystem function, condition, and health. Due to the seasonality associated with some of these measurements, the Phase 3 data are generally collected during a three-month window (Jun, Jul,

and Aug). The measurements on the Phase 3 subset of plots can be grouped into the following categories:

- i.* Crown Conditions – generally, poor crown conditions are symptoms of trees under stress, and trees with good crown conditions are vigorous.
- ii.* Soil Erosion Potential – estimates of soil erosion potential help identify areas that may contribute to water quality degradation.
- iii.* Soil Chemical Analyses – collection and analysis of soil samples include estimates of site fertility and in some cases potential toxicity relating to acidic soils that relate to productivity.
- iv.* Lichen Communities – the presence or absence of certain lichen species is indicative of air quality and climate changes.
- v.* Ozone Bioindicator Plants – these plants have known sensitivities to ground-level ozone, although they are not necessarily collected on the Phase 3 plots (this effort can occur in the general plot area).
- vi.* Vegetation Structure – the composition of vegetation (species and growth forms), abundance, and spatial arrangement in the forest. Also the presence of exotic and introduced plant species can be extracted from the collected data.
- vii.* Down Woody Debris – this measurement is useful in determining fire fuel potential, and this information with the vegetation structure data can be used in wildlife habitat models.

Though the FIA program has been in existence since the 1930s, the data collection methods have been modified periodically, and the grid system was recently revamped to improve the statistical validity of the sampling. Currently, 10% of the plots in the western United States are scheduled to be sampled every year.

Regardless of whether a plot is Phase 2 or Phase 3, after two or more visits have occurred at a single plot location, it is possible to analyze the data to derive estimates of trends in desired future conditions (DFCs) (see Table C.1 in Appendix C or nest-roost habitat, Table C.2 in Appendix C).

Habitat Monitoring Methods

As mentioned above, an essential feature of the FIA program is the confidentiality of the data. Because data are collected from all land ownerships and because the data would be biased if landowners or others knew the location of the plots and treated them differently than areas outside the plots, these locations and much of the data from them are not available directly to agencies. Instead, the agencies must craft specific questions for the FIA program, and then FIA responds with answers to the data queries.

We believe existing FIA sampling schemes for all three phases provide adequate data to meet the proposed delisting criteria. Owl-relevant FIA variables should be used to monitor trends in owl habitat, providing a range-wide habitat sampling scheme. Phase 1 data provide a comprehensive coverage of changes amount and type of forest habitat. Phase 2 provides information on changes in forest-stand structure. Phase 3 provides information on additional habitat variables important to owls, such as down woody debris

For purposes of Mexican spotted owl recovery planning, the FIA plots would be aggregated into strata that would be based on (1) EMU, (2) elevation, and (3) forest type. Stratification is important because it distributes samples throughout an EMU and improves precision of the habitat estimates.

5. RELATING HABITAT AND OWL OCCUPANCY MONITORING

For purposes of understanding progress towards recovery of the Mexican spotted owl, monitoring should document the changes in the owl population and its habitat when, in fact, such changes are occurring. Thus, an effective monitoring program requires measuring changes in both habitat quantity and owl occurrence across the landscape. To link the monitoring of owl occupancy in forest habitat with the habitat conditions, analysis of occupancy monitoring data should incorporate FIA data.

Linking occupancy monitoring to FIA monitoring is recommended for three reasons. First, the FIA inventory (both Phase 2 and Phase 3) provides microhabitat measurements that can be used to improve the occupancy monitoring scheme, providing predictor variables that will improve the estimation of the probability of occupancy and detection for the plots sampled.

Second, important microhabitat variables that are correlated with owl occupancy will be determined that can then be used to evaluate temporal trends in microhabitat. A strength of this approach is that FIA data collected prior to occupancy monitoring can also be analyzed to determine long-term trends in these variables. In summary, linking FIA data with the occupancy monitoring sampling plots will provide: (1) the opportunity to identify microhabitat variables that relate to owl occupancy and detection rates, and (2) the ability to evaluate trends in these microhabitat variables through time.

Third, FIA is a well-funded, ongoing effort. Thus, it provides a unique opportunity to collect data potentially useful in monitoring trend in owl habitat, without requiring a separate and prohibitively expensive sampling effort.

6. CONCLUSIONS

The technology and expertise are available to monitor trends in Mexican spotted owl habitat and population size. Clearly, the objectives and design of the monitoring program must be defined explicitly, and they must be attainable. To implement the process, knowledgeable, dedicated people must be assigned the task. Adequate training and constant feedback mechanisms are critical aspects to a successful monitoring program, as tenable conclusions can be based only on reliable data.

APPENDIX G

LAWS, REGULATIONS, AND AUTHORITIES FOR RECOVERY PLAN IMPLEMENTATION

This Mexican Spotted Owl Recovery Plan, First Revision is based or predicated upon laws that designate specific legal authority and responsibility to government agencies for managing public resources, including wildlife and wildlife habitat. The following summarizes relevant laws and authorities applicable to implementation of this Recovery Plan.

1. ENDANGERED SPECIES ACT

Section 2(c)(2) of the ESA expresses the policy of Congress that “...all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of [the] Act.” Section 7(a)(1) of the ESA requires Federal agencies to “...utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of endangered species and threatened species....” Thus, Congress clearly intended conservation of endangered and threatened species to be considered in implementation of Federal programs and actions. In addition, other Federal laws and regulations require consideration of endangered and threatened species in program implementation, including the National Forest Management Act (NFMA) and the National Environmental Policy Act (NEPA).

Implementation of the ESA is the responsibility of the Secretary of the Interior for listed terrestrial species. The Secretary generally delegates implementation authority to the FWS. The following sections of the ESA are relevant to implementation of species recovery efforts:

A. Section 4

Section 4 includes the listing and recovery provisions of the ESA. Section 4(b) of the ESA provides for designation of critical habitat for endangered and threatened species. Regulations governing listing and critical habitat designation are codified at 50 CFR 424. Protection of critical habitat is administered under section 7 of the ESA (discussed below). Critical habitat is defined under section 3(5)(A) of the ESA as:

“(i) the specific areas within the geographical area occupied by the species...on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
“(ii) specific areas outside the geographical area occupied by the species...upon a determination by the Secretary that such areas are essential for the conservation of the species.”

Section 4(d) of the ESA provides for promulgation of special rules for threatened species only. This allows the Secretary to issue regulations as deemed necessary and advisable for the conservation of such species. Special rules can be useful in enacting regulatory provisions

uniquely applicable to the species at hand and can be promulgated to avoid unnecessary regulatory burden.

B. Section 5

Section 5 directs the Secretary to utilize funds and authorities of other laws in acquisition of lands, as deemed appropriate for conservation of endangered and threatened species.

C. Section 6

This section authorizes cooperation with the States in conservation of threatened and endangered species. Among its provisions is the authority to enter into management agreements and cooperative agreements and to allocate funds to the States that have entered into such agreements.

D. Section 7

Section 7 and its implementing regulations at 50 CFR 402 govern cooperation between Federal agencies. Federal agencies must, in consultation with and with the assistance of the Secretary, ensure that any action they fund, authorize, or carry out is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of a listed species' designated critical habitat. Regulations at 50 CFR 402 provide the following definitions:

“‘Jeopardize the continued existence of’ means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.”

“‘Destruction or adverse modification’ means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species.” This regulatory definition has been legally challenged and is no longer used by FWS; no new regulatory definition has been promulgated to date.

Section 7 requires action agencies to assess the effects of proposed actions on listed species and their critical habitat. If, as a result of that assessment, the agency determines that an action may affect a listed species or its critical habitat, the agency must enter into consultation with FWS. That consultation may result in a biological opinion from FWS, in which a determination is made as to whether jeopardy to the species and/or destruction or adverse modification of its critical habitat are likely to result from the agency action.

If a biological opinion concludes that jeopardy to the species and/or adverse modification of its critical habitat are not likely to result from a proposed action, the action may proceed. The FWS may provide conservation recommendations to the agency on ways to minimize or avoid potential adverse effects on the listed species and/or critical habitat. Implementation of the conservation recommendations are at the action agencies' discretion. In cases where the action is likely to result in the incidental taking of a species, FWS may provide reasonable and prudent

measures to minimize the amount or extent of the take. The terms and conditions that accompany and implement any reasonable and prudent measures are nondiscretionary and must be implemented. However, reasonable and prudent measures and their implementing terms and conditions cannot alter the basic design, location, scope, duration, or timing of the action; and they may involve only minor changes.

If a biological opinion determines that jeopardy and/or adverse modification is likely to result from the proposed action, the FWS and the action agency develop reasonable and prudent alternatives, if any, to the proposed action. Reasonable and prudent alternatives refer to alternative actions that are consistent with the intended purpose of the proposed action, that can be implemented within an action agency's legal authority, that are economically and technologically feasible, and that FWS believes will not result in jeopardy to the listed species or destruction or adverse modification of critical habitat. If no reasonable or prudent alternatives can be identified, the action agency may apply to the Endangered Species Committee for an exemption to prohibition of jeopardy and/or destruction or adverse modification of critical habitat.

E. Section 8

Section 8 authorizes international cooperation in conservation and endangered and threatened species. Included under this section is the authority to provide financial assistance to foreign countries to assist in their conservation efforts.

F. Section 9

Section 9 covers prohibited acts in regard to listed species. Of relevance to the Mexican spotted owl is the prohibition of taking individuals. "Taking" is defined as "...to harass, harm, pursue, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Permits for direct taking of threatened species may be issued for scientific purposes, to enhance propagation or survival, in cases of economic hardship, for zoological exhibition, or for educational purposes (50 CFR 17.32).

Taking of spotted owls is most likely to occur through "incidental take." "Incidental take" is defined as the taking that results from, but is not the purpose of, carrying out an otherwise lawful activity. Incidental taking of spotted owls may result from activities such as timber harvest, if that activity results in habitat loss to an extent that an individual spotted owl's normal behavior patterns are impaired. In cases where incidental taking will not result in jeopardy to a listed species, the FWS may issue an incidental take statement in a biological opinion on a proposed Federal action, thereby exempting the action agency from the take prohibition. Relief from taking prohibition for non-Federal activities is discussed under "Section 10" below.

G. Section 10

Section 10 authorizes the FWS to issue permits for takings otherwise prohibited under section 9. Permits for purposeful taking may be issued under 10(a)(1)(A) of the ESA for research purposes and to implement recovery actions. In addition, 10(a)(1)(B) of the ESA allows permits for

incidental takings that may result from an activity provided an applicant submits a conservation plan that specifies:

“(i) the impact which will likely result from such taking;

“(ii) what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps;

“(iii) what alternative actions to such taking the applicants considered and the reasons why such alternatives are not being utilized; and

“(iv) such other measures that the [FWS] may require as being necessary or appropriate for purposes of the plan.”

2. NATIONAL FOREST MANAGEMENT ACT

The NFMA governs Forest Service Management on National Forest Service lands. The first planning regulations (rule) articulating implementing language were provided in 1979 and then revised in 1982. In 1997, the Secretary of Agriculture convened a committee of scientists to provide recommendations on how to better implement NFMA. This led to a series of planning rule revisions (2000, 2002, 2005, 2008) that have yet to gain final approval. In 2009 the Forest Service issued a Notice of Intent to prepare an environmental impact statement for a new planning rule, starting a new planning-rule-revision effort. As an interim measure, the Department of Agriculture republished the 2000 rule as amended in the Federal Register in order to make it available to the public in the Code of Federal Regulations (36 CFR Part 219; Federal Register 2009). This interim rule is currently in effect. Below are relevant parts of the interim rule relevant to recovery planning.

Section 219.20 (Species Diversity) states:

“(a)(2)(ii) *Evaluations of species diversity.* Evaluations of species diversity must include, as appropriate, assessments of the risks to species viability and the identification of ecological conditions needed to maintain species viability over time based on the following:

“(A) The viability of each species listed under the Endangered Species Act as threatened, endangered, candidate, and proposed species must be assessed. Individual species assessments must be used for these species.

“(D) In analyzing viability, the extent of information available about species, their habitats, the dynamic nature of ecosystems, and the ecological conditions needed to support them must be identified. Species assessments may rely on general conservation principles and expert opinion. When detailed information on species habitat relationships, demographics, genetics, and risk factors is available, that information should be considered.”

Section 219.20 further provides guidance pertaining to forest plan decisions related to species diversity:

“(b)(2) *Species diversity*. (i) Plan decisions affecting species diversity must provide for ecological conditions that the responsible official determines provide a high likelihood that those conditions are capable of supporting over time the viability of native and desired non-native species well distributed throughout their ranges within the plan area, except as provided in paragraphs (b)(2)(ii) through (iv) of this section. Methods described in paragraph (a)(2)(ii) of this section may be used to make the determinations of ecological conditions needed to maintain viability. A species is well distributed when individuals can interact with each other in the portion of the species range that occurs within the plan area. When a plan area occupies the entire range of a species, these decisions must provide for ecological conditions capable of supporting viability of the species and its component populations throughout that range. When a plan area encompasses one or more naturally disjunct and self-sustaining populations of a species, these decisions must provide ecological conditions capable of supporting over time viability of each population. When a plan area encompasses only a part of a population, these decisions must provide ecological conditions capable of supporting viability of that population well distributed throughout its range within the plan area.

“(b)(3)(i) *Federally listed threatened and endangered species*. Plan decisions must provide for implementing actions in conservation agreements with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service that provide a basis for not needing to list a species. In some situations, conditions or events beyond the control or authority of the agency may limit the Forest Service’s ability to prevent the need for Federal listing. Plan decisions should reflect the unique opportunities that National Forest System lands provide to contribute to recovery of listed species.

“(b)(3)(ii) Plan decisions involving species listed under the Endangered Species Act must include, at the scale determined by the responsible official to be appropriate to the plan decision, reasonable and prudent measures and associated terms and conditions contained in final biological opinions issued under 50 CFR part 402. The plan decision documents must provide a rationale for adoption or rejection of discretionary conservation recommendations contained in final biological opinions.”

3. NATIONAL ENVIRONMENTAL POLICY ACT

The NEPA requires Federal agencies to prepare Environmental Impacts Statements (EIS) or Environmental Assessments (EA) for implementation of agency actions and issuance or modification of agency policies and guidance. Impacts of the proposed action or policy amendment on endangered and threatened species must be evaluated, including a range of alternatives. If a deciding official determines that no significant impact will result from an action or policy amendment, a “Finding of No Significant Impact” is issued. If an agency determines that a significant impact will result from the proposed action or policy amendment, an EIS must be prepared. It is released for public review and comment, after which an alternative is selected and a Record of Decision is signed by the deciding official.

4. MIGRATORY BIRD TREATY ACT (MBTA)

Prior to listing the Mexican spotted owl as threatened, the MBTA provided the only Federal protection for the subspecies other than that afforded by land-management agencies. Under the provisions of the MBTA, it is unlawful to pursue, hunt, take, capture, or kill in any manner any migratory bird unless permitted by regulations. The MBTA applies in both the United States and Mexico. Because the Mexican spotted owl exhibits migratory behavior in some areas, it is included on the list of birds protected under the MBTA.

5. TRIBAL LANDS

The FWS recognizes that Tribes have management jurisdiction over tribal lands and supports tribal efforts to implement the provisions of this Recovery Plan to achieve management consistency throughout the Mexican spotted owl's range. In accordance with Secretarial Order 3206 entitled "American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act," signed by the Secretaries of the Department of the Interior and the Department of Commerce in 1997, the FWS is required to formally consult with Tribes for any ESA actions that may impact Tribal lands and culturally significant resources.

6. STATE AND PRIVATE LANDS

Although relatively few Mexican spotted owls are known on state and private lands in the United States, the FWS encourages states to continue and/or begin a program to inventory forests and canyons for the presence of Mexican spotted owls. As discussed in Part I.B.1.d (Inadequacy of existing regulatory mechanisms), all states within the U.S. range of the owl have protections in place to prohibit the direct taking of Mexican spotted owls. However, we are unaware of any provisions under state law to regulate the loss of Mexican spotted owl habitat. In addition, the FWS should evaluate the importance of state and private lands to the Mexican spotted owl, and consider promulgating a special rule under 4(d) of the ESA that specifies habitat-altering activities that can be allowed on private lands without violating the prohibition of incidentally taking Mexican spotted owls.

7. MEXICO

In México there are various legal mechanisms aimed at the regulation of conservation and sustainable uses of wildlife and its habitat, as well as conservation and protection of endangered species. These are found in a suite of laws, official Mexican standards (Normas Oficiales Mexicanas), and international agreements, among others, and provide the basis for the development of actions for conservation, protection, and recovery of the populations of species listed under some risk category, such as the spotted owl.

A. General Law of Ecological Equilibrium and Environmental Protection (Ley General del Equilibrio Ecológico y la Protección al Ambiente)

This is the main body of law dealing with environmental matters in Mexico, and it integrally regulates the general terms of environmental protection. This law defines the basic principles of Mexican environmental law and the instruments for its implementation, as well as the mechanisms for the conservation of ecological equilibrium, environmental protection, and the establishment and administration of natural protected areas, among other matters.

Chapter III of this law is directly focused on conservation and sustainable use of wildlife (fauna and flora). Section III of article 79 states that the conservation of species in the endemic, threatened, endangered, or special protection categories should be one of the criteria to be taken into account when granting concessions, permits, and authorizations for use, possession, administration, conservation, repopulation, propagation, and development of wildlife.

B. General Wildlife Law and its Regulations (Ley General de Vida Silvestre y su Reglamento)

This law is part of the national environmental policies and it seeks to balance wildlife conservation with its use. It fosters the implementation of activities oriented to protect wildlife while creating new opportunities that allow the use of natural resources for social benefit. It creates support for conservation by engaging the population in conservation actions that generate income.

This law regulates extractive and non-extractive uses of wildlife specimens, parts, and derivatives, including those species listed in a risk category in the NOM-059-SEMARNAT-2010, and priority species, seeking at all times the viability and permanence of wildlife in nature.

The most important conservation tools promoted by this law are Management Units for the Conservation of Wildlife (UMAs, Unidades de Manejo para la Conservación de Vida Silvestre). These are collective or private land holdings where the following activities take place: conservation, restoration, protection, maintenance, recovery, reproduction, repopulation, reintroduction, research, rescue, shelter, rehabilitation, exhibition, recreation, environmental education, and sustainable use of wildlife and its habitat.

C. General Law of Sustainable Forest Development and its Regulations (Ley General de Desarrollo Forestal Sustentable y su Reglamento)

This legal body regulates the forestry policy of Mexico with the objective of contributing to social, economic, and ecological development through conservation, protection, restoration, production, zoning, cultivation, management, and use of the forest resources and forested ecosystems of the country.

This law is entrusted with: (1) regulating all matters relative to conservation, management, and use of forest resources, (2) establishing measures for forest conservation, as well as control, surveillance, and sanctions, and (3) encouraging social participation. It is of particular importance in the conservation of forested areas, including the forests in which the spotted owl is found.

D. Official Mexican Standard NOM-059-SEMARNAT-2010 (Norma Oficial Mexicana NOM-059-SEMARNAT-2010)

This identifies and lists within an at-risk category all those species that are at risk and groups them in four categories: P-endangered, A-threatened, Pr-subject to special protection, and E-probably extinct in the wild.

Even though this standard in itself does not constitute an instrument that fosters species conservation, it is a tool that assists in prioritizing projects related to these species. Based on this, the Secretary of the Environment and Natural Resources is mandated to promote and foster the conservation of species and populations at risk through the development of conservation projects.

E. *In situ* conservation strategies

The implementation of the Recovery Plan in Mexico would be carried out through *in situ* conservation instruments included in the environmental legal framework. The following section describes the available plans and implementation mechanisms for the conservation of the spotted owl and associated species.

i. *Natural Protected Areas (Áreas Naturales Protegidas)*

Natural Protected Areas have been the main instrument for natural habitat and biodiversity conservation in Mexico's environmental policies. CONANP (National Commission of Natural Protected Areas) is responsible for implementing actions focused on conservation, recovery, restoration, and management, including attention to species at risk found within protected areas as well as in their influence zones. NPAs (Natural Protected Areas) have Management Programs that outline the activities that will be implemented, including species monitoring. Currently, there are 174 NPAs that are managed by CONANP, including those where the spotted owl is present, as mentioned in previous sections.

ii. *Certified Conservation Areas (Áreas Certificadas para la Conservación)*

This is a tool designed for landowners (communities, ejidos, or private lands) that are interested in the conservation of their land to voluntarily access conservation schemes. Once owners join this program they have access to funding and other benefits through programs of the government or civil society organizations. Under this scheme owners commit to manage their land as if it was a private natural protected area, which allows for conservation of the natural habitat, thus complementing the objectives of natural protected areas.

iii. *Management Units for the Conservation of Wildlife (UMAs, Unidades de Manejo para la Conservación de Vida Silvestre)*

These are mostly private properties registered to undertake wildlife management, generally associated to economic interests; they also usually undertake activities for conservation of the natural habitat, populations, and wildlife. They are managed by the owners themselves, and

represent a source of income derived from the sustainable use of wildlife. Thus, owners become the most interested party in guaranteeing the viability of wild populations and their natural habitat, undertaking surveillance, monitoring, and management of habitat and populations.

iv. *Program of Conservation of Species at Risk (PROCER) (Programa de Conservación de Especies en Riesgo--PROCER)*

This program is carried out by CONANP, the National Commission of Natural Protected Areas, and its objective is to recover 30 species at risk. Its main tool is the elaboration and execution of Action Programs for the Conservation of Species (PACE), which establish conservation strategies for each priority species, as well as specific actions aimed at conserving, protecting and recovering their populations and habitat.

This program is tightly linked to the work that is conducted inside Natural Protected Areas; however, its action scope is beyond the limits of the NPAs and considers the execution of other forms of conservation activities as well as activities for other species.

F. Other development programs associated with biodiversity conservation

i. *Program for Payment for Environmental Services (Programa de Pago por Servicios Ambientales)*

These programs are operated by the National Forestry Commission (CONAFOR), and its resources provide support to communities, ejidos, Regional Forestry Associations, and private owners of forested lands, who receive a payment in exchange for biodiversity conservation. Supported categories include projects related to biodiversity conservation, agroforestry systems, and carbon capture, among others. Currently, CONANP and CONAFOR have worked jointly to define priority areas for conservation of species at risk.

ii. *Program for Conservation for Sustainable Development (Programa de Conservación para el Desarrollo Sostenible)*

This subsidy program is operated by the CONANP and promotes the conservation of ecosystems and their biodiversity through the active participation of the population in actions and projects that encompass conservation of natural resources, as well as alternative production projects that decrease pressure on natural resources. In this way communities and regional stakeholders view sustainable development as a form through which they can improve their quality of life while conserving natural resources, and converts them into important allies in the conservation of biodiversity.

APPENDIX H

CONSERVATION MEASURES AND MANAGEMENT IN THE UNITED STATES AND MEXICO

A. Federal Agencies

a. U.S. Fish and Wildlife Service

The FWS has only one record of Mexican spotted owls on its lands (in Brown Canyon on Buenos Aries National Wildlife Refuge), so the FWS's main management responsibility involves conducting the processes associated with listed species under the ESA, such as Section 7 consultation on Federal actions that may affect the species and/or its critical habitat, issuance of research permits under Section 10, and recovery planning under Section 4. Over 200 formal Section 7 consultations have been conducted on actions proposed by numerous Federal agencies, and several hundred informal consultations have occurred as well. The FWS has reviewed two petitions to delist the species. In both cases, delisting was determined to be "not warranted" because the petitions failed to present substantial scientific and commercial information to support their assertion that the species should be delisted. Notices of those findings, including discussions of the issues raised in the petitions, were published in the Federal Register on 23 September 1993 (58 FR 49467) and 1 April 1994 (59 FR 15361). The FWS findings were upheld in legal challenges.

b. U.S. Forest Service

The primary administrator of lands supporting Mexican spotted owls in the United States is the USFS. Most spotted owls have been found within USFS Region 3 (including 11 National Forests in Arizona and New Mexico). The Rocky Mountain (Region 2, including two National Forests in Colorado) and Intermountain Regions (Region 4, including three National Forests in Utah) support fewer spotted owls.

i. U.S. Forest Service Southwestern Region (Region 3)

On 5 June 1996, Regional Forester Charles W. Cartwright signed a Record of Decision (ROD) to implement Alternative G of the Final Environmental Impact Statement for Amendment of Forest Plans (FEIS; USDA FS 1996). That decision directs individual National Forests to incorporate recovery plan recommendations, as well as those of the Management Guidelines for Northern Goshawk in Southwestern U.S., into their forest plans. The USFS then consulted with the FWS under Section 7 of the ESA on the forest plan amendments. The FWS issued a biological opinion finding that implementation of the forest plan amendments would not likely jeopardize the continued existence of the Mexican spotted owl or other listed species. In addition, the Mexican Spotted Owl Recovery Team reviewed the forest plan amendments and concluded that the direction detailed in the FEIS was generally compatible with the original Mexican Spotted Owl Recovery Plan recommendations, although some disparities and management concerns were recognized. In addition, on January 17, 2003, the FWS completed a reinitiation of the 1996 Forest Plan Amendments non-jeopardy biological opinion, and again reached a non-jeopardy

conclusion. Consultation on individual actions under these biological opinions anticipated incidental take in the form of harm and/or harassment of owls associated with 243 PACs on U.S. Forest Service Region 3 lands. The USFS Region 3 reinitiated consultation on the Land and Resource Management Plans (LRMPs) on April 8, 2004. On June 10, 2005, the FWS issued a revised non-jeopardy biological opinion on the amended LRMPs.

Region 3 of the USFS continues to manage under the recovery plan recommendations except where overriding resource, social, or economic considerations (e.g., fuels-reduction projects for the purpose of reducing the risk of high-severity fire in the WUI) require the agency to deviate from those recommendations. Deviations from the direction in the ROD and FEIS require Section 7 consultation with FWS to ensure that USFS programs and individual projects will not jeopardize the continued existence of the Mexican spotted owl.

The Southwestern Region of the U.S. Forest Service has conducted spotted owl inventories since 1988. In 1994, the U.S. Forest Service reported 846 owl “sites” reported between 1984 and 1993 (Fletcher and Hollis 1994). Prior to the listing of the Mexican spotted owl, Region 3 issued guidelines for its management. Those guidelines were issued as Interim Directive Number 1 in June 1989, then revised and reissued as Interim Directive Number 2 approximately one year later. Interim Directive Number 2 guidelines required establishing management territories around all nesting and roosting spotted owls and around territorial owls that were detected at night for which daytime locations were not recorded. All management territories (except those on the Lincoln and Gila National Forests) consisted of approximately 800 ha (2,000 ac) of habitat per territory. Since that time, the U.S. Forest Service’s Region 3 has incorporated the recommendation of the original Mexican Spotted Owl Recovery Plan and established approximately 1,061 240-ha (600-ac) PACs at all Mexican spotted owl sites known from 1989 to present (Table I.1). Due to intensive survey efforts, the number of known owl sites has increased since 1996. The relative percentage of known sites by National Forest has not changed significantly.

ii. U.S. Forest Service Rocky Mountain Region (Region 2)

Region 2 of the U.S. Forest Service continues to manage under the original Mexican Spotted Owl Recovery Plan recommendations. Most projects occurring in Mexican spotted owl habitat consist of fuels-reduction treatments that have been able to meet the Protected and Restricted Habitat Guidelines in the original recovery plan. Projects rarely occur within PACs.

Since 1990, the Rocky Mountain Region of the U.S. Forest Service has conducted spotted owl inventories in most of the National Forests in Colorado. Currently occupied Mexican spotted owl sites are present on the Pike/San Isabel and San Juan National Forests. The U.S. Forest Service’s Region 2 has established PACs of at least 240-ha (600-ac) in size at all Mexican spotted owl sites where owls have shown some level of occupancy (i.e., not believed to be transitory owls) since 1990. Several owl sites are being further evaluated for potential establishment of PACs. The number of occupied owl sites on National Forest System lands has generally decreased since 2000.

iii. *U.S. Forest Service Intermountain Region (Region 4)*

Potential Mexican spotted owl habitat in the U.S. Forest Service's Intermountain Region is limited to small portions of the Dixie, Fishlake, and Manti LaSal National Forests in southern Utah. Employees of the Intermountain Region have collected site-specific Mexican spotted owl data since 1990. Survey efforts covered approximately 335,930 ha (830,100 ac) of habitat statewide on Forest Service-administered lands. Few Mexican spotted owl breeding pairs have been documented on these National Forests. The inventories in southern Utah encompassed a wide range of habitat types, but all owls detected were found in steep-walled sandstone canyons, some of which contained intermittent streams and stringers of mixed conifer and/or deciduous multi-layered vegetation. In southern Utah, owls were found nesting only on ledges or small caves in these steep-walled canyons. As a result of these extensive survey efforts, spotted owl inventories were discontinued in rolling forested landscapes of the Intermountain Region and were focused on steep-walled canyon areas consistent with where owls were documented. Broad-scale survey efforts were replaced with forest-level surveys, as needed to determine owl presence in proposed project areas. In 2003, approximately 2,400 ha (6,000 ac) were surveyed on the Teasdale and Escalante Ranger Districts with two detections. As a result of these refocused survey efforts, one additional owl was detected in 2008 and the Dixie National Forest designated three PACs.

The USFS has regulatory mechanisms and management direction in place to protect and recover the Mexican spotted owl. The U.S. Forest Service Manual requires review of all USFS planned, funded, executed, or permitted programs and activities for possible effects on the owl (FSM 2672.4). Additionally, each National Forest is required to complete consultation with the FWS for all agency programs or activities that may affect the species (FSM 2671.45c). Existing forest plans for the Dixie, Fishlake, and Manti LaSal National Forests require that spotted owl habitat be protected, maintained, or improved. Additionally, these forests' plans are currently under revision, and owl habitat and recovery are being addressed in the revision process. The existing recovery plan guidance is also implemented as appropriate on these three southern Utah forests.

c. National Park Service (NPS)

In the range of the Mexican spotted owl, the NPS has 57 administrative units. However, most of these park units are very small in acreage and/or have habitat not suitable for spotted owls. Other parks with potentially suitable habitat have been surveyed and no owls have been found (Arches NP, Rocky Mountain NP, Great Sand Dunes NP and Preserve, Black Canyon NP, and Curecanti NRA). As a result, 18 parks are known or expected to have spotted owls or owl habitat. Some of the 18 parks have not been surveyed for spotted owls, so the actual presence of owls has not been confirmed. Designation of PACs has been inconsistent in national park units in part because much of the acreage in the 18 parks is wilderness, proposed wilderness, or backcountry land designations. These land-management categories greatly reduce the potential for most management impacts to owls and owl habitat. As a consequence, there is less need for park managers to identify the specific acreage to be managed for owls through PAC designations. Increases in human recreation in the parks is heightening concern for spotted owls in these less-developed portions of parks and may stimulate designation of more PACs to focus

protection of the owls. This is true particularly where owls are using canyon habitats and may have less ability to retreat from human disturbances.

Generally, the most pressing issue of managing owl habitat in national parks is the need to reduce fire fuels and reintroduce natural fire regimes, while maintaining or improving owl populations. Fire Management Plans commonly include owl habitat management as a focus issue in decisions for planned and unplanned fire management.

The following summaries provide detail on owl populations in the 18 parks that are known or expected to have owls or owl habitat.

i. Bandelier National Monument, New Mexico

Mexican spotted owls were first reported at Bandelier National Monument in 1910. Management-related owl surveys began in 1985. Mexican spotted owls in Bandelier nest in canyons with cool, moist, mixed-conifer forests. The majority of the spotted owl habitat is within the Bandelier Wilderness. Instead of delineating PACs, the park designated nine Nesting-Roosting Zones (NRZs) and Suitable Nesting Areas (SNAs) as part of its 1998 Fire Management Plan. These alternative methods of delineating owl areas were used to recognize the intention of returning fire into these areas; the park proposed treating NRZs with low-intensity fire in an effort to reduce the threat of crown fires. Through formal consultation, the FWS approved such designations. The NRZs cover approximately 2,800 ha (6,900 ac, or 20% of the park), have areas with steep slopes in mixed-conifer habitat types, and have been monitored consistently prior to any planned management action. During 1998-2009, 400 ha (980 ac) of NRZ habitat have been treated with prescribed fire.

ii. Bryce Canyon National Park, Utah

There are no documented owl territories within Bryce Canyon National Park. Surveys have been performed throughout the park in areas predicted to be suitable habitat (1993-1995) and in connection to proposed projects (2003, 2008, 2009). No surveys detected spotted owls. Most of the potential Mexican spotted owl habitat occurs in proposed wilderness areas where it is protected from development. No prescribed fire treatments are currently planned for the potential owl habitat in the park. Unplanned fire and recreation impacts are currently the greatest threat to the possibility of owls occurring at Bryce Canyon. A lightning-caused event in July 2009 burned several hundred acres in potential Mexican spotted owl habitat. Owl surveys in that area prior to the fire had not located Mexican spotted owls. Surveys for Mexican spotted owls will continue, generally related to proposed activities within or adjacent to potential habitat.

iii. Canyon de Chelly National Monument, Arizona

Canyon de Chelly's primary mission is to protect the prehistoric ruins and other features of scientific or historical interest. The monument encompasses approximately 34,000 ha (84,000 ac) within the Navajo Nation. The Navajo Nation and NPS share management responsibility for wildlife resources in the monument. Mexican spotted owls and their habitat are managed under the Navajo Nation Management Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*)

(2000). Records show the species has been known to occupy parts of the monument since the mid-1980s. Surveys since 2005 have found that owls are widely but patchily distributed throughout the monument, resulting in designation of five PACs. Both the NPS and Navajo Nation recognize the potential for more PACs in the monument due to the abundance of steep, north-facing canyon walls, perennial streams, and patches of Douglas-fir that have not yet been surveyed.

iv. Canyonlands National Park, Utah

The first study of Mexican spotted owls in Canyonlands was in 1977. A series of owl studies were conducted in the 1990s (Van Riper and Willey 1992, Willey 1995, 1996, 1998; Swarthout and Steidl 2000, 2001, 2003; Willey and Van Riper 2000). These studies investigated demographics, owl sensitivity to recreational disturbance, prey base, home range size, habitat use, and natal dispersal of the birds. In 1996, PACs were designated around all 22 known owl territories [about 9,300 ha (23,000 ac)], and a GIS layer was developed to manage activities occurring in this owl habitat. Although monitoring has been sporadic, owls have been located in these PACs whenever they have been checked. In 2002 and 2003, a comprehensive re-survey of the entire park was undertaken to determine the status of the owl population (Schelz et al. 2004). Most of the 22 PACs were surveyed, as were other areas. The resulting 47 Mexican spotted owls (10 pairs and 27 individuals) led to a current estimate of 29 owl territories in the park. The top issues threatening the owls in Canyonlands are increased human activity in the remote backcountry and the loss and degradation of riparian habitat.

There are approximately 77,000 ha (190,000 ac) of potential owl habitat in the park, of which about 49,000 ha (120,000 ac) have been surveyed to protocol. Owl nesting habitat in the park is rugged, steep-canyon topography with vertical cliffs and numerous caves with small patches of woodland vegetation (pinyon-juniper being the most common type). As owl habitat in the park is not fire-dependent, prescribed fires are not used as a management tool, and no acres of owl habitat have been lost to canopy fire.

v. Capitol Reef National Park, Utah

Capitol Reef National Park has nine owl sites designated as PACs. Breeding was confirmed at all nine sites during the 1990s (Willey 1998b). The most recent surveys have occurred during 2008-2010 and all nine PACs were visited; a pair was observed at one site, a single male was observed at three others, and no owls were detected at the remaining five sites, suggesting these sites have not been recolonized. The park does not have an estimate of amount of potential owl habitat or of the acreage surveyed. Fires are rare in the park, and large fires would be unlikely to occur near owl territories due to vegetation patterns. No owl habitat in the park has been lost to fire or treated with fuels-management methods. Potential impacts to owls could arise from increased human recreation in areas occupied by owls. Some research has been conducted in the park examining owl response to human activity.

vi. *Carlsbad Caverns National Park, New Mexico*

Carlsbad Caverns National Park has seven records of Mexican spotted owls. While most of these records suggest that the owls were dispersing or wintering individuals, the most recent observations (spring 2005 and early fall 2007) were of adult pairs in different remote canyons, either during breeding season or just after, with evidence (pellets and fecal white-wash) indicating each pair was resident. The park is characterized by steep-walled canyons with caves and ledges, with limited areas of scattered ponderosa pine and maple-oak ravine woodlands. These canyons may provide nesting habitat for Mexican spotted owls. The woodlands are less than 4% of the park acreage and tend to occur on north-facing slopes above 1,500 m (4,900 ft) or in canyon bottoms.

The park backcountry receives little human use, and there are no special management restrictions for owls. The Fire Management Plan guides the most prevalent vegetation management in the park. The western half of the park, with rugged canyons and the majority of woodland patch habitats, is slated for management as a wildland fire use study area under the plan. Several large fires since the 1970s have burned most of the park west of Slaughter Canyon. The influence of these fires may limit woodland regeneration and favor montane shrublands. Formal surveys of Mexican spotted owls in Carlsbad Caverns National Park were conducted in 2010. Results from these surveys will be used to assess the efficacy of three different predictive models of Mexican spotted owl habitat in the park.

vii. *Chiricahua National Monument, Arizona*

There is one site of known spotted owl occupancy that is managed as a PAC. Management of this acreage is addressed in the Fire Management Plan.

viii. *Coronado National Memorial, Arizona*

Coronado National Memorial (Memorial) has surveyed for Mexican spotted owls in most years since 1997 and has detected one pair. The pair nested in the same location in 1997 and 1999, fledging two young each year. In 1998 the same pair was detected near the 1997/1999 location, but they did not nest. In 2000, 2001, and 2003 only one owl was heard in August of 2000. In 2002 and 2004 no surveys were done. As part of a study of the population biology of Mexican spotted owls in sub-Mogollon Arizona (Duncan and Spiech 2002), the adult owls and their young from 1997 and 1999 were captured, marked with color bands and aluminum bands, and monitored through 2000. The purpose of this study was to determine survivorship, reproductive success, environmental variation, and population trends. Research has also been done on rodent populations in the PAC.

About 400 ha (1,000 ac) of potential owl habitat exists in the Memorial. About 350 ha (850 ac) of this area is in the PAC, and the other areas have been surveyed to protocol at least once. No owl habitat has been lost to canopy fire in the last 10 years or received prescribed fire or other treatments to reduce fire risk. However, the Peak Fire of 1988 burned about 324 ha (800 ac) of what was likely spotted owl habitat. The biggest threats to owls in the Memorial are risk of

stand-replacing fire and disturbance from undocumented immigrants and drug smugglers, who regularly hike through the Memorial, especially at night.

ix. Dinosaur National Monument, Colorado

There is one known owl territory in Dinosaur National Monument where a single bird was observed in two consecutive years in the late 1990s. The territory is located within an extremely remote area of the park that receives no human use. The site has not been designated as a PAC due to the remote location and lack of management action there. There are no known threats to this territory. The surveys conducted in the late 1990s are the only studies conducted on owls in the monument.

x. Gila Cliff Dwellings National Monument, New Mexico

The Gila Cliff Dwellings National Monument consists of 216 ha (533 ac) and does not have any spotted owl records from within the unit. However, it is surrounded by Gila National Forest acreage, and the park acreage could contribute to owl home ranges that are centered on U.S. Forest Service lands.

xi. Glen Canyon National Recreation Area, Arizona and Utah

Glen Canyon National Recreation Area has eight locations of potential spotted owl territories, and three of these are managed as PACs. No surveys have been conducted since the late 1990s, although surveys in Capitol Reef National Park included a visit to Miller Canyon, where a pair was observed in 2009.

xii. Grand Canyon National Park, Arizona

There are 41 known Mexican spotted owl territories within Grand Canyon National Park, all of which have been mapped as PACs. Due to restricted access to many PACs, annual monitoring of all PACs is not possible. However, a minimum of 18 PACs were occupied in 2001, 20 PACs in 2002, 13 PACs in 2003, and 10 PACs in 2004. One owl in each of seven PACs was radio-tracked in 2004 (Bowden 2008). Systematic surveys continue to be implemented yearly on the North and South Rim prior to undertaking fire-related activities.

In Grand Canyon National Park, Mexican spotted owls have been located primarily in canyon habitat; however, one owl was confirmed on the plateau at the rim's edge on the South Rim, and one owl was detected in several locations on the North Rim plateau <0.8 km (0.5 mi) from the rim (Bowden 2008). All other owl locations and all roost and nest sites have been confirmed below the rim in canyon habitat. Radio-tracking data and home-range analyses from 2004-2007 (Bowden 2008) showed that owls at Grand Canyon roosted and nested in canyon habitat and occasionally foraged on the high plateau within 1 km (0.6 mi) of the rim in ponderosa pine and mixed-conifer forests. All mixed-conifer forest on the North Rim has been surveyed at least twice since 1991, with one owl detected in 2007 (D. Willey pers. obs.). Approximately 16,000 ha (40,000 ac) of predicted canyon habitat occurs in the park and approximately 50% of it has been surveyed. Continuing surveys and radio-tracking efforts will provide additional

information on habitat usage of owls at Grand Canyon. Until further information is available, the Park continues to survey for owls in mixed conifer habitat on the North Rim and in canyon habitat throughout the park.

xiii. Guadalupe Mountains National Park, Texas

There are at least six Mexican spotted owl pairs within Guadalupe Mountains National Park, and several other single male owls have been located in the park. The owls are found in areas of steep-walled canyons with wooded bottoms consisting of a well-developed overstory and open understory. Owls may not occupy some survey areas due to an overly dense understory that may limit the owls' ability to forage. Spotted owl observations over the past 30 years cluster the birds' activity areas in about six locations in the park, and some areas remain unsurveyed. Production of young has been documented intermittently since 1994. Most owl habitat is located in remote areas of the park and is not routinely subject to disturbance from human activity. The park has restricted potentially impacting activities (e.g., helicopter use and blasting activity for trail improvements) near known territories during the breeding season. The greatest threat to the owl is habitat loss from stand-replacing wildfire, and the park has initiated fuels treatments to reduce this threat.

xiv. Mesa Verde National Park, Colorado

There are three sites documented as breeding territories within Mesa Verde National Park and other areas where calling owls have been heard. However, breeding has not been documented since the 1990s. The lack of owl detections recently is a concern and suggests the need for continued surveys. Owl habitat is in sandstone canyons and side canyons with Gambel oak thickets and stands of pinyon-juniper and Douglas-fir. Areas used by spotted owls are managed as de facto PACs but designation is still pending. Recent severe wildfires have burned thousands of acres of pinyon-juniper, Douglas-fir, and woodlands on the mesas adjacent to the canyons, which may provide foraging habitat for the canyon-dwelling owls. Stand-replacing fires continue to be a threat to owls and owl habitat in the park. A unique management issue at Mesa Verde National Park is the Mexican spotted owl's use of Ancestral Puebloan architecture (ruins) for nesting and roosting. This creates a potential conflict with modern human use of these sites by visitors and archeologists.

xv. Navajo National Monument, Arizona

Land within the Navajo National Monument is owned by the Navajo Nation but is under National Park Service management for administrative care of culturally significant structures and recreation control. Navajo National Monument preserves three Ancestral Puebloan intact cliff dwellings located on three small disjunct tracts. A visitor center, museum, two short self-guided trails, two small campgrounds, and a picnic area provide service to visitors at the Monument headquarters, which is located adjacent to the Betatakin Unit. The Monument is approximately 243 ha (600 ac) in size and receives approximately 66,000 visitors per year.

The Monument contains canyon habitat for the Mexican spotted owl. Mexican spotted owls were initially identified within the Monument in 1986 and the Navajo Nation established a PAC

in Betatakin Canyon in 1997. A majority of the PAC area is outside the Monument on Navajo Nation lands. However, the head of Betatakin Canyon, which is within the Monument, contains spotted owl nesting habitat and there are several records of spotted owl detections in this area. That portion of the PAC on the Monument is subject to the Navajo Nation Management Plan for the Mexican Spotted Owl, but the National Park Service is still required to consult under Section 7 of the Act for any projects that may affect the owl.

Currently, visitors to Betatakin cliff dwellings pass within 0.27 km (0.17 mi) of an owl activity center, located outside the head of the canyon. The Aspen Trail, which has been closed to visitors since 1983, runs down the middle of Betatakin Canyon where it varies in width from 91 to 152 m (300 to 500 ft). The National Park Service proposed opening the Aspen Trail as the primary access to the cliff dwellings in 2010. The National Park Service will offer guided tours throughout the spotted owl breeding season, with limited tours of up to 15 visitors per tour, 3 times per week early in the breeding season (mid-March through late May), and 2 tours per day of up to 25 visitors per tour thereafter. The National Park Service and the Navajo Nation are making efforts to minimize recreational impacts to Mexican spotted owls; however, the Aspen Trail will likely result in effects to owl use of the area.

xvi. Saguaro National Park, Arizona

Resident Mexican spotted owls were first detected in Saguaro National Park in 1992. The park currently supports five breeding territories in the Rincon Mountain District of the park, each with a designated PAC and core area [1,200 ha (3,000 ac) total]. Radio telemetry studies from 1996-1998 confirmed the number and territories of breeding pairs, their reproductive success, roosting and foraging habitat, and diet, and documented owl behavioral responses to local prescribed burns (Willey 1998a). The owls have been monitored intermittently since that time in relation to fire-management activities. At least one adult (usually a male) has been located in each PAC every year that surveys have been conducted. For management purposes, all vegetated acreage above 2,000 m (6,000 ft) elevation is considered potential spotted owl habitat. Habitat loss from wildfire and human disturbances related to fire management are probably the greatest potential threats to the park's owls.

Mexican spotted owl breeding habitat is limited to the upper elevations of the Rincon Mountains in the park, usually on north facing slopes; virtually this entire habitat is now in PACs. Prescribed burns have been conducted in about 800 ha (2,000 ac) of such habitat, and wildfires have occurred in PAC acreage. Approximately 200 ha (500 ac) have been affected by canopy fire (mostly from wildfire) in the past 10 years.

xvii. Walnut Canyon National Monument, Arizona

The earliest record of Mexican spotted owl activity at Walnut Canyon National Monument dates to 1980, when a use/perch site was reported. A pair of owls was observed near this location again in 1986, but no nest was found. There are approximately 730 ha (1,800 ac) of owl habitat in the park, all of which has been surveyed to protocol at least once. Informal and protocol surveys occurred in nine breeding seasons between 1987 and 1999. Surveys between 2000 and 2003 did not result in owl detections, though an owl was documented in 2003 in an incidental

observation. The area in the east canyon that was added to the park in 1996 has not been formally inventoried. Four PACs were established within and adjacent to the monument. Surveys suggest that only two of the four PACs may be occupied during any given breeding season. The monument also classifies steep areas >40% as protected areas. No areas within owl habitat have been treated with prescribed fire or mechanical thinning, nor have any areas of habitat been lost to canopy fire within the past 10 years. The Fire Management Plan includes some site-specific mechanical thinning to protect natural and cultural sites at risk, but it does not propose prescribed fire in PACs due to topography. Greatest threats to owls at Walnut Canyon National Monument include growth and development of nearby human communities, drought and insect-related conifer mortality, risk of crown fire, changes in riparian vegetation, and increases in outdoor recreational use.

The four PACs encompass most of the Douglas-fir-Gambel oak, ponderosa pine-Gambel oak, pinyon-juniper-shrub-succulent vegetation on steep slopes, and much of the riparian corridor along the bottom of Walnut Canyon National Monument within and adjacent to the monument. All four PACs include acreage outside of the monument boundary on the surrounding Coconino National Forest.

xviii. Zion National Park, Utah

There are 29 known Mexican spotted owl territories within Zion National Park (Zion), which are mapped into 20 PACs (8,757 ha [21,639ac]). In 2009, owls were detected in 81% of 27 territories monitored. These areas are managed according to the recommendations in the 1995 Mexican Spotted Owl Recovery Plan. The oldest record for owls in the park, a single juvenile, is from 1928. There were no subsequent owl observations until 1963 and 1974, with formal owl surveys beginning in the 1970s. Research on the owls in Zion occurred between 1987 and 2000; studies included owl distribution, habitat characteristics, home ranges and juvenile dispersal, and habitat disturbance effects on owls. Zion has been monitoring Mexican spotted owl territory occupancy and nesting activity on a regular basis since 1995. Prescribed burning has been used as a management tool on approximately 1,700 ha (4,200 ac) of owl habitat with no effects to the forest canopy. The greatest threat to spotted owls in Zion comes from increased visitor use, especially visitation to canyons containing owl habitat. Some of the nesting sites are in heavy human-use areas. All of the canyons requiring technical climbing ability and equipment require access permits and have use limits. A three-year study on the effects of recreation in canyons on owl occupancy and reproduction was initiated in 2008. Other concerns include higher severity fires in foraging habitat as a result of increases in fuels where fire has been suppressed for years. Reintroducing fire is a priority here.

Spotted owl nesting habitat in Zion is found in canyons and adjoining areas are used for foraging. The habitat in these landscapes is described as vertical and overhanging cliffs; parallel-walled canyons with cool, north-facing aspects; complex side canyons; and a mosaic of vegetation types. The rock walls must include caves, ledges, and fractured zones that provide protected nesting sites. The canyons also include patchy areas of vegetation along canyon bottoms, on flat benches, or on plateau or mesa tops above the canyon rim. Canyon habitat in the park is estimated at roughly 25,000 ha (62,000 ac). For this estimate, mesa tops between the

canyons were included because the owls may use these areas for foraging. However, this does not imply the mesa tops are considered nesting habitat.

d. Bureau of Land Management (BLM)

i. *Arizona*

Most BLM-administered spotted owl habitat in Arizona is in the Arizona Strip area of the Colorado Plateau (CP) Recovery Unit. Protection and recovery considerations are oriented toward the vicinity of steep-walled rocky canyons that meet criteria as potential nest/roost habitat. The BLM is implementing the original Mexican Spotted Owl Recovery Plan in this area by avoiding habitat-altering projects such as timber harvest within 1.6 km (1 mi) of canyons that could support breeding or roosting owls. No mixed-conifer forest occurs on public land in the Arizona Strip. The BLM continues to periodically survey for Mexican spotted owls in a few accessible areas. No birds have been found. The BLM in the Arizona Strip addresses Mexican spotted owl recovery opportunities in its Resource Management Plan.

The Hualapai Mountains, administered by the Kingman Field Office (FO), support one historical breeding location for spotted owls. Much of the 1,750 ha (4,300 ac) of ponderosa pine and mixed conifer forest in the Hualapais is shared by the owl and the endangered Hualapai Mexican vole, which also has a recovery plan under implementation. Since the most recent record of Mexican spotted owl breeding activity dates from 1979, no PAC has been designated. As on the Arizona Strip, the BLM continues to periodically survey for Mexican spotted owls in a few accessible areas thought to contain spotted owl habitat, yet no birds have been found. The BLM's activities are oriented to maintaining the existing ponderosa-pine forest and a very small amount of mixed-conifer forest in the Hualapai Mountains. Activities in historical spotted owl habitat are compatible with the original recovery plan and those identified in the Hualapai Mexican Vole Recovery Plan (T. Cordery, USDI BLM, pers. comm.).

ii. *New Mexico*

Of the 849,840 ha (2.1 million ac) designated as Mexican spotted owl critical habitat in New Mexico, only 879 ha (2,171 ac) are located on BLM-administered lands. Furthermore, there are no protected owl habitats, as defined in the original recovery plan, or known extant Mexican spotted owl populations on BLM-administered lands in New Mexico. Historically, BLM lands in New Mexico likely contained forest stands suitable for the owl. However, from as early as the 1800s, homesteaders, owners of land grants, and private logging companies removed most of the large commercial timber, and few dense, old-growth forests exist today. Of the six BLM field offices (FO) in New Mexico, four have implemented management actions for the Mexican spotted owl: Farmington FO, Taos FO, Rio Puerco FO, and Socorro FO (M. Ramsey, USDI BLM New Mexico State Office, pers. comm.). Of the four FOs, the Farmington FO is the only one to administer lands with critical habitat and has the greatest potential for supporting an owl population. However, Mexican spotted owl surveys were conducted from 1992 through 2009 and no owls were reported. A single owl was heard in 2002, but it was determined that it was a "floater" moving through the area (USDI BLM 2002). Only limited areas of BLM lands within the Taos FO have the potential to meet the habitat criteria to support the owl and there has only

been a single confirmed owl sighting within the FO; on 26 June 1991, an “inferred Mexican spotted owl” was detected in a Douglas-fir tree on BLM lands on the east side of Archuleta Mesa (UNM 1995). A BLM protocol survey for the owl was conducted in 1993 along the same transects where the owl was recorded in 1991, but no responses from spotted owls were elicited (USDI BLM 1993). Mexican spotted owl surveys were conducted by the Rio Puerco FO in 1992, but no responses from spotted owls were elicited and no suitable habitat was identified (M. Ramsey, USDI BLM New Mexico State Office, pers. comm.). The Rio Puerco FO has not subsequently conducted any surveys for the owl. Although owls are known to occur in mountains in west- and south-central New Mexico, including Mogollon and Tularosa mountains in Catron County, and the San Mateo Mountains in Socorro County, no owls or suitable habitats were documented during owl surveys conducted by the Socorro FO in 1992, 1993, and 1998 (M. Ramsey, USDI BLM New Mexico State Office, pers. comm.).

Considering the most current information on the limited distribution of the Mexican spotted owl and its required habitats on BLM-administered land in New Mexico, ongoing programs within FOs have very little potential to create disturbances to the Mexican spotted owl. Nonetheless, in any areas where Mexican spotted owls or their habitat are identified on BLM-administered lands or where BLM-administered lands are adjacent to other lands that have been identified as Mexican spotted owl habitat, the BLM will follow guidelines in the Recovery Plan in managing its timber and fuelwood programs, oil and gas development, coal leasing and development activities, and off highway vehicle activity.

iii. Utah

Five separate critical habitat units were designated for the owl in Utah totaling some 912,000 ha (2,252,857 ac) (69 FR 53181). Of that total, approximately 147,000 ha (362,135 ac) are located on public lands administered by BLM. The administrative units with designated critical habitat are the Price, Moab, Monticello, Richfield, Kanab, Cedar City, and St. George FOs and the Grand Staircase-Escalante National Monument.

Much of the Utah habitat has been inventoried and monitored by Utah Division of Wildlife Resources (UDWR) personnel with funding from the Utah State BLM Office. As a result of these studies, over 100 protected activity centers (PACs) in Utah have been identified, of which approximately 20% occur on BLM-administered lands. These studies are continuing, and Utah BLM also continues to work collaboratively with UDWR to develop habitat models to guide survey efforts and to assist in project evaluations. Predictive habitat models developed in 1997, 2000, and 2007 (e.g., Willey 2007) are currently being used in determining habitat and potential impacts to the owl and its habitat from actions authorized by BLM.

In 2008, Utah BLM completed work on six land use plans. This effort included major plan revisions for the Vernal, Price, Moab, Monticello, Richfield, and Kanab FOs. Section 7 consultation was a major aspect of plan preparation and appropriate conservation measures were incorporated into the plans. The St. George FO and Grand Staircase-Escalante National Monument also are current in their land management plan Section 7 consultations for the owl.

iv. *Colorado*

The BLM in Colorado has been managing under the 1995 Recovery Plan recommendations. Most owl habitat occurs in narrow, rocky canyons with difficult access. Few projects occur in these sites, but those that do include grazing permits, transmission line rights-of-way, and a rock quarry. Projects rarely occur within PACs. These projects are generally managed consistent with the guidelines in the 1995 Recovery Plan.

Since 1990, the BLM conducted spotted owl inventories on BLM lands throughout Colorado. Currently occupied owl sites on BLM land in Colorado are located along the Front Range in the Canon City area. The BLM has established PACs of at least 240-ha (600-ac) in size at all Mexican spotted owl sites where owls have shown some level of occupancy (i.e., not believed to be transitory owls) since 1990 (Table BLM-CO-PAC list). Several owl sites are being further evaluated for potential establishment of PACs. The number of occupied owl sites on BLM lands in Colorado has generally remained steady since 1992, with several of the sites showing strong site fidelity by resident birds. One such site has been occupied by the same male for the past 17 years, as documented by banding by the BLM.

e. Department of Defense (DOD)

i. *Fort Huachuca Military Reservation, Arizona*

The Fort Huachuca Military Reservation (Post) in southeastern Arizona is known to support nesting Mexican spotted owls. Fort Huachuca manages owls, habitat, and the activities that may affect owls under the terms of a programmatic biological opinion issued by FWS (14 June 2007). Activities in spotted owl habitat generally are confined to various foot maneuvers and driving wheeled vehicles on dirt roads through canyon bottoms, although law-enforcement activities to interdict illegal immigration and smuggling are frequent and widespread in some owl habitat.

Public recreation accounts for the greatest amount and frequency of human activity in spotted owl habitat. One spotted owl site has been popular with birders for over three decades, but the effect of this activity on owls is unknown. Unauthorized off-trail walking has proliferated at this and at least one other site, and these side trails in the canyon bottoms where owls tend to be found have increased forest-floor disturbance and erosion. Undocumented immigrant passage increased dramatically in 2002 and has been significant and frequent through all canyons and spotted owl habitat. Extensive new trail networks have appeared throughout spotted owl habitat. Law enforcement interdiction efforts day and night have similarly increased in scope and frequency.

Whereas unregulated recreation is considered the mostly likely source of impacts on individual owls, the Army considers wildland fire to be the greatest potential threat at the population level. The Army assesses the possibility of wildland fire ignition and spread when planning, designing, and authorizing military activities on the Post (S. Stone, DOD, Fort Huachuca, pers. comm.).

ii. *Camp Navajo Garrison Training Center, Arizona*

Camp Navajo Garrison Training Center is located in northern Arizona, west of the City of Flagstaff. The installation contains protected, recovery, and designated critical habitat. The Volunteer Canyon PAC was designated in 1988 on the southern end of the installation, in portions of Volunteer Canyon, extending into the Coconino National Forest. Mexican spotted owl surveys of Camp Navajo have been conducted since 1997, primarily within the southern and western portions of the installation. Adult Mexican spotted owls and potential juveniles were heard within the PAC on Camp Navajo during the summer of 2000 and a pair of owls was found in this same location in 2010. Mexican spotted owls were located primarily along the rim and side drainages of Volunteer Canyon near the installation's southern boundary with the Coconino National Forest.

Recovery habitat also occurs along the western portion of the installation. A telemetry study in the fall of 1995 found that a dispersing juvenile Mexican spotted owl spent approximately two weeks in the immediate vicinity of Volunteer Mountain before dispersing onto the Kaibab National Forest (J. Ganey, USDA FS, pers. comm.). The 2008 surveys conducted by the Arizona Game and Fish Department (AGFD) detected an owl in the Volunteer Mountain area; however, no responses were noted during subsequent visits to the site or adjacent sites during the 2008 field season. Therefore, the recovery habitat within the Camp Navajo facility could serve as an important corridor for dispersing owls. Designated critical habitat for the MSO is located along the southern portion of the installation and includes the majority of Volunteer Canyon.

iii. *U.S. Naval Observatory Flagstaff Station, Arizona*

The U.S. Naval Observatory Flagstaff Station (NOFS) is located in northern Arizona, just outside the City of Flagstaff. The NOFS has joint management of the Dry Lake PAC with the Arizona State Land Department and the Coconino National Forest. Surveys for Mexican spotted owls at NOFS and the Dry Lake Crater Caldera began in 1994 when Arizona State Land Department personnel first detected an owl either immediately adjacent to or on the NOFS property. Since 1994, surveys have been conducted by the Arizona State Land Department, U.S. Forest Service, and United States Geological Survey/Southwest Biological Science Center/Colorado Plateau Research Station. The owls associated with the Dry Lake PAC are usually located on U.S. Forest Service lands, but the NOFS has been managing its portion of the PAC and recovery habitat per the 1995 Recovery Plan recommendations.

iv. *Kirtland Air Force Base, New Mexico*

On 20 March 2009, Kirtland Air Force Base (KAFB) personnel detected a male Mexican spotted owl of unknown age incidental to general avian point count surveys (Enviroligical Services, Inc. 2009). KAFB personnel were not successful in their attempts to relocate the owl on 2 April 2009. In response to this first confirmed detection of a spotted owl on KAFB, standardized FWS owl surveys were completed on base from 4 May to 11 July 2009. No spotted owls were detected during the surveys, but some suitable habitat was delineated. Suitable spotted owl habitat on KAFB is patchily distributed and is interspersed with large tracts of open or arid and unusable habitat. Suitable habitat includes stands of ponderosa pine with Gambel oak

understory, some drainage bottoms with deciduous components, and some cliff bands. On KAFB, ponderosa pine is generally distributed at higher elevations or in drainage bottoms. Most canyons with a northern exposure on KAFB are wide, with cliffs occurring in bands usually toward the top of the canyon. As these canyons are broad, these bands receive a high degree of solar radiation and, therefore, are less suitable for breeding spotted owls. Because KAFB contains only pockets of habitat for owls and no mixed-conifer habitat, spotted owls likely do not breed on the base. However, KAFB might provide adequate habitat for dispersing or wintering birds. KAFB does not allow recreational activities in the area where the owl was detected, though unregulated recreational activity (e.g., mountain biking) does occur. Activity in KAFB owl habitat can include occasional law-enforcement activities, hiking by official personnel, biologists conducting wildlife surveys, helicopter activity, and various foot maneuvers.

v. *Other U.S. Military Involvement*

Low-level military air operations have been identified through Section 7 consultations as actions that may affect Mexican spotted owls. Low-level flights from air-rescue and attack model helicopters along with jet aircraft have flown over PACs in Upper Gila Mountains and Basin and Range-East EMUs. Emergency training missions of attack helicopters based out of Holloman Air Force Base occurred over several PACs in the Sacramento Mountains as recently as 2009 (J. P. Ward, Mexican Spotted Owl Recovery Team, pers. comm.). It is currently unknown if these types of training missions will continue in the future. Additionally, Fort Bliss near El Paso, Texas, is increasing its troop capacity and future training missions may include helicopter flights over owl sites in nearby mountain ranges of the Basin and Range-East EMU. Holloman Air Force Base has funded studies to assess the effects of low-level flights but we are not aware that those results have been published.

f. Department of Energy

i. *Los Alamos National Laboratory, New Mexico*

Mexican spotted owls were first reported at Los Alamos National Laboratory (LANL) in 1995 when management-related owl surveys located a nesting pair. At LANL, owls nest in canyons with cool, moist, mixed-conifer forests. The majority of owl habitat is within the central to western portions of LANL. The owls at LANL have been found to nest in cliff cavities rather than trees. Instead of PAC delineation, Areas of Environmental Interest (AEIs) were mapped as part of LANL's 2000 Habitat Management Plan. An AEI consists of a core boundary around suitable nesting habitat with an accompanying buffer habitat extending 420 m (0.25 mi) beyond this boundary. These alternative methods of delineating owl habitat areas were used instead of known nesting areas. The AEIs are surveyed annually and access, noise, and habitat modification restrictions are in place each year until occupancy is determined.

Owl surveys have been conducted on LANL property annually since 1994. In 1995, a pair of Mexican spotted owls was located and the AEI has been occupied each year since. In 2004, 2005, and 2006, a second AEI was found to be occupied by at least one Mexican spotted owl. In 2007, a pair of spotted owls was located in a third canyon and this AEI has been occupied each year since. The two AEIs with active pairs have successfully bred in most years.

B. States

a. Arizona

All of Arizona's native wildlife, including threatened and endangered species, is protected under the general provisions of Arizona Revised Statutes, Title 17. It is illegal to "take" wildlife unless authorized by the Arizona Game and Fish Commission. "Take" is specifically defined under A.R.S. § 17-101 to mean "pursuing, shooting, hunting, fishing, trapping, killing, capturing, snaring or netting wildlife or the placing or using of any net or other device or trap in a manner that may result in the capturing or killing of wildlife." Further, the Mexican spotted owl is protected under A.R.S. § 17-236 which makes it "unlawful to take or injure any bird or harass any bird upon its nest, or remove the nests or eggs of any bird, except as ...authorized by commission order." There is no commission order in Arizona allowing for the "take" of Mexican spotted owl as defined in Title 17.

Currently, in Arizona's State Wildlife Action Plan, the owl is a Species of Greatest Conservation Need. It is listed as a Tier 1a species because it is federally listed as threatened. Species identified in the State Wildlife Action Plan have the highest priority for conservation management and are eligible for congressionally appropriated funds.

Management actions taken by the AGFD for the spotted owl have included: (1) participation in the original USFS-sponsored Mexican Spotted Owl Task Force; (2) member of the FWS-sponsored Mexican Spotted Owl Status Review Team; (3) member of the Mexican Spotted Owl Recovery Team; (4) member of three Mexican Spotted Owl EMU Working Teams; (5) funding research and surveys to determine the status of the Mexican spotted owl in Arizona; and (6) continued review and technical guidance on projects that might impact Mexican spotted owl occupied or potential habitat.

Only one Mexican spotted owl nest has been located on Arizona State land, although approximately seven primary activity centers are on state or private lands located within Coconino, Santa Cruz, and Cochise counties. However, more Mexican spotted owls may occur on state lands than what is known because no standardized surveys have been completed on these lands in over a decade.

b. Colorado

The Mexican spotted owl was state-listed as threatened by the Colorado Division of Wildlife (CDOW) in 1993. "Threatened" wildlife is defined as "...any species or subspecies of wildlife which, as determined by the Colorado Wildlife Commission, is not in immediate jeopardy of extinction but is vulnerable because it exists in such small numbers or is so extremely restricted throughout all or a significant portion of its range that it may become endangered." Threatened status protects wildlife species by making it unlawful "...for any person to take, possess, transport, export, process, sell or offer for sale...any species or subspecies of [threatened] wildlife...." In addition, the CDOW is legislatively mandated to "...establish such programs including acquisition of land...as are deemed necessary for management of...threatened species."

c. New Mexico

Although the Mexican spotted owl is not state-listed under the New Mexico Wildlife Conservation Act (17-2-37 New Mexico Statutes Annotated [NMSA 1978]), it and other owls are protected by Statute 17-2-14 (NMSA 1978), which states that it is unlawful for any person to take, attempt to take, possess, trap, ensnare, or in any manner injure, maim, or destroy owls. Under this statute, it is also unlawful to purchase, sell, trade, or possess for the purpose of selling or trading any owl parts. The owl is also listed as a Species of Greatest Conservation Need in the Comprehensive Wildlife Conservation Strategy of New Mexico (NMDGF 2006), which is New Mexico's strategic action plan for conserving the state's biodiversity and, thereby, precluding the necessity of listing more species as threatened and endangered.

Management actions taken by the New Mexico Department of Game and Fish for the spotted owl include: (1) participation in the original USFS-sponsored Mexican Spotted Owl Task Force; (2) serving as a member of the FWS-sponsored Mexican Spotted Owl Status Review Team; (3) serving as a consultant to the Mexican Spotted Owl Recovery Team; (4) serving as a member of Mexican Spotted Owl EMU Working Teams; (5) funding research to determine the status of the Mexican spotted owl in New Mexico; (6) funding surveys in Mexico and on non-Federal lands in New Mexico; (7) oversight of the creation of the first Mexican spotted owl statewide database; and (8) continued review and technical guidance on projects that might impact Mexican spotted owl occupied or potential habitat, as authorized by Statute 17-1-5.1 (NMSA 1978; M. Watson, New Mexico Department of Fish and Game, pers. comm.).

Mexican spotted owls or their required habitats are not known to occur on any state-administered lands, largely due to the fact that much of New Mexico's State lands have not been surveyed. Although spotted owls and their required habitats might occur on state park lands and New Mexico Department of Game and Fish Wildlife Management Areas, no standardized surveys have ever been completed on these lands (S. Cary, New Mexico State Parks Department, pers. comm., J. Hirsch, New Mexico Department of Game and Fish, pers. comm.). However, spotted owls have been detected within 1.6 km (1 mile) of State Park and New Mexico Department of Game and Fish co-managed land near Fenton Lake (Sandoval County) during spotted owl surveys completed by the US Forest Service (J. Hirsch, New Mexico Department of Game and Fish, pers. comm.). Similar to other state lands, New Mexico State Trust Lands (Trust Lands) are not known to support Mexican spotted owls (S. Knox, New Mexico State Land Office, pers. comm.). Still, it is possible that spotted owls occur on Trust Lands as potential suitable spotted owl habitat has been identified on Trust Lands in southern Colfax County, southern Lincoln County, northwestern Union County, eastern Catron County, and northern Otero County. Surveys have been conducted only when forest-thinning projects were proposed within potential spotted owl habitat on Trust lands near Black Lake (Colfax County), Valley of the Utes (Colfax County), and Moon Mountain (Lincoln County). Thus, spotted owl occupancy of potential suitable habitat cannot be determined until other Trust Lands are surveyed. Funding options are currently being explored for surveying other potential habitat on Trust Lands (S. Knox, New Mexico State Land Office, pers. comm.).

d. Texas

Few Mexican spotted owls are documented for Texas, and most of the location records are in Guadalupe National Park (see section on Guadalupe Mountains National Park, Texas, above). However, there are four known spotted owl locations in the Davis Mountains of Jeff Davis County based on owl detections since the mid-1990s. These locations are in the Davis Mountains preserve, owned by The Nature Conservancy. Given the size of the Davis Mountains, the extensive amount of canyon and mesic pine-oak habitat, and recent results from predictive habitat models (Chihuahuan Desert Network, USDI NPS, unpublished data), it is likely that there are a number of undiscovered owls in that area. There is also one visual observation of a Mexican spotted owl in Big Bend National Park.

The State of Texas has listed the species as threatened. In addition, Chapters 67 and 68 of the Texas Parks and Wildlife Code, and Sections 65.171-65.176 of the Texas Administrative Code, prohibit the taking, possession, transportation, or sale of any animal species designated by state law as endangered or threatened without issuance of a permit. Destruction of eggs and nests of nongame birds is also prohibited

(<http://www.tpwd.state.tx.us/huntwild/wild/species/ending/regulations/texas/index.phtml>).

e. Utah

The Mexican spotted owl is included on the Utah State Sensitive Species list and the Utah Wildlife Action Plan as a Federally Threatened Species and Tier I Species of Greatest Conservation Need, respectively. Threatened species receive protected status under Utah wildlife code. For species under protected status, "...[A] person may not take...protected wildlife or their parts; an occupied nest of protected wildlife; or an egg of protected wildlife." Nor may a person "...transport,...sell or purchase...or possess protected wildlife or their parts."

The Utah Division of Wildlife Resources (UDWR) has been collaborating with Federal agencies in implementing recommendations from the 1995 Recovery Plan. The three primary thrusts of this work have been to fill gaps in data on spotted owl distribution and status, to develop multivariate models of spotted owl canyon habitat in Utah, and to test occupancy sampling as a monitoring tool. The UDWR also works closely with the Utah Field Office of FWS and other Federal and state agencies in providing information for formal and informal consultations.

C. Tribes

Tribal beliefs and philosophies guide resource management on Tribal lands. Included within this cultural context, many Tribes employ the federally accepted survey methodology and management techniques consistent with those contained in this Recovery Plan. Several Tribes consider owls a bad omen or a warning of danger or neglect, so owls play an important cultural role. Tribal beliefs also dictate that all living creatures are essential parts of nature and, as such, they are revered and protected. For example, the Elders Council of San Carlos Apache Tribe expressed the traditional view that owls and their homes should not be disturbed.

Tribes are sovereign governments with management authority over wildlife and other natural and cultural resources on their lands. Many Tribes maintain professionally staffed wildlife and natural resources management programs to ensure prudent management and protection of Tribal resources, including threatened and endangered species.

Mexican spotted owl habitat or potential habitat exists on 10 Indian reservations in the United States. Nine of the Tribes have conducted spotted owl surveys, and six Tribes have located spotted owls on their lands. Two other Tribes have historical spotted owl records. The FWS is aware of spotted owl conservation efforts on seven Indian Reservations/Pueblos: the Mescalero Apache, Fort Apache (White Mountain Apache Tribe), San Carlos Apache, Jicarilla Apache, Navajo Nation, Southern Ute, and Northern and Southern Pueblos Agencies.

a. Mescalero Apache Tribe (New Mexico)

The Mescalero Apache Tribe began conducting surveys for the Mexican spotted owl in 1988, five years prior to its listing as a threatened species under the ESA. Since that time, more than 48,500 ha (120,000 ac) of forested reservation lands have been surveyed for the owl. The first draft of the Mescalero's Mexican Spotted Owl Management Plan was completed in 1995 and, after six years of negotiations and revisions, the plan was accepted by the FWS in 2001.

Forest management on the Mescalero Apache Reservation emphasizes uneven-aged silvicultural techniques, specifically single-tree and group-selection cutting methods. Uneven-aged management results in a relatively unfragmented forest with stand-level conditions exhibiting vertical and horizontal structural diversity and moderate to thick canopy cover. As in many areas of the southwestern United States, stand-replacing fires are the primary threat to preserving Mexican spotted owl habitat. The Mescalero Apache Tribe maintains an active resource management program that includes forest stand improvement, fuels reduction in the WUI, and watershed restoration treatments.

b. White Mountain Apache Tribe (Arizona)

We have no approved write-up for the White Mountain Apache Tribe.

c. San Carlos Apache Tribe (Arizona)

The San Carlos Apache Tribe has delineated PACs around known owl sites. Forested habitat of the reservation is divided into management units (Malay Gap, Point of Pines, and Hilltop). All three management units are managed under an approved management plan that adheres to the 1995 Recovery Plan. The San Carlos Apache Tribe developed a Mexican spotted owl conservation plan to ensure that Tribal land-management activities and policies do not jeopardize continued existence of Mexican spotted owls on the San Carlos Apache Indian Reservation. Jeopardizing the existence of any species would be counter to the Apache cultural belief that all things were created for a purpose and have value.

Mexican spotted owl habitat has been identified and delineated throughout the reservation. Approximately 90% of tribally identified nesting, roosting, and foraging habitats is on lands

inoperable for timber harvest and therefore are not in the commercial timber base. This leaves wildfire as the greatest threat to owl habitat on the reservation. The San Carlos Apache Tribe is addressing this threat through fuels-treatment programs as available funding allows and through the development of a Wildland Fire Management Plan.

In 2004, the San Carlos Apache Tribe received funding from the FWS Tribal Wildlife Grant Program to conduct a study on habitat use, population structure, and dispersal patterns of juvenile Mexican spotted owls on the San Carlos Apache Indian Reservation. This study increased the Tribe's capacity to manage its lands for the betterment of the Mexican spotted owl.

d. Jicarilla Apache Tribe (New Mexico)

The Jicarilla Apache Nation has developed a Mexican spotted owl conservation plan, approved by the Jicarilla Legislative Council and accepted by the FWS. No resident spotted owls have been detected on the reservation; however, in the event resident owls are detected, the Jicarilla Apache Tribe has proposed to designate a 405 ha (1,000 ac) management territory. Uneven-aged timber management will be allowed to continue in all but 40 ha (100 ac) of the territory. In the absence of confirmed resident owls, all mixed-conifer stands ≥ 10 ha (25 ac) are treated as roosting/nesting sites and timber harvest is not allowed. A seasonal restriction is also proposed around any located active nest sites.

e. Navajo Nation (Arizona, New Mexico, Utah)

The Navajo Nation occupies over 69,930 km² (27,000 mi²) on the Colorado Plateau within Arizona, New Mexico, and Utah. The Navajo Nation's Department of Fish and Wildlife (Department), under the oversight of the Navajo Nation Council's Resources Committee, is the entity within the Navajo Nation Government that is responsible for management and protection of the Mexican spotted owl on Navajo lands. The Department developed the "Navajo Nation Management Plan for the Mexican Spotted Owl," which was approved by the Resources Committee of the Navajo Nation Council in 2000. Threats to the owl identified in that management plan include abandoned mine reclamation, commercial timber harvest, wildfire and fire management, fuelwood harvest, livestock grazing, home-site development, large-scale coal mining, recreation, road building and reconstruction, and other human developments and activities.

Although no comprehensive surveys for spotted owls have been performed across the Navajo Nation, this species has been found during pre-project, clearance-type surveys and other biological surveys. This survey information, along with knowledge about the distribution of habitat, gives the Department a relatively good understanding of spotted owl distribution on Navajo lands. The owls occupy three habitat types on the Navajo Nation including the traditional, steep-sloped, mixed-conifer forests; cool, mesic canyons; and a unique habitat referred to as Black Mesa. The latter is restricted to the Black Mesa region near the center of the Navajo Nation, and it is unique because it consists of low- to moderately-sloped drainages containing small patches of Douglas-fir within a matrix of pinyon-juniper woodlands. There is no federally designated critical habitat for the spotted owl on the Navajo Nation.

The Navajo Nation Management Plan for the Mexican Spotted Owl (Management Plan) outlines the various components by which the owl is managed and protected. The owl is protected from “take” under Navajo Nation Code due to its status on the Navajo Endangered Species List; this adds an additional layer of regulation beyond the Federal ESA and Migratory Bird Treaty Act. Their Management Plan provides protection to the owl through: (1) the Tribal project-approval process; (2) mandatory pre-action surveys using the accepted Mexican Spotted Owl Inventory Protocol; (3) establishment of PACs around all recent and historical owl sites consistent with the 1995 Recovery Plan; and (4) Federal agency consultations with the FWS for Federal actions. In addition, the Department has been a member of the Colorado Plateau Mexican Spotted Owl Recovery Implementation Working Team since its inception.

f. Southern Ute (Colorado)

Both the Southern Ute Tribe and the U.S. Bureau of Indian Affairs, Southern Ute Agency, have shown a strong willingness to work with the FWS in all aspects of MSO conservation, including extensive survey work and implementation of appropriate mitigation measures for planned projects. More than 12,150 ha (30,000 ac) of forested reservation lands have been surveyed for the owl since 1990. Management guidelines have been developed for areas of Tribal land proposed for fuels-reduction projects. These guidelines generally coincide with those set forth in the 1995 Recovery Plan for Restricted and Protected Steep Slope Habitats. Also, fuels-reduction treatments on mesa tops emphasize stand-level conditions with vertical and horizontal structural diversity and the retention of large, downed logs and snags, where possible, while still meeting the fuels reduction goal.

g. Northern and Southern Pueblos Agencies (New Mexico)

Twenty-three federally recognized and two Self-Governance Tribes have land within New Mexico’s boundaries. The U.S. Bureau of Indian Affairs Southwest Regional Office has a Federal trust responsibility to provide intergovernmental assistance to all of New Mexico’s tribes through nine agencies: Jicarilla, Laguna, Mescalero, Northern Pueblos, Ramah Navajo, Southern Pueblos, Southern Ute, Ute Mountain, and Zuni. The agencies can provide technical guidance and support for various forest and wildlife programs, such as completing Mexican spotted owl surveys in areas targeted for forest thinning. Tribes served by the Northern Pueblos Agency – the Pueblos of Nambe, Picuris, Pojoaque, San Ildefonso, Ohkay Owingeh, Santa Clara, Taos, and Tesuque – and Tribes served by the Southern Pueblos Agency – the Pueblos of Acoma, Cochiti, Isleta, Jemez, Sandia, San Felipe, Santa Ana, Santo Domingo, Ysleta del Sur Pueblo, and Zia – are considered to not support spotted owl habitat or to only support a limited amount of habitat (L. Abeita, Southern Pueblos Agency, pers. comm.; N. Jojola, Northern Pueblos Agency, pers. comm.). Information on extent of spotted owl habitat on other Tribal lands within New Mexico is not available. Nonetheless, when Tribal projects are funded with Federal dollars, Mexican spotted owl surveys are completed on Tribal land in compliance with requirements of the National Environmental Policy Act. In addition, some Tribes complete non-federally required spotted owl surveys on their lands, e.g., when completing forest thinning projects or evaluating the effects of wildfire. Two of the 10 tribes served by the Southern Pueblo Agency have completed spotted owl surveys, which were done in association with federally funded forest management projects, and no owls were located (L. Abieta, Southern Pueblos Agency, pers.

comm.). Lands within the vicinity of the Pueblos of Santa Clara and San Ildefonso were surveyed for owls after the 2000 Cerro Grande Fire. Since then, only one of the eight tribes served by the Northern Pueblos Agency has completed spotted owl surveys, which were done in association with a non-federally funded forest management project (N. Jojola, Northern Pueblos Agency, pers. comm.).

2. Conservation Measures and Management in Mexico

A. Protection Status

In Mexico, the Norma Oficial Mexicana 059 (NOM-059-SEMARNAT-2001) is the official list for endangered species. Proposed species are assigned to several threat categories following a review by several Mexican specialists. The Mexican spotted owl is listed as a Threatened species on this list (SEMARNAT 2002).

Under the international treaty Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), *Strix occidentalis lucida* is listed on Appendix II (UNEP-WCMC, 2010). The IUCN Red List of Threatened Species includes this bird in the category Near Threatened-NT, mentioning declining populations (BirdLife International 2008).

B. Records from Natural Protected Areas (NPAs)

Several Natural Protected Areas (Áreas Naturales Protegidas) in Mexico have records of this species (see Table 6 and Table 7 in Recovery Plan). The Zona Sujeta a Conservación Ecológica “Sierra Fría” in Aguascalientes is a state protected area where pairs of owls have been documented in six different localities: Barranca El Tiznado, Cueva Prieta, El Carrizal, El Pinal, El Tejamanil, and La Angostura. Since nests have not been found, it is unclear if the species nests in the area (Márquez-Olivas et al. 2002). It is important to mention that in Sierra Fría logging is prohibited and security guards inspect every vehicle driving through the area to stop illegal timber harvest as part of the protected area management (Tarango et al. 2001). There are also records of *Strix occidentalis lucida* in the Reserva de la Biosfera de la Michilía, a federal protected area in southeastern Durango.

C. Binational Conservation Efforts

Wildlife agencies from Canada, the United States, and Mexico signed a memorandum of understanding in 1996 for the official collaboration among the three countries to protect the wildlife and ecosystems of North America through the establishment of the Trilateral Committee for Wildlife and Ecosystem Conservation and Management. At annual meetings, the Committee addresses a broad array of biodiversity issues, including key strategies for conservation in currently active working groups. One of their working groups, the Species of Common Concern, facilitates dialogue with government wildlife managers to determine species with shared interest and the implementation of protection and recovery actions.

Likewise the CONANP is currently implementing Endangered Species Recovery Plans (Programa de Conservación de Especies en Riesgo [PROCER]) and developing Species

Conservation Action Plans (Programas de Acción para la Conservación de Especies [PACE]) to influence protection and recovery of species. Although PROCER is starting with 30 taxa, it is not limited to them because the objective is to pay attention to threatened and priority species in and out of NPAs in Mexico. Based on that premise, *Strix occidentalis lucida*, a listed threatened species by the NOM-059-SEMARNAT-2001, is not excluded from PROCER. It is worth mentioning that although conservation actions focused directly on this species have not been implemented yet, habitat protection has been started for species sharing the owl habitat and protection needs since 2008.

APPENDIX I

ACRONYMS USED IN THE MEXICAN SPOTTED OWL RECOVERY PLAN

AEI	Areas of Environmental Interest
AGFD	Arizona Game and Fish Department
AOU	American Ornithologists' Union
ATV	All-terrain vehicle
BA	Basal area
BACI	Before-After-Control-Impact
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BRE	Basin and Range-East
BRW	Basin and Range-West
CDC	Center for Disease Control
CDOW	Colorado Division of Wildlife
CFR	Code of Federal Regulations
CP	Colorado Plateau Recovery Unit
dbh	Diameter at breast height
DFC	Desired Future Condition
DMA	Designated Management Area
DOD	United States Department of Defense
DPS	Distinct Population Segment
EMU	Ecological Management Unit
ERA	Forest Ecosystem Restoration Analysis
ESA	Endangered Species Act
ESR	Emergency stabilization and rehabilitation
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
FIA	Forest Inventory and Analysis
FLRA	Forest Landscape and Restoration Act
FO	Field office
FSM	Forest Service Manual
FWS	United States Fish and Wildlife Service
GIS	Geographic Information System
GPS	Global Positioning System
HFRA	Healthy Forests Restoration Act
IDT	Interdisciplinary Team
KAFB	Kirtland Air Force Base
LANL	Los Alamos National Laboratory
MLE	Maximum likelihood estimation
NEPA	National Environmental Policy Act
NMDGF	New Mexico Department of Game and Fish
NMSA	New Mexico Statutes Annotated
NOFS	Naval Observatory Flagstaff Station
NPS	National Park Service

NRZs	Nesting-roosting Zones
OHV	Off-highway vehicle
PAC	Protected Activity Center
PFC	Proper functioning condition
PNV	Potential natural vegetation
QMD	Quadratic Mean Diameter
RMSTAND	Stand-exam analysis routines
ROD	Record of Decision
RU	Recovery Units
SDI	Stand Density Index
SMR	Soil moisture
SNA	Suitable Nesting Area
SRM	Southern Rocky Mountain
STR	Soil temperature
SWWP	Southwestern white pine
TIN	Triangulated irregular network
UDWR	Utah Division of Wildlife Resources
UGM	Upper Gila Mountain
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFS	Forest Service
UTM	Universal Transverse Mercator
SGCNA	Species of Greatest Conservation Need in Arizona
WNV	West Nile Virus
WSCA	Wildlife of Special Concern in Arizona
WUI	Wildland-urban interface

APPENDIX J

LATIN NAMES FOR COMMON NAMES USED IN THE TEXT

Names appear in taxonomic order.

Common Name

Scientific Name

ANIMALS

Golden eagle	<i>Haliaeetus leucocephalus</i>
Northern goshawks	<i>Accipiter gentilis</i>
Red-tailed hawk	<i>Buteo jamaicensis</i>
Great horned owl	<i>Bubo virginianus</i>
Northern spotted owl	<i>Strix occidentalis caurina</i>
Mexican spotted owl	<i>Strix occidentalis lucida</i>
California spotted owl	<i>Strix occidentalis occidentalis</i>
Barred owl	<i>Strix varia</i>
Fulvous owl	<i>Strix fulvescens</i>
Pocket gophers	<i>Thomomys</i> spp.
Voles	<i>Microtus</i> spp.
Long-tailed vole	<i>Microtus longicaudus</i>
Mexican vole	<i>Microuis mexicanus</i>
Rabbits	<i>Sylvilagus</i> spp.

PLANTS

Mexican pinyon	<i>Pinus cembroides</i>
Pinyon pine	<i>Pinus edulis</i>
Bristlecone pine	<i>Pinus aristata</i>
Limber pine	<i>Pinus flexilis</i>
Southwestern white pine	<i>Pinus strobiformis</i>
Chihuahua pine	<i>Pinus leiophylla</i>
Ponderosa pine	<i>Pinus ponderosa</i>
Arizona pine	<i>Pinus ponderosa</i> var. <i>arizonica</i> , or <i>Pinus arizonica</i>
Apache pine	<i>Pinus engelmannii</i>
Aztec pine	<i>Pinus teocote</i>
Engelmann spruce	<i>Picea engelmannii</i>
Blue spruce	<i>Picea pungens</i>
Douglas-fir	<i>Pseudotsuga menziesii</i>
Rocky Mountain Douglas-fir	<i>Pseudotsuga menziesii</i> var. <i>glauca</i>
True fir	<i>Abies</i> spp.
White fir	<i>Abies concolor</i>
Corkbark fir	<i>Abies lasiocarpa</i> var. <i>arizonica</i>
Subalpine fir	<i>A. lasiocarpa</i> var. <i>lasiocarpa</i>
Willow	<i>Salix</i> spp.
Cottonwood	<i>Populus</i> spp.

Quaking aspen	<i>Populus tremuloides</i>
Gray oak	<i>Quercus grisea</i>
Silverleaf oak	<i>Quercus hypoleucoides</i>
Gambel oak	<i>Quercus gambelii</i>
No common name	<i>Quercus resinosa</i>
Gentry's oak	<i>Quercus gentry</i>
Mexican red oak	<i>Quercus eduardii</i>
Chihuahua oak	<i>Quercus chihuahuensis</i>
Mexican white oak	<i>Quercus potosina/ Quercus laeta</i>
Encino manzano	<i>Quercus coccolobifolia</i>
Boxelder	<i>Acer negundo</i>
Rocky Mountain maple	<i>Acer glabrum</i>
Bigtooth maple	<i>Acer grandidentatum</i>
Texas madrone	<i>Arbutus xalapensis</i>

APPENDIX K

GLOSSARY

- A -

adaptive kernel (AK) - Refers to a method of estimating home-range size. This method involves estimating a bivariate probability distribution from the observed animal locations, and it can be used to compute the area containing a specified proportion of those locations.

adaptive management - A deliberate and iterative process to optimize management strategies. The process entails formation of a management model, management implementation, monitoring and interpretation of system responses, and ultimately refinement of management model given lessons learned.

- B -

basal area - The cross-sectional area of a tree stem near its base, generally measured at breast height (including bark).

before-after-control-impact (BACI) - A specific type of manipulative experiment. Under the BACI design, potential responses are examined before and after proposed manipulations at control (or reference) sites and at impact sites.

biomass - With respect to individuals, this refers to the weight (mass) of a plant or an animal. With respect to areas or communities, this refers to the total mass of living organisms in that area or community at any given time. With respect to owl diet, this refers to the relative contribution of one species (or group) of prey animals to the overall diet.

bosque - A discrete grove or thicket of trees, particularly in lowland or riparian areas of the Southwestern United States and Mexico; for example a cottonwood bosque or a mesquite bosque.

- C -

canopy - A layer of foliage, generally the uppermost layer, in a forest stand. Can be used to refer to midstory or ***understory*** vegetation in multi-layered stands.

canopy closure - An estimate of the amount of overhead tree cover (also canopy cover).

commercial forest land - Forested land deemed tentatively suitable for the production of crops of timber that has not been withdrawn administratively from timber production (see ***reserved land***).

confidence interval - An interval constructed around a parameter estimate in which that estimate should occur with a specified probability, such as 95% of the time.

connectivity - An estimate of the extent to which intervening habitats connect subpopulations of spotted owls.

- D -

demography - The quantitative analysis of population structure and trend.

diameter at breast height (dbh) - A standard measure of tree size.

dispersal - The movement of organisms from their birth place to another location where they produce offspring.

disturbance - Significant alteration of habitat structure or composition. May be natural (e.g., fire) or human-caused events (e.g., timber harvest).

- E -

early seral stage - An area that is in the early stages of ecological succession.

ecological management unit (EMU) - An updated term for what was previously referred to in the 1995 Recovery Plan as a **recovery unit** (RU). A specific geographic area, identified mainly from physiographic provinces, used to evaluate the status of the Mexican spotted owl and within which to develop specific management guidelines.

ecological succession - The orderly progression of an area through time from one vegetative community to another in the absence of disturbance. For example, an area may proceed from grass-forb through aspen forest to mixed-conifer forest.

ecosystem - An interacting biophysical system of organisms and their environment.

emigration - Permanent movement of individuals away from a population.

encinal - Of or relating to oaks, particularly plant communities dominated by live oaks.

environmental stochasticity - Random variation in environmental attributes, such as weather patterns or fire regimes.

even-aged forest/stands - Refers to forests composed of trees with a time span of <20 years between oldest and youngest individuals.

even-aged management - The application of a combination of actions that result in the creation of stands in which trees are essentially all of the same age. Cutting methods that produce even-aged stands include clearcuts, seed-tree cuts, and shelterwood cuts.

- F -

fire regime - A description of the frequency, severity, and extent of fires that typically occur in an area or vegetation type.

floater - A member of a spotted owl population that does not hold, maintain, or defend a territory (see Franklin 1992).

forb - A broadleaved, herbaceous plant (e.g., columbine).

fragmentation - The process of reducing the size and connectivity of habitat patches.

fuel loads - The amount of combustible material present per unit area.

fuels - combustible materials.

fuelwood - Wood, either green or dead, harvested for purposes of cooking or space heating, and usually measured in cords (1 cord = 128 cubic feet.).

- G -

gene flow - The movement of genetic material among populations.

Geographical Information System (GIS) – A computer system capable of storing and working with spatial data.

graminoids - Any plants of the grass family in particular and also those plants in other families that have a grass-like form or appearance (e.g., sedges).

group-selection cutting - Removal during harvest of groups of trees.

- H -

habitat - Suite of existing environmental conditions required by an organism for survival and reproduction. The place where an organism typically lives.

habitat fragmentation - See *fragmentation*.

habitat type - See *vegetation type*.

hanging canyon - A side canyon, the mouth of which lies above the floor of a larger canyon to which the side canyon is tributary.

home range - The area used by an animal in its day-to-day activities.

- I -

immigration - The movement of individuals from other areas into a given area.

intermediate/suppressed tree position - Trees that are shorter than the dominant and co-dominant, larger trees, yet taller than understory shrubs and herbaceous vegetation.

Intermountain Region - An administrative region of the USDA Forest Service, lying between the Pacific Coastal and Rocky Mountain Ranges and including Utah, Nevada, southern Idaho, and parts of Wyoming and Montana.

- K -

key grazing areas - Primarily riparian areas, meadows (natural), and created openings that receive disproportionate grazing by ungulates due to their location, the quantity and quality of forage they produce, and their grazing or browsing value (Holechek et al. 2001).

- L -

large tree - In this Recovery Plan, large trees are defined as trees ≥ 46 -cm [18-inches] dbh.

ladder fuel - Dead or living fuels that connect fuels on the forest floor to the canopy and promote the spread of surface fires to tree crowns.

Land Management Plan (LMP) - A plan written for the management of a National Forest. These plans were mandated by the National Forest Management Act of 1976.

late seral stage forest - A forest in the latter stages of development, usually dominated by large, old trees.

- M -

macrohabitat - Landscape-scale features that are correlated with the distribution of a species; often used to describe seral stages or discrete arrays of specific vegetation types.

madrean - Pertaining to Mexico's Sierra Madre cordillera, or to plant species or communities whose primary affinity is to that region (see also **Petran**).

madrean pine-oak forest - Forests in which any of several pines characterize the overstory and in which midstory oaks are mostly evergreen species. Many of the dominant species are **Madrean** in affinity. See Marshall (1957) for descriptions. This habitat type was included as pine-oak by Fletcher and Hollis (1994).

management experiment - A manipulative experiment conducted through partnership of professional managers and scientists to quantify the effects of one or more management activities.

mesic - Of or relating to conditions between hydric and **xeric** or the specific quality of being adapted to conditions between wet and dry.

metapopulation - Systems of local populations connected by dispersing individuals.

midstory - Intermediate tree position in a forested stand. These trees are shorter than the dominant and co-dominant, larger trees, yet taller than understory shrubs and herbaceous vegetation.

microhabitat - Habitat features at a fine scale; often identifies a unique set of local habitat features.

microtine - For the purposes this plan, any vole of the genus *Microtus*.

migration - The seasonal movement from one area to another and back.

mixed-conifer forest type - Overstory species in these forests include Rocky Mountain Douglas-fir, white fir, Rocky Mountain ponderosa pine, quaking aspen, southwestern white pine, limber pine, and blue spruce. Refer to Section II.C for a more precise discussion and definition of mixed-conifer forest type.

model - A representation of reality, based on a set of assumptions, that is developed and used to describe, analyze, and understand the behavior of a system of interest.

monitoring - The process of collecting information to track changes of selected parameters over time.

mousing - a technique used to assess reproductive status of a pair of spotted owls. Entails feeding mice to adult owls and observing the owls' subsequent behavior.

multi-layered (or multi-storied) stands – Forest stands with >2 distinct canopy layers. Applied to forest stands that contain trees of various heights and diameters and therefore support foliage at various heights in the vertical profile of the stand.

- N -

null hypothesis - A hypothesis stating that there is no difference between units being compared.

- O -

old growth - An old forest stand, typically dominated by large, old trees, with relatively high canopy closure and a high incidence of snags, as well as logs and other woody debris.

opening - A break in overstory and understory plant canopy as created by the natural absence or physical removal of trees and shrubs. Quantitative descriptions may be based on overhead canopy closure (e.g., an area of defined size with <10% cover) or on density of trees (e.g., an area of relevant size with fewer than five trees ≥ 11 inches in diameter). The size of area will depend on the ecological objective being considered. Relevant to habitat use by spotted owls, a small opening would be 0.25 ac, and a large opening would be >2 ac.

other forest and woodland types – Vegetation types that are neither ***restricted*** or within ***PACs*** as to management recommendations provided in this Recovery Plan.

other riparian - Classified as those areas that are not regularly used by owls, but these areas may occasionally provide “stepping stones” for movement between population segments or be used by wintering owls.

overstory - The highest limbs and foliage of a tree, and consequently extending and relating to the upper layers of a forest canopy.

- P -

pellet - A compact mass of undigested material remaining after preliminary digestion and eliminated by regurgitation rather than by defecation.

peromyscid - Any mouse in the genus *Peromyscus* of the family Muridae (formerly Cricetidae).

petran - Pertaining to the Rocky Mountain area. Used to identify plant associations or species that have their primary affinity to the Rocky Mountain area (see also ***madrean***).

physiographic province - A geographic region in which climate and geology have given rise to a distinct array of land forms and habitats.

pine-oak forest type - Stands within the *Pinus ponderosa* and *Pinus leiophylla* series that exhibit a pine overstory and oak understory. Refer to Section II.C for these criteria and a more precise discussion and definition.

pre-commercial thinning - The practice of removing some of the smaller trees in a stand so that remaining trees will grow faster.

prescribed fire - A fire burning under specified conditions; may result from either planned or unplanned ignitions.

ponderosa pine forest type - Any forested stand of the *Pinus ponderosa* Series not included in the pine-oak forest type definition, or any stand that qualifies as pure (i.e., any stand where a single species contributes >80% of the basal area of dominant and codominant trees) ponderosa pine, regardless of the series or habitat (see also Eyre 1980). Refer to Section II.C for a more precise discussion and definition.

population - A collection of individuals that share a common gene pool.

population density - The number of individuals per unit area.

population viability - The probability that a population will persist for a specific period of time, despite demographic and environmental stochasticity.

power - with respect to statistical comparisons, refers to the probability of not making a Type-II error.

Protected Activity Center (PAC) - An area established around an owl nest (or sometimes roost) site, for the purpose of protecting that area. Management of these areas is largely restricted to managing for forest-health objectives.

protected areas - As used in this Plan, refers to areas that are protected and where most management activities are very restricted or disallowed. Includes ***Protected Activity Centers***.

- R -

recovery - As provided by the Endangered Species Act and its implementing regulations, the process of returning a threatened or endangered species to the point at which protection under the Endangered Species Act is no longer necessary.

Recovery Plan - as provided by the Endangered Species Act, a plan for management of a threatened or endangered species that lays out the steps necessary to recover a species (see *recovery*).

Recovery Team - A team of experts appointed by the Fish and Wildlife Service whose charge is development of a **Recovery Plan**.

Recovery Unit (RU) - A specific geographic area, identified mainly from physiographic provinces, used to evaluate the status of the Mexican spotted owl and within which to develop specific management guidelines. This term has been replaced by **ecological management unit (EMU)** in the first revision (2011) of this plan.

recruitment - The addition of individuals to a population from birth and immigration.

reserved lands - Lands that have been administratively withdrawn from commercial activities, such as wilderness areas or research natural areas.

restricted areas - As used in this Recovery Plan, refers to areas that are not protected (see **protected areas**), but where specific guidelines for management activities are proposed.

riparian - Of or relating to a river; specifically applied to ecology, this term describes the land immediately adjoining and directly influenced by streams. For example, riparian vegetation includes any and all plant-life growing on the land adjoining a stream and directly influenced by that stream.

riparian forests - Forests along rivers, streams, and other wetland environments, typically characterized by the presence of riparian-obligate plants such as cottonwoods, willows, sycamores, or alders. Descriptions are provided by Dick-Peddie (1993) and others.

Rocky Mountain Region - An administrative region of the U.S. Department of Agriculture Forest Service, including Colorado, Nebraska, South Dakota, and parts of Wyoming.

rotation - The planned number of years between regeneration of a forest stand and final harvest of that stand.

- S -

salvage - See **sanitation salvage**.

sanitation salvage - Removal of dead, damaged, or susceptible trees primarily to prevent the spread of pests or pathogens and to promote forest health.

seral species - Any plant or animal that is typical of a seral community (stage).

seral stage - Any plant community whose plant composition is changing in a predictable way; for example, an aspen community changing to a coniferous forest community.

shelterwood cut - An even-aged regeneration cutting in which new tree seedlings are established under the partial shade of remnant seed trees.

silviculture - The practice of controlling the establishment, composition, and growth of forests.

single-tree selection cutting - A cutting method based on removal of individual trees, rather than groups of trees (see also group selection cutting).

snag - A standing dead tree.

source - In a population sense, refers to a population where birth rate exceeds death rate. Such a population produces an excess of juveniles that can disperse to other populations (see ***sink***).

Southwestern Region - An administrative unit of the U.S. Department of Agriculture Forest Service, including Arizona and New Mexico; and an administrative unit of the U.S. Department of Interior Fish and Wildlife Service, including Arizona, New Mexico, Texas and Oklahoma.

spruce-fir forest type - High-elevation forests occurring on cold sites with short growing seasons, heavy snow accumulations, and strong ecological and floristic affinities to cold forests of higher latitudes. In general, dominant trees include Englemann spruce, subalpine and/or corkbark fir, or sometimes bristlecone pine. Refer to Section II.C for a more precise discussion and definition.

stand - Any homogeneous area of vegetation with more or less uniform soils, landform, and vegetation. Typically used to refer to forested areas.

stochastic - Eandom or uncertain.

stringers - Narrow bands of trees that extend into confined areas of suitable habitat such as in ravines.

subpopulation - A well-defined set of individuals that comprises a subset of a larger, interbreeding population (see also ***metapopulation***).

survivorship - The proportion of newborn individuals that are alive at any given age.

- T -

target population - The group of subjects for which a scientific conclusion can be applied. The target population is established at the onset of a scientific investigation and helps to shape sampling procedures.

Team - The Mexican Spotted Owl Recovery Team.

territory - The area that an animal defends against intruders of its own species. Not synonymous with **home range**, as parts of the home range are typically shared with other individuals.

Type-I error - The error made when a null hypothesis that is true is inappropriately rejected, as when concluding that two samples from a single population come from two different populations.

Type-II error - The error that is made when a null hypothesis that is false is not rejected, as when concluding that two samples from different populations came from a single population.

- U -

understory - Any vegetation whose canopy (foliage) is below, or closer to the ground than, canopies of other plants. The opposite of **overstory**.

uneven-aged management - The application of a combination of actions needed to simultaneously maintain continuous tall forest cover, recurring regeneration of desirable species, and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single-tree selection and group selection.

- V -

vegetation types - A land classification system based upon the concept of distinct plant associations. Vegetation or habitat types (plant associations) have been documented for western forests, and keys to their identification are available. The primary vegetation (or habitat) types used by Mexican spotted owls are discussed in Section II.C.

viability - Ability of a population to persist through time (see **population viability**).

vital rates - Collective term for age- or stagespecific demographic rates, such as birth and death rates, of a population.

vole - Any small rodent in the genus *Microtus*, *Clethrionomys*, or *Phenacomys*, all in the family Muridae.

- X -

xeric - Of or relating to perennially dry conditions or the specific quality of being adapted to dry conditions.