U.S. Fish & Wildlife Service

Farallon Islands National Wildlife Refuge

Estimated Lead Agency Total Costs Associated with Developing and Producing This EIS

$1,185,000

South Farallon Islands Invasive House Mouse Eradication Project: Final Environmental Impact Statement

Photos Courtesy of Island Conservation

This page intentionally left blank

Final Environmental Impact Statement

South Farallon Islands Invasive House Mouse Eradication Project

U.S. Department of the Interior
Fish and Wildlife Service
Pacific Southwest Region

Prepared by:

San Francisco Bay National Wildlife Refuge Complex
Fremont, California

March 2019

This page intentionally left blank

South Farallon Islands Invasive House Mouse Eradication Project: Final Environmental Impact Statement

March 2019

Lead agency:
U.S. Fish and Wildlife Service
San Francisco Bay National Wildlife Refuge Complex

Abstract
The United States Fish and Wildlife Service (Service) proposes to eradicate invasive, introduced house mice (*Mus musculus*) from the South Farallon Islands and eliminate their negative impacts to the ecosystem of the Farallon Islands National Wildlife Refuge. In accordance with the National Environmental Policy Act (NEPA) and its associated regulations, the Service has prepared this Final Environmental Impact Statement (EIS) to determine whether mouse eradication on the South Farallon Islands (or South Farallones) would have significant impacts on the quality of the human environment. The Service has considered three alternatives to address the problem of invasive mice on the South Farallones:

A. *Alternative A: No Action, which would allow house mice to remain on the South Farallon Islands to continue to negatively impact storm-petrels and other native and endemic species of the islands;*

B. *Alternative B (preferred alternative): Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of rodent bait containing Brodifacoum-25D Conservation as the primary method of bait delivery; and*

C. *Alternative* C: *Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of rodent bait containing Diphacinone-50 Conservation as the primary method of bait delivery.*

The Service has solicited comments from the interested public and prepared a Final EIS based on the responses to comments as well as updates needed between the Revised Draft and Final EIS. The Service expects to release a Record of Decision (ROD) after the 30-day wait period ends following the release of this Final EIS.

FOR FURTHER INFORMATION CONTACT:
Gerry McChesney, Refuge Manager
510–792–0222, ext. 222 (phone); gerry_mcchesney@fws.gov (email)

Executive Summary

The U.S. Fish and Wildlife Service (Service) is proposing to eradicate introduced, invasive house mice (*Mus musculus*) from the South Farallon Islands (or, South Farallones) within the Farallon Islands National Wildlife Refuge (Refuge), California. House mice are impacting the native ecosystem of the islands, including several native species and wilderness. Eradicating invasive mice is expected to benefit native seabirds, amphibians, terrestrial invertebrates, and plants and will help restore natural ecosystem processes on the islands. Eradicating house mice would eliminate the last remaining invasive mammal species on the Refuge, enhancing the recovery of this sensitive ecosystem.

Several species are expected to benefit from invasive house mouse eradication. The ashy storm-petrel (*Oceanodroma homochroa*) is a Service Bird Species of Conservation Concern; about half the world population of this species breeds on the South Farallones. The similar Leach's storm-petrel (*O. leucorhoa*), which is more abundant elsewhere, also likely will benefit. Removal of house mice is expected to dramatically reduce predation by burrowing owls (*Athene cunicularia*) on these species, an indirect impact of mice. The fall migrant owls are attracted to stay on the islands through the winter by an abundant mouse supply; after the mouse population crashes, the owls switch to feeding on the storm-petrels. The rare and endemic Farallon arboreal salamander (*Aneides lugubris farallonensis)* and Farallon camel cricket (*Farallonophilus cavernicolus*) are found nowhere else. Mice compete for invertebrate prey with the salamanders and possibly feed on the juveniles or eggs of the salamanders. Mice prey on the camel crickets. The maritime goldfield (*Lasthenia maritima)* is an annual plant endemic to seabird nesting islands along the coasts of California and Oregon; its largest population is on the South Farallones where it forms the basis of a unique plant community. Mice feed heavily on plant seeds and other plant parts, including the goldfields. Mouse predation is likely suppressing native plant populations in favor of more hardy introduced perennial plants.

The benefit of this conservation action is significant from a national perspective because of the importance of the South Farallon Islands for breeding seabirds and for their endemic species. The islands hold the largest seabird breeding colony in the lower 48 United States, including the world's largest colony of ashy storm-petrels. Mouse removal would help satisfy the Service's goal of invasive species control in the United States. Additionally, the eradication of house mice at the South Farallon Islands supports the Service's priority to facilitate ecological adaptation in the face of accelerated global climate change by removing a non-climate change stressor from the Farallones ecosystem. Mouse removal will also benefit wilderness character since mice significantly impact the natural character of the Farallon wilderness.

The South Farallon Islands are about 30 miles west of the Golden Gate Bridge and the City of San Francisco, California. The Farallon Islands National Wildlife Refuge was established in 1909 through Executive Order 1043 "… as a preserve and breeding ground for native birds," and originally included North and Middle Farallon Islands and Noonday Rock. The South Farallon Islands were added to the Refuge in 1969. In 1974, Congress designated all of the emergent land except the island of Southeast Farallon as wilderness under the Wilderness Act of 1964. The Service has cooperative agreements with Point Blue Conservation Science and the U.S. Coast Guard to assist with Refuge stewardship and/or wildlife monitoring. The waters around the

Farallones below the mean high tide line are part of the Greater Farallones National Marine Sanctuary.

The Farallones' isolated nature, varied and extensive habitats, and adjacent productive marine environment makes them an ideal breeding and resting location for wildlife. The Farallon Islands have experienced extensive human impacts beginning in the early 19th century when marine mammals were harvested for fur, oil, and food, while birds were impacted by subsistence hunting and an extensive egg gathering venture in the mid to late 19th century. A military outpost was built and operated during two world wars, and the U.S. Light Service and U.S. Coast Guard operated a manned light station until 1972. The overexploitation of Farallon seabirds and marine mammals in the 19th century resulted in the near to complete extirpation of several species. Offshore, oil pollution, commercial fisheries, and marine ecosystem changes since the early 20th century further impacted the Farallones' seabirds and marine mammals. On the islands, disturbance from long-time resident lightkeepers, U.S. Navy in the early to mid-20th century, combined with the introductions of invasive plants, rabbits and mice, caused dramatic changes to Farallon habitats and ecosystem. Since Service stewardship of the South Farallon Islands began in 1969, some extirpated species have re-colonized the islands and many wildlife populations are recovering. However, other species remain at reduced population levels or are declining on the Refuge, and wildlife remains vulnerable to the impacts of introduced animals and plants, oil spills, other pollution, fisheries interactions, and global climate change. All of these impacts affect the relationship between land and marine resources and compromise the Service's ability to achieve the Refuge goals and objectives to protect and restore populations of native species to the Refuge.

For the Farallon Islands National Wildlife Refuge, the eradication of introduced house mice would aid in achieving the following Refuge goals and objectives, which were set forth in the 2009 *Comprehensive Conservation Plan* for the Refuge:

- Protect, inventory, monitor, and restore the historic levels of breeding populations of 12 seabird species, five marine mammal species, and other native wildlife.

- Reduce or eliminate invasive wildlife species that threaten the viability of seabird and marine mammal species.

- Restore degraded habitat and reduce the prevalence of invasive vegetation in order to re-establish historic abundance and distribution of native plant species by reducing consumption of native species and reducing the spread of invasive plants by house mice.

- Comply with Objective 1.1 of the Refuge's 2009 Comprehensive Conservation Plan (CCP), which established a goal of reducing the impacts of invasive wildlife on the island ecosystem.

The Service published a Notice of Intent to prepare an Environmental Impact Statement (EIS) on April 13, 2011. The action alternatives were developed to focus on the primary issues identified by resource specialists within the Service, national and international experts in island rodent eradication, public comments received after the Notice of Intent to prepare the EIS was released, and government regulatory agencies that have a stake in the decision-making process. To decide

which action alternatives to fully analyze in the EIS, the Service utilized a Structured Decision Making (SDM) approach to assess and compare a total of 49 potential mouse removal methods. In order to be retained for consideration, an alternative had to 1) be consistent with the Service's management guidelines, 2) be feasible to implement, and 3) meet the Service's safety and logistic requirements. Using this information, a Draft EIS (DEIS) was prepared and released to the public for comment on August 16, 2013. A Revised Draft EIS (RDEIS) was released on October 25, 2013 to clarify potential impacts of mice to ashy storm-petrels. In the RDEIS and this Final EIS, the potential impacts of a No Action alternative and two action alternatives were fully analyzed, with no preferred alternative selected. The alternatives include:

A. *Alternative A: No Action, which would allow house mice to remain on the South Farallon Islands;*

B. *Alternative B: Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of the rodent bait Brodifacoum-25D Conservation as the primary method of bait delivery; and*

C. *Alternative C: Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of the rodent bait Diphacinone-50 Conservation as the primary method of bait delivery.*

The Service received more than 550 individual correspondences from the public and interested agencies during the extended Public Comment Period held from August 16 through December 9, 2013. Following the public comment period, comments were collated and responses to substantive comments prepared. Responses to comments resulted in a variety of changes leading to this Final EIS (FEIS), including incorporation of additional literature, additional analyses of action alternatives, descriptions of lessons learned, a study on the potential hazards of anticoagulant rodenticides on salamanders, and revised impacts analyses. After considering this additional information, the Service identified Alternative B has been recommended as the preferred alternative because of its greater potential to successfully eradicate house mice from the South Farallon Islands and lower impact to wilderness.

Alternatives B and C both entail the aerial broadcast of rodent bait containing either the anticoagulant rodenticide brodifacoum or diphacinone from a helicopter using a specialized bait bucket. The bait spreading bucket would broadcast bait at the appropriate rate in a manner that targets all potential mouse territories within a short operational period. Efforts to minimize impacts to island resources include timing of implementation to avoid sensitive breeding periods and times when migratory wildlife are most abundant, a hazing plan to protect gulls and other birds from exposure to potential risks, capture and hold or relocation of predatory birds, and the use of bait stations in certain sensitive areas, as well as the use of specialized equipment and techniques to minimize the risk of bait drift into the marine environment.

Within this document, we provide a quantitative and qualitative assessment of the environmental consequences for each of the alternatives. The potential significance of the environmental consequences (or "impacts") of each action alternative and the No Action alternative are discussed on a case-by-case basis for each environmental issue considered.

The issues analyzed in the document include:

- Impacts to physical resources
    - Impacts to water resources
    - Impacts to geology and soil
    - Impacts to wilderness character
- Impacts to biological resources
    - Impacts to plant and animal species
- Impacts to the social and cultural resources
    - Impacts to personnel from operations
    - Impacts to refuge visitors and recreation
    - Impacts to fisheries resources
    - Impacts to economic and cultural resources
- Unavoidable adverse impacts
- Cumulative impacts
- Irreversible or irretrievable commitments of resources
- Relationship of short-term uses to long-term ecological productivity.

This page intentionally left blank

Table of Contents

Executive Summary ..... **vi**
1 Purpose and Need **2**
1.1 Purpose of and Need for the Proposed Action 2
1.1.1 Introduction 2
1.1.2 Changes Made to Final EIS 3
1.1.3 Purpose Statement 4
1.1.4 Need Statement 4
1.1.5 Project Goals 5
1.1.6 Project Objectives 5
1.2 Need for Action 6
1.2.1 Background: The Problem of Introduced Species on Islands 6
1.2.1.1 Introduced species and the importance of island ecosystems 6
1.2.1.2 Invasive house mice 6
1.2.1.3 Impacts of invasive house mice on island ecosystems 7
1.2.1.4 Hyperpredation on islands 8
1.2.2 House Mouse Impacts on the South Farallon Islands Ecosystem 9
1.2.2.1 Impacts of mice on storm-petrels 10
1.2.2.2 Impacts of mice on salamanders 13
1.2.2.3 Impacts of mice on native invertebrates 13
1.2.2.4 Impacts of mice on native plants 13
1.3 Benefits of House Mouse Eradication 14
1.3.1 Removing the Impacts of Mice on Storm-Petrels 14
1.3.2 Removing the impacts of mice on wilderness character 18
1.3.3 Removing the impacts of mice on native invertebrates 18
1.3.4 Removing the impacts of mice on native salamanders 18
1.3.5 Removing the impacts of mice on native plants 19
1.4 Past Actions to Reduce Mouse Impacts on the South Farallon Islands 19
1.5 Lessons Learned 19
1.5.1 Overall Lessons Learned 20
1.5.2 Ornithological Council's Recommendations for Island Rodent Eradications 20
1.6.1 Other Applicable Laws, Policies and Plans 23
1.7 Scope of the Action Alternatives 25
1.7.1 Summary of Scoping 26
1.7.2 Summary of EA and EIS Scoping Processes 26
1.8 Environmental Issues (Impact Topics) Identified 27
1.8.1 Impact Topic: Physical Resources 27
1.8.2 Impact Topic: Biological Resources 27
1.8.3 Impact Topic: Social and Cultural Resources 28
2 Alternatives **30**
2.1 Introduction 30
2.1.1 Integrated Pest Management 31
2.2 Summary of the Alternatives Selection Process 31
2.3 A Comparison of Rodent Control and Eradication Strategies 33

2.4 Comparison of Mouse and Rat Ecology Relevant to the Removal of Mice from the South Farallon Islands ... 35
2.5 History of Rodent Eradications ... 36
2.6 Anticoagulant Rodenticides ... 38
2.6.1 Rodent bait products currently registered in the U.S. for conservation purposes ... 38
2.6.2 Diphacinone ... 39
2.6.3 Brodifacoum ... 40
2.6.4 Rationale for Proposing the Rodent Bait Products and Toxicants ... 41
2.6.5 Best Management Practices for Rodent Eradications ... 42
2.7 Alternatives Considered but Dismissed ... 44
2.7.1 Use of Toxicants other than Diphacinone or Brodifacoum ... 44
2.7.2 Control as the Primary Method ... 44
2.7.3 Bait Stations as the Primary Method ... 45
2.7.4 Hand Broadcasting Rodent Bait as the Primary Method ... 45
2.7.5 Trapping ... 45
2.7.6 Use of Disease ... 46
2.7.7 Biological Control ... 46
2.7.8 Fertility Control (Immunocontraception and Genetic Mutation) ... 46
2.7.9 Burrowing Owl Translocation Only ... 46
2.8 Pre-Eradication Studies Conducted on the Farallones ... 47
2.8.1 Farallon Mouse Eradication Trial Studies (2010-2012) ... 47
2.8.2 House Mouse Density Estimate Study ... 47
2.8.3 Bait Palatability and Preference Trials ... 48
2.8.4 Bait Exposure Rates (Efficacy) ... 48
2.8.5 Bait Availability ... 49
2.8.6 Bait Station Field Test ... 50
2.8.7 Mapping of Accessible and Sensitive Wildlife Areas ... 50
2.8.8 Commensal Habitat Assessment ... 51
2.8.9 Collection of Mouse Samples and Genetic Analysis ... 51
2.8.10 Bait Degradation Trials ... 52
2.8.11 Bird Mitigation Trials ... 53
2.8.12 Salamander Toxicity Study ... 54
2.9 Alternative A: No Action ... 55
2.10 Features Common to both Action Alternatives ... 56
2.10.1 Introduction ... 56
2.10.2 Adaptive Management ... 56
2.10.3 Environmental Concerns Considered ... 57
2.10.4 Operational Timing ... 57
2.10.5 Operational Specifications ... 60
2.10.5.1 Operational Area ... 60
2.10.5.2 Bait Type ... 61
2.10.5.3 Bait Application ... 61
2.10.5.4 Bait Application Rate ... 61
2.10.5.5 Aerial Bait Application ... 61
2.10.5.6 Additional Air Operations ... 64
2.10.5.7 Staging for Aerial Bait Application ... 64

2.10.5.8 Areas to be excluded from Aerial Bait Application ... 65
2.10.5.9 Hand Baiting ... 65
2.10.5.10 Bait Stations ... 65
2.10.5.11 Treatment of Structures ... 67
2.10.5.12 Schedule for Bait Application ... 67
2.10.5.13 Follow-up bait application ... 68
2.10.5.14 Response to a spill of rodent bait or helicopter fuel ... 68
2.10.5.15 Use of Traps ... 68
2.10.6 Protecting Human Health and Safety ... 69
2.10.7 Mitigation Measures to Protect Biological Resources ... 70
2.10.7.1 Gull hazing ... 70
2.10.7.1.1 Hazing Trial ... 70
2.10.7.1.2 Hazing Plan ... 72
2.10.7.2 Carcass removal ... 73
2.10.7.3 Manually Reducing Bait Availability ... 73
2.10.7.4 Raptor Capture, Captive Management and Release ... 73
2.10.7.5 Captive Management of Salamanders ... 74
2.10.7.6 Reducing Disturbance ... 74
2.10.7.7 Preventing Bait Drift into the Marine Environment ... 75
2.10.7.8 Use of bait stations for mitigation purposes ... 76
2.10.8 Minimizing Impacts to Wilderness ... 76
2.10.9 Protecting Cultural Resources ... 76
2.10.10 Monitoring ... 76
2.10.10.1 Operational Monitoring ... 77
2.10.10.2 Monitoring of Mitigation Objectives ... 77
2.10.10.3 Monitoring of Non-target Mortality ... 78
2.10.10.4 Monitoring of Ecosystem Restoration Objectives ... 78
2.10.10.4.1 Bird Monitoring ... 79
2.10.10.4.2 Salamander and Camel Cricket Monitoring ... 79
2.10.10.4.3 Vegetation Monitoring ... 79
2.10.10.4.4 Intertidal Monitoring ... 79
2.10.11 Contingency Plans ... 80
2.10.12 Biosecurity Measures ... 81
2.11 Alternative B: Aerial Broadcast of Brodifacoum-25D Conservation (Preferred Alternative) ... 82
2.11.1 Bait Product: Brodifacoum-25D Conservation ... 82
2.11.2 Bait Application Rate and Number of Applications ... 82
2.11.3 Bait Application Timing and Schedule ... 83
2.11.4 Alternative B: Summary ... 84
2.12 Alternative C: Aerial Broadcast of Diphacinone-50 Conservation ... 84
2.12.1 Bait Product: Diphacinone-50 Conservation ... 84
2.12.2 Bait Application Rate and Number of Applications ... 84
2.12.3 Bait Application Timing and Schedule ... 86
2.12.4 Alternative C: Summary ... 87
2.13 Comparative Summary of Actions by Alternative ... 87
3 Affected Environment ... 90

3.1 Purpose and Structure of this Chapter ... 90
3.2 General Description of the South Farallon Islands ... 91
3.2.1 Geographical Setting ... 91
3.2.2 Size and Topography ... 91
3.2.3 Climate ... 92
3.3 Physical Resources ... 94
3.3.1 Water Resources ... 94
3.3.2 Geology and Soils ... 96
3.3.3 Wilderness Character ... 96
3.4 Biological Resources ... 97
3.4.1 Introduction ... 97
3.4.2 Birds on the South Farallon Islands ... 97
3.4.2.1 Seabirds ... 98
3.4.2.2 Shorebirds ... 101
3.4.2.3 Raptors ... 101
3.4.2.4 Other Landbirds ... 101
3.4.2.5 Avian Seasonal patterns of the South Farallon Islands ... 102
3.4.2.5.1 Breeding Seabirds and Waterfowl ... 102
3.4.2.5.2 Non-breeding Seabirds ... 103
3.4.2.6 Shorebirds ... 103
3.4.2.7 Raptors ... 103
3.4.2.8 Other Landbirds ... 104
3.4.2.9 Special status bird species ... 104
3.4.3 Other Terrestrial Wildlife of the South Farallon Islands ... 105
3.4.3.1 Salamanders ... 105
3.4.3.2 Bats ... 107
3.4.3.3 Terrestrial Invertebrates ... 108
3.4.3.4 Introduced birds and mammals ... 109
3.4.4 Intertidal and Nearshore Ecosystems ... 110
3.4.4.1 Intertidal Invertebrates and algae ... 110
3.4.4.2 Nearshore Fish and Invertebrates ... 111
3.4.5 Marine Mammals ... 115
3.4.5.1 California sea lion ... 115
3.4.5.2 Northern elephant seal ... 115
3.4.5.3 Pacific harbor seal ... 116
3.4.5.4 Northern fur seal ... 116
3.4.5.5 Steller sea lion ... 117
3.4.5.6 Other marine mammals in the Gulf of the Farallones ... 117
3.4.5.7 Special legal protection for marine mammals ... 118
3.4.6 Breeding Seabird and Pinniped Seasonality ... 118
3.4.7 Terrestrial Vegetation ... 119
3.5 Social and Cultural Resources ... 120
3.5.1 Ownership/Management/Major Stakeholders ... 120
3.5.2 Recreational and Aesthetic Uses ... 121
3.5.3 Commercial Fisheries ... 123
3.5.3.1 Essential Fish Habitat Assessment ... 123

3.5.4 Cultural Resources ... 124
4 Environmental Consequences ... 128
4.1 Purpose and Structure of this Chapter ... 128
4.2 Environmental Issues (Impact Topics) Addressed ... 129
4.2.1 Scoping for Environmental Issues (Impact Topics) ... 129
4.2.2 Impact Topics ... 129
4.2.3 Significance Thresholds for the Farallon Islands ... 129
4.2.3.1 Significance Thresholds by Impact topic ... 130
4.3 Aspects of the Environment Excluded from Detailed Analysis (with Rationale) ... 130
4.3.1 Air quality ... 130
4.3.2 Cetaceans (e.g., whales and dolphins) and Sharks ... 131
4.3.3 Environmental Justice ... 131
4.4 Consequences: Physical Resources ... 131
4.4.1 Water Resources ... 131
4.4.1.1 Analysis framework for water resources ... 131
4.4.1.2 Alternative A: No action ... 131
4.4.1.3 Alternative B: Aerial Broadcast of Brodifacoum ... 132
4.4.1.4 Alternative C: Aerial Broadcast of Diphacinone ... 132
4.4.2 Geology and Soils ... 133
4.4.2.1 Analysis framework for geology and soils ... 133
4.4.2.2 Alternative A: No action ... 133
4.4.2.3 Alternative B: Aerial Broadcast of Brodifacoum ... 134
4.4.2.4 Alternative C: Aerial Broadcast of Diphacinone ... 135
4.4.3 Wilderness ... 135
4.4.3.1 Analysis framework for wilderness character ... 135
4.4.3.2 Alternative A: No action ... 136
4.4.3.3 Alternative B: Aerial Broadcast of Brodifacoum-25D Conservation ... 136
4.4.3.4 Alternative C: Aerial Broadcast of Diphacinone-50 Conservation ... 137
4.5 Consequences: Biological Resources ... 138
4.5.1 Introduction ... 138
4.5.1.1 Lessons Learned from Other Rodent Eradication Projects ... 138
4.5.2 Assessing Significance of Impacts to Biological Resources ... 140
4.5.2.1 Special considerations for ESA-listed species ... 141
4.5.2.2 Special considerations for MMPA-listed species ... 142
4.5.3 Impacts of Alternative A (No Action) on Biological Resources ... 142
4.5.3.1 Introduction ... 142
4.5.3.2 Impacts on Birds ... 142
4.5.3.3 Impacts on Mammals ... 144
4.5.3.4 Impacts on Amphibians ... 144
4.5.3.5 Impacts on Fish ... 145
4.5.3.6 Impacts on Invertebrates ... 145
4.5.3.7 Impacts on Vegetation ... 146
4.5.4 Impacts of Action Alternatives on Biological Resources ... 146
4.5.4.1 Analysis framework for impacts from toxicant use ... 146
4.5.4.2 Toxicant Exposure ... 146
4.5.4.2.1 Primary exposure ... 147

4.5.4.2.2 Secondary exposure ... 147
4.5.4.3 Toxicity ... 148
4.5.4.3.1 Toxicity to birds and mammals ... 148
4.5.4.3.2 Toxicity to amphibians ... 150
4.5.4.3.3 Toxicity to fish ... 152
4.5.4.3.4 Toxicity to invertebrates ... 154
4.5.4.3.5 Sublethal effects ... 155
4.5.4.4 Analysis of High-Risk Species ... 156
4.5.4.4.1 Western Gulls ... 156
4.5.5 Analysis framework for impacts from disturbance ... 161
4.5.5.1 Helicopter operations ... 161
4.5.5.2 Personnel activities ... 162
4.5.5.3 Gull Hazing ... 163
4.5.6 Impact Indices ... 163
4.5.6.1 Impacts of Alternative B on Biological Resources: Aerial Brodifacoum-25D Conservation ... 167
4.5.6.1.1 Impacts on Birds ... 167
4.5.6.1.2 Impacts on Mammals ... 188
4.5.6.1.3 Impacts on Amphibians ... 190
4.5.6.1.4 Impacts on Fish ... 191
4.5.6.1.5 Impacts on Invertebrates ... 192
4.5.6.1.6 Impacts on Vegetation ... 195
4.5.6.1.7 Impacts Table for Alternative B: Aerial Broadcast of Brodifacoum: ... 197
4.5.6.2 Impacts of Alternative C on Biological Resources: Aerial Diphacinone-50 Conservation ... 200
4.5.6.2.1 Impacts on Birds ... 200
4.5.6.2.2 Impacts on Mammals ... 221
4.5.6.2.3 Impacts on Amphibians ... 223
4.5.6.2.4 Impacts on Fish ... 224
4.5.6.2.5 Impacts on Invertebrates ... 224
4.5.6.2.6 Impacts on Vegetation ... 228
4.5.6.2.7 Impacts Table for Alternative C on Biological Resources: Aerial Broadcast of Diphacinone ... 229
4.6 Consequences: Social and Cultural Resources ... 232
4.6.1 Personnel Safety ... 232
4.6.1.1 Analysis framework for personnel safety ... 232
4.6.1.2 Alternative A ... 232
4.6.1.3 Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone ... 232
4.6.2 Recreation and Tourism ... 232
4.6.2.1 Analysis framework for Refuge visitors and recreation ... 232
4.6.2.2 Alternative A: No action ... 233
4.6.2.3 Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone ... 233
4.6.3 Fishery Resources ... 234
4.6.3.1 Analysis framework for fishing resources ... 234
4.6.3.2 Alternative A: No action ... 234
4.6.3.3 Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone ... 234

4.6.4 Cultural Resources ... 235
4.6.4.1 Analysis framework for cultural resources ... 235
4.6.4.2 Alternative A: No action ... 235
4.6.4.3 Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone .. 235
4.7 Unavoidable Adverse Impacts ... 235
4.7.1 Alternative A: No Action ... 236
4.7.2 Alternative B: Aerial Brodifacoum ... 236
4.7.3 Alternative C: Aerial Diphacinone ... 238
4.8 Cumulative Impacts ... 239
4.8.1 Assessing Cumulative Impacts ... 239
4.8.2 Past Actions ... 239
4.8.3 Current and Ongoing Actions ... 242
4.8.4 Future Actions ... 249
4.8.5 Summary of Effects from Past, Present, and Future Projects ... 250
4.8.6 Incremental Effect of the Action Alternative to Cumulative Impacts ... 253
4.8.7 Summary of Cumulative Impacts Under Alternative A (No Action) ... 253
4.8.7.1 Summary of Combined Affects with Alternative A ... 253
4.8.8 Summary of Cumulative Impacts under Alternative B ... 255
4.8.8.1 Summary of Combined Effects with Alternative B ... 255
4.8.9 Summary of Cumulative Impacts under Alternative C ... 259
4.8.9.1 Summary of Combined Effects with Alternative C ... 259
4.9 Irreversible and Irretrievable Impacts ... 262
4.9.1 Alternative A ... 262
4.9.2 Alternatives B and C ... 262
4.10 Short-term Uses and Long-term Ecological Productivity ... 262
5 Consultation and Coordination ... 264
5.1 Introduction ... 264
5.2 Regulatory Framework of the Alternatives ... 264
5.2.1 Federal Laws ... 264
5.2.2 California State Laws and Authorities ... 265
5.3 Agency Consultation ... 266
5.4 Public Scoping and Review ... 267
5.5 Comments Received on the DEIS ... 268
5.6 Preparers and Primary Contributors ... 269
6 References ... 272
7 Index ... 300

Figures

1.1	Ashy storm-petrel.	p. 5
1.2	A house mouse feeding on a seabird carcass on Gough Island.	p. 8
1.3	Food web of house mice on the South Farallon Islands.	p. 10
1.4	Seasonal cycle of house mouse abundance, ashy storm-petrel predation and burrowing owl abundance on Southeast Farallon Island.	p. 11
1.5	Ashy storm-petrel remains at a burrowing owl roost on Southeast Farallon Island.	p. 12
1.6	Farallon ashy storm-petrel population projections under three levels of reduction in burrowing owl abundance.	p. 17
2.1	Chemical structure of diphacinone.	p. 39
2.2	Chemical structure of brodifacoum.	p. 40
2.3	Topographical map of the South Farallon Islands showing steep areas that have limited or no safe access.	p. 51
2.4	Brodifacoum-25D bait pellets before and after exposure to moisture.	p. 61
2.5	Bait-spreading bucket.	p. 62
2.6	Aerial bait application types.	p. 63
2.7	Aircraft GPS navigation bar.	p. 63
2.8	Helicopter with bait spreading bucket.	p. 64
2.9	Bait station.	p. 66
3.1	Aerial photograph of the South Farallon Islands.	p. 92
3.2	Mean air temperature and precipitation on Southeast Farallon Island, 1971-2010.	p. 93
3.3	Wind speeds on Southeast Farallon Island, 2000-2010.	p. 93
3.4	Map of the Greater Farallones National Marine Sanctuary.	p. 95
3.5	Farallon arboreal salamander.	p. 106
3.6	Southeast Farallon Island State Marine Reserve and Southeast Farallon Island Marine Conservation Area.	p. 121
3.7	Houses on Southeast Farallon Island.	p. 126

Tables

2.1	Comparison of the key characteristics of eradication and control operations.	p. 33
2.2	Summary of House Mouse Eradication Attempts utilizing rodenticides with documented results and methods.	p. 37
2.3	Monthly index (trap success rate) of house mouse abundance on Southeast Farallon Island, 2010-2012.	p. 48
2.4	Overall project timing considerations.	p. 59
2.5	Comparison of important operational attributes for each action alternative.	p. 87
3.1	Marine bird breeding population estimates (numbers of breeding birds) on the South Farallon Islands.	p. 100
3.2	Seabird and pinniped seasonality.	p. 118
3.3	Monthly totals of sightseeing and shark cage diving tour boats recorded at the South Farallon Islands, October to December 2014-2016.	p. 122
3.4	Status of historical and potential historical elements on Southeast Farallon Island.	p. 124
4.1	Acute toxicity of brodifacoum to avian species.	p. 149
4.2	Acute toxicity of diphacinone to avian species.	p. 150
4.3	Bait consumption and impacts to amphibian species from anti-coagulants.	p. 151

4.4	Impacts of Alternative B on biological resources.	p. 197
4.5	Impacts of Alternative C on biological resources.	p. 229

Appendices (included as a separate volume of the FEIS)

Appendix A	Project Feasibility and Non-Target Risk Trial Report
Appendix B	Biosecurity Plan
Appendix C	Alternatives Selection Report
Appendix D	Bait Degradation Trial Report
Appendix E	2012 Gull Hazing Trial Report
Appendix F	Western Gull Risk Assessment
Appendix G	Wilderness Act Minimum Requirements Analysis
Appendix H	Avian Species List
Appendix I	Map of Western Gull Roosting Sites
Appendix J	Intertidal Species List
Appendix K	Maps of Pinniped Haul-Out Sites
Appendix L	Plant Species List
Appendix M	Modeling the Impacts of House Mouse Eradication on Ashy Storm-Petrels on Southeast Farallon Island
Appendix N	Western Gull Population Viability Analysis
Appendix O	Scoping Report
Appendix P	RDEIS Comment Response Report
Appendix Q	Salamander Toxicity Study Report

List of Acronyms

AM	Adaptive Management
APHIS	Animal and Plant Health Inspection Service
ASBS	Area of Special Biological Significance
ASSP	Ashy Storm-Petrel
AVMA	American Veterinary Medical Association
BUOW	Burrowing Owl
CBD	Center for Biological Diversity
CBNMS	Cordell Bank National Marine Sanctuary
CCMP	California Coastal Management Program
CCP	Comprehensive Conservation Plan
CDFW	California Department of Fish and Wildlife
CDPR	California Department of Pesticide Regulations
CESA	California Endangered Species Act
CEQ	Council on Environmental Quality
CSIRO	Commonwealth Scientific and Industrial Research Organization
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DDT	Dichlorodiphenyltrichloroethane

DEIS	Draft Environmental Impact Statement
DOI	Department of the Interior
DPR	California Department of Pesticide Regulations
DPS	Distinct Population Segment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FNWR	Farallon Islands National Wildlife Refuge
FIRWD	Farallon Islands Radioactive Waste Dump
FWS	U.S. Fish and Wildlife Service
GECI	Grupo de Ecología y Conservación de Islas, A.C.
GFNMS	Greater Farallones National Marine Sanctuary
GIS	Geographic Information Systems
GPS	Global Positioning System
IC	Island Conservation
IHA	Incidental Harassment Authorization
IOA	Index of Abundance
IPM	Integrated Pest Management
IUCN	International Union for Conservation of Nature
ISSG	Invasive Species Specialist Group
LD_{50}	Lethal Dose to 50 percent of animals
MBTA	Migratory Bird Treaty Act
MHWS	Mean High Water Spring
MLPA	Marine Life Protection Act
MMPA	Marine Mammal Protection Act
MRA	Minimum Requirements Analysis
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic Atmospheric Administration
NPS	National Park Service
NPDES	National Pollution Discharge Elimination System
NWR	National Wildlife Refuge
NWRSAA	National Wildlife Refuge System Administrative Act
NWRSIA	National Wildlife Refuge System Improvement Act
PCB	Polychlorinated Biphenyl
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PPE	Personal Protective Equipment

PRBO	Point Reyes Bird Observatory, now Point Blue Conservation Science
PVA	Population Viability Analysis
PVC	Polyvinal Chloride
ROD	Record of Decision
SEFI	Southeast Farallon Island
SFI	South Farallon Islands
SDM	Structured Decision Making
SEAS	Sanctuary Ecosystem Assessment Surveys
SHPO	State Historic Preservation Office
SMR	State Marine Reserve
SMCA	State Marine Conservation Area
SVL	Snout-Vent-Length
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WEGU	Western Gull
WEI	West End Island

This page intentionally left blank

1 Purpose and Need

1.1 Purpose of and Need for the Proposed Action

1.1.1 Introduction

The Farallon Islands National Wildlife Refuge (or, Refuge) was established by President Theodore Roosevelt under Executive Order 1043 in 1909 as a "… preserve and breeding ground for marine birds." Called the Farallon Reservation, the designation included the North Farallon Islands, Middle Farallon Island, and Noonday Rock. The Farallon Reservation was redesignated as the Farallon Islands National Wildlife Refuge by Presidential Proclamation No. 2416 on July 30, 1940. Public Land Order 4671 on June 23, 1969 expanded the Refuge to include the South Farallon Islands, including Southeast Farallon Island, West End Island, and surrounding islets. In 1974, all of the islands with the exception of Southeast Farallon Island were designated by Congress as wilderness under the Wilderness Act of 1964. In 2017, the name of the refuge was changed to the Farallon Islands National Wildlife Refuge. The land area of the Refuge totals about 211 acres, with about 120 acres on the South Farallon Islands.

The Farallon Islands, or Farallones, host a unique ecosystem. This is particularly true for the South Farallon Islands, the largest islands of the group. The South Farallones are comprised of several islands and islets, including Southeast Farallon Island, West End (or, Maintop) Island, Sugarloaf, Arch Rock, Aulon Islet, Finger Rock, Sea Lion Islet, Chocolate Chip Islet, Saddle (or, Seal) Rock, and Drunk Uncle's Islets. They hold the largest seabird breeding colony in the contiguous United States, with approximately 300,000-350,000 birds of 13 species, several of which have significant populations there (Ainley and Boekelheide 1990, USFWS 2009, McChesney et al. 2013, Warzybok et al. 2018). Populations of five marine mammal species use the islands for resting and breeding, including one of only two rookeries for northern fur seal (*Callorhinus ursinus*) south of Alaska. Hundreds of species of migratory birds stop there to rest and feed. Several rare species occur, including the ashy storm-petrel (*Oceanodroma homochroa*), endemic Farallon arboreal salamander (*Aneides lugubris farallonensis*), and endemic Farallon camel cricket (*Farallonophilus cavernicolus*) (USFWS 2009).

The Farallon Islands ecosystem evolved in the absence of terrestrial mammals. However, introductions of invasive mammals to the South Farallon Islands in the 19th and early 20th centuries have led to long-term ecological damage. Introduced European rabbits (*Oryctolagus cuniculus*) and domestic cats (*Felis catus*) had caused severe impacts to vegetation and birds until they were both removed from the islands in the early 1970s (Ainley and Lewis 1974).

With the removal of introduced rabbits and cats, house mice (*Mus musculus*) are the only remaining invasive mammal on the Farallones and are believed to have been introduced to the islands in the early to mid-19th century. House mice cause major impacts to the native Farallon ecosystem. They provide a temporary food source for migratory burrowing owls (*Athene cunicularia*) that switch to preying on rare ashy storm-petrels after the mouse population crashes. House mice also consume native invertebrates, including the endemic Farallon camel cricket, altering the makeup of the Farallon invertebrate fauna and competing with native wildlife such as the endemic Farallon arboreal salamander. Mice also consume large numbers of seeds and other

plant parts of native vegetation, reducing native vegetation cover in favor of hardier, invasive plants. At their annual peak, invasive house mice on the South Farallones are present in extremely high densities, numbering over 490 per acre (1,200 per hectare) (Appendix C). House mouse densities recorded from the South Farallon Islands are among the highest for any island in the world (Appendix C, Pearson 1963, Mackay et al. 2011).

Under the National Wildlife Refuge System Improvement Act (1997), the U.S. Fish and Wildlife Service (Service) is required to prepare Comprehensive Conservation Plans for each refuge. Among other things, Comprehensive Conservation Plans identify refuge purposes and any significant problems adversely affecting a refuge's native plants and animals together with actions necessary to correct or mitigate such problems. In 2009, the Service issued a Comprehensive Conservation Plan (CCP) for the Refuge (USFWS 2009). The CCP was prepared in accordance with the National Environmental Policy Act and was informed by public comment. The CCP identified the protection of native bird habitat as a principal purpose of the Refuge, based on the 1909 Executive Order establishing the Refuge. In furtherance of this purpose, the CCP established a goal of protecting the (then) 12 species of breeding seabirds and restoring them to historic breeding population levels (a 13th species, California gull, *Larus californicus*, has colonized the islands since 2009). Another CCP goal was to restore degraded habitat and reduce the prevalence of nonnative vegetation in order to re-establish historic abundance and distribution of native plant species. The CCP identified methods to accomplish these goals including removal of predators and habitat restoration. The CCP identified predation by house mice as an impact on certain native seabird species on the Refuge, including ashy storm-petrels. The CCP called for the elimination of invasive house mice from the Farallon Islands to help restore native seabird populations (USFWS 2009). This EIS is tiered from the policy decision set forth in the CCP to eliminate invasive house mice.

1.1.2 **Changes Made to Final EIS**

Following the publication of the Draft EIS (DEIS) and Revised Draft EIS (RDEIS) on August 16, 2013 and October 25, 2013, respectively, the Service received more than 550 individual correspondences from the public and interested agencies during the extended Public Comment Period held from August 16 through December 9, 2013. Many revisions have been made to this FEIS based on those comments (see Responses to Comments in Chapter 5). As a response to certain comments received, sections describing lessons learned from past eradication projects that were incorporated into this planning process were added to the FEIS (Sections 1.5, 2.6.5, and 4.5.1.1). An extensive search and review of applicable new literature was conducted and incorporated into the FEIS as appropriate. Two reports that are included as Appendices A and D were revised following peer review. Another report (Grout et al. 2013) that was included as Appendix E was replaced with Warzybok et al. (2013) following completion of additional assessments. Appendix O, the Scoping Report, was revised to be more comprehensive. Reference to unpublished reports or theses that were used in preparation of the RDEIS that have been since published have been revised to now reference the published source. Reports or documents that were included in the appendices and revised since the RDEIS have been updated in the appendices. A study on the potential hazards of anticoagulant rodenticides to Farallon arboreal salamanders was conducted and included in the FEIS as Appendix Q, with the results

incorporated into the FEIS. In May 2017, the name of the Refuge was changed to the Farallon Islands National Wildlife Refuge; the name has been updated throughout the document.

Section 4.5.2.3 Special Considerations for MBTA-listed Species was removed from the FEIS because of a recent change to Migratory Bird Treaty Act regulations (see Section 1.6.1). For the assessments of impacts to birds from Alternative B and Alternative C (Chapter 4), we refined and clarified the criteria for selecting which species to include and re-analyzed data from the 2000-2009 period used to estimate the numbers of birds of each species that may be present during the operational stages of each alternative. This resulted is certain species being added or removed from assessments, as well as changes to estimated numbers of birds of each species that may be present during each operational periods. Also, species with substantially changed status since the RDEIS were re-examined using more recent occurrence information. This included the Canada goose (*Branta canadensis*) and common raven (*Corvus corax*). Canada geese began nesting on the islands in 2010 and have increased in occurrence. A territorial pair of common ravens were irregularly present on the islands from 2009 to 2013, with evidence of breeding in 2010. However, no ravens have been observed on the islands since 2013 (Point Blue, unpublished data). In addition, impact indices were re-evaluated for all biological resources and updated as necessary.

1.1.3 **Purpose Statement**

The purpose of this project is to meet the Service's management goal of eradicating invasive house mice from the Farallon Islands National Wildlife Refuge in order to eliminate their negative impacts on the native ecosystem of the South Farallon Islands.

1.1.4 **Need Statement**

The need of this EIS is to comply with the 2009 CCP which provided that the Service should, within five years of the completion of the CCP, develop a plan to reduce the impacts of non-native species on the islands' ecosystem. To implement this goal, the CCP determined that the Service would "develop and implement a plan to eradicate the non-native house mouse and prevent future human introductions of mice" (USFWS 2009).

It is anticipated that the complete removal of mice from the South Farallon Islands would allow many of the island's natural ecosystem processes to be restored, thereby furthering important CCP goals. The following benefits to the South Farallon Islands ecosystem are anticipated as a consequence of eradicating house mice:

1. **Seabirds**: Nesting seabirds are expected to benefit as a consequence of decreased depredation and resulting improved survivorship. In particular, eradicating house mice is expected to result in increased populations of at least one seabird species, the ashy storm-petrel (Figure 1.1), and likely also the Leach's storm-petrel (*Oceanodroma leucorhoa*), by reducing the numbers of over-wintering burrowing owls and resulting owl predation on storm-petrels. Migrant burrowing owls stop at the islands each autumn. Encouraged by the abundance of mice present at that time, each year several owls remain through the winter or spring. In winter, after the mouse population crashes and storm-petrels begin arriving back at the islands for breeding activities, owls switch their diet to feed primarily

on rare ashy storm-petrels (Chandler et al. 2016, Mills 2016). Years with high owl predation on storm-petrels causes negative impacts to the Farallon ashy storm-petrel population (Nur et al. 2013a, in review). The loss of mice as a food resource would greatly reduce the suitability of the Farallon Islands as a wintering ground for burrowing owls, reducing or eliminating the combined impacts of owls and mice on storm-petrels.

2. **Salamanders**: The endemic Farallon arboreal salamander is anticipated to benefit from the removal of a competitor for invertebrate prey and a potential predator of salamander eggs and juveniles.
3. **Invertebrates**: Both mice and the over-wintering burrowing owls that mice sustain prey heavily on invertebrates, including the endemic Farallon camel cricket (Rowe-Rowe et al. 1989, Jones and Golightly 2006, Angel et al. 2009, Chandler et al. 2016, Mills 2016). Native invertebrates of the South Farallon Islands, including the, are expected to benefit from reduced predation pressure from invasive mice and other predators attracted to the islands by the mice, such as burrowing owls.
4. **Plants**: House mice prey heavily on native plants (Jones and Golightly 2006). Native plants stand to benefit as a consequence of reduced seed and seedling predation by mice.
5. **Wilderness character**: Invasive house mice, and the impacts they cause to native resources, negatively impact the natural character of the Farallon Wilderness. Eradication of mice would restore the natural character of the wilderness.

1.1.5 Project Goals

The goals for removing invasive house mice from the South Farallon Islands are:

1. To increase the population sizes of ashy and Leach's storm-petrels;
2. To restore native ecosystem functions altered by invasive house mice;
3. To increase the abundance and recruitment of native vegetation;
4. To increase the productivity and abundance of endemic Farallon arboreal salamanders;
5. To increase the productivity and abundance of endemic Farallon camel crickets and other native invertebrates;
6. To improve the wilderness character of the Farallon islands; and
7. To improve species and ecosystem adaptability and resilience in light of projected future climate change.

1.1.6 Project Objectives

The objectives for eradicating invasive house mice from the Farallon Islands include:

1. The complete removal of invasive house mice from the South Farallon Islands using the best available methods;
2. Meet the Refuge's management and policy guidelines (See Section 2.2);
3. Minimize and mitigate any negative impact to the native species and other natural and cultural resources of the islands;
4. Ensure human safety is preserved during project implementation and mitigation;

Figure 1.1: Ashy storm-petrel.
Photo Courtesy of Duncan Wright

5. Ensure that long-term benefits of mouse removal outweigh any short-term negative effects to ecological processes from project implementation; and
6. Prevent the future reinvasion of house mice through the implementation of a biosecurity plan (Appendix B).

1.2 Need for Action

1.2.1 Background: The Problem of Introduced Species on Islands

1.2.1.1 *Introduced species and the importance of island ecosystems*

It is widely accepted that the natural world is facing a very high rate of species extinction (Raup 1988), that most recent extinctions can be directly attributed to human activity (Diamond 1989), and that for ethical, cultural, aesthetic, and economic reasons this current rate of extinction is cause for considerable concern (Ehrlich 1988, Ledec and Goodland 1988). One of the major worldwide causes of anthropogenic extinctions is the introduction of species. The introduction of species into new environments is responsible for over 50 percent of all of the recorded animal extinctions since 1600 for which a cause could be attributed (Clavero and Garcia-Berthou 2005).

Island ecosystems are key areas for biodiversity conservation worldwide. While islands make up only about three percent of the earth's surface, they are home to 15-20 percent of all plant, reptile, and bird species (Whittaker 1998 and Holmes et al. 2015). However, small population sizes and limited habitat availability make species that live on islands susceptible to extinction, and their adaptation to isolated environments makes them particularly vulnerable to introduced species (Diamond 1985, 1989, Olson 1989). Of the 245 recorded animal species extinctions since 1500, 75 percent were species endemic to islands (World Conservation Monitoring Centre 1992). Introduced species were at least partially responsible for a minimum of 54 percent of these island extinctions, based on the 170 island species for which the cause of extinction is known (Ricketts et al. 2005).

1.2.1.2 *Invasive house mice*

The house mouse, which originated from Asia, is now among the most widespread of all mammals. This is a direct result of their close association with humans and the relative ease with which they have been transported and introduced to new locations. House mice are present on islands in all of the world's major oceans, and at least 64 island groups in the Pacific. While an accurate number is unknown, house mice have become established as invasive pests on hundreds of islands around the world (Atkinson 1989) and they are listed as one of the World's Worst 100 Invasive Alien Species by the Invasive Species Specialist Group (ISSG) of the IUCN (Lowe et al. 2000). The adaptability of house mice is evident from their global distribution and their broad habitat range including buildings, agricultural land, coastal regions, grasslands, salt marshes, deserts, forests, and sub-Antarctic areas (Efford et al. 1988, Triggs 1991, Atkinson and Atkinson 2000).

1.2.1.3 *Impacts of invasive house mice on island ecosystems*

House mice are an omnivorous species that eat a variety of seeds, fungi, insects, reptiles, other small animals, as well as bird eggs, chicks, and adults. Despite their widespread introduction on islands worldwide, their impacts on island ecosystems are less well understood than for other invasive mammals such as rats, cats, and pigs. A main reason for this is that mice usually co-occur with other invasive mammals, such as rats, which can predominate over mice and suppress their impacts (Angel et al. 2009). The most conclusive studies of house mouse impacts on islands have been in the Southern Ocean where mice were the only invasive mammal (Angel et al. 2009). Invasive house mice, like rats, have been shown to impact island ecosystems at multiple levels and both directly and indirectly.

Mice feed on a variety of native plants and seeds. At sub-Antarctic Marion Island, mouse predation on the seeds and young shoots of the native sedge *Uncinia compacta* has led to the near extirpation of that species. Similar impacts may be occurring to the herbaceous *Acaena magellanica*. At Marion Island, the importance of plant material in mouse diet increased over three decades, possibly because of decreased alternate prey (e.g., invertebrates; reviewed in Angel et al. 2009).

Invasive rodents, including mice, are known to have dramatic, negative impacts on island native invertebrates (Rowe-Rowe et al. 1989, Cole et al. 2000, Angel et al. 2009, St. Clair 2011). Impacts to invertebrate populations from invasive rodents (mainly rats) have led to extinctions but population suppression is more common (Angel et al. 2009, St. Clair 2011). Negative impacts to large arthropods, especially Coleoptera (beetles) and Orthoptera (crickets, grasshoppers, weta and locusts), by rodents have been reported the most (reviewed in St. Clair 2011). On Marion Island, house mice affect populations of a number of endemic invertebrates, especially the Marion flightless moth (*Pringleophaga marioni*), the single most important decomposer on the island (Angel et al. 2009). Mice are also believed to be responsible for the extirpations of several invertebrate species on the Antipodes Islands, and species of flightless Lepidoptera (moths and butterflies) are impacted by mice on the Antipodes and Gough islands (Angel et al. 2009). Following mouse eradication from Mana Island, New Zealand, the endemic giant cricket (*Deinacrida rugosa*) population increased, suggesting its population was suppressed by mice (Newman 1994). Direct impacts on arthropods in turn have the potential to cause other impacts within an ecosystem, as arthropods are often crucial in the pollination and recruitment strategies used by plants, the decomposition of dead plant and animal matter, and as a food source for other native species (Seastedt and Crossley 1984, Angel et al. 2009, St. Clair 2011).

Furthermore, house mice may affect the amount of food available for native insectivorous species. For example, lesser sheathbill (*Chionis minor*) flocks on Marion Island are much smaller than those on nearby, mouse-free Prince Edward Island, suggesting that food competition from house mice is affecting the Marion Island's lesser sheathbill population (Rowe et al. 1989, Crafford 1990).

House mice can also have a substantial negative impact on native reptiles and amphibians (Lukis 2009) on islands. On Mana Island in New Zealand, Newman (1994) found mice were a major contributing factor in the population collapse of the island's rare McGregor's skink (*Cyclodina*

macgragori). After a successful mouse eradication, populations of McGregor's skink and common gecko (*Hoplodactylus maculates*) increased significantly (Newman 1994).

One of the more surprising effects of mice on islands, given their relatively small size, is the negative impact they can have on seabird and native landbird populations through direct predation on eggs and chicks. This impact appears to be particularly acute when mice are the only invasive mammal present (Angel et al. 2009). On Gough Island in the southern Atlantic Ocean, introduced house mice prey on chicks of the rare Tristan albatross (*Diomedea dabbenena*), Atlantic petrel (*Pterodroma incerta*), and probably several other petrel species (Cuthbert and Hilton 2004, Wanless et al. 2007, Cuthbert et al. 2013). Dramatic video footage has shown mice in the process of killing these large seabird chicks (up to 10 kg) by burrowing inside the birds and eating their organs while the birds are still alive (Wanless et al. 2007). High chick predation by mice is contributing to very low breeding success for the albatross and Atlantic petrel, raising the possibility of extinction of these species if conservation efforts are not taken soon (Cuthbert and Hilton 2004, Wanless et al. 2007, Cuthbert et al. 2013). Additional studies showed that low burrow occupancy rates and low breeding season by several other petrel species on Gough Island are also the result of mouse predation; populations of these species are also expected to decline as a result (Cuthbert et al. 2013). The causes of this somewhat unusual situation appear to be due to several factors, including the large size of Gough Island mice, low seasonal variability in mouse population densities, and an unusual number of breeding seabirds present during the winter (when most predation occurs). It appears that seabird chicks are sustaining mice through the winter at a time when other food sources are less abundant (Cuthbert et al. 2016). In addition, mice on Gough Island appear to limit the breeding range of the endemic Gough bunting (*Rowettia goughensis*) to the small amount of mouse-free habitat remaining on the island (Cuthbert and Hilton 2004).

On Marion Island, where the recent eradication of feral cats left mice as the only invasive mammal on the island, researchers recorded several wandering albatrosses (*Diomedea exulans*) killed by mice (Figure 1.2) (Wanless et al. 2007, Angel et al. 2009). On Midway Atoll in the tropical Pacific Ocean, an eradication of black rats (*Rattus rattus*) in 1996 has left house mice as the only mammalian predator. In 2015, house mice were first documented attacking and killing adult Laysan (*Phoebastria immutabilis*) and black-footed (P. *nigripes*) albatrosses and the behavior increased the following year, leading to mouse control efforts. Other potential causes for this change in mouse behavior include eradication efforts for an invasive plant (possible mouse food source) and a change in the annual rainfall pattern (USFWS 2018; B. Flint, USFWS, pers. comm.).

Figure 1.2. A house mouse feeding on a seabird carcass on Gough Island. Photo courtesy ofR. Wanless and A. Angel.

1.2.1.4 *Hyperpredation on islands*

Hyperpredation refers to increased levels of predation on a secondary prey species due to an increase in the population of a predator, or a sudden decline in abundance of the predator's

principal prey species. Numerous cases of hyperpredation impacting native species following the introduction of invasive species have been documented (Holt 1977, Smith and Quin 1996, Moleón et al. 2008). The introduction of house mice is believed to have led to a hyperpredation (increased predation levels) situation on the South Farallones, resulting in burrowing owls preying on large numbers of ashy storm-petrels and probably Leach's storm-petrels. The mechanisms in place on the Farallones are more fully described in Section 1.2.2.

A number of similar examples, involving one or more invasive species that contribute to declines in native island species, have recently been described. On Allen Cay (Island) in the Bahamas, invasive house mice attracted higher numbers of barn owls (*Tyto alba*) than other ecologically similar sites in the region. Because the owls also preyed upon Audubon's shearwaters (*Puffinus lherminieri*), the shearwater population on Allen's Cay experienced a mortality rate that was considered to be twice as high as the shearwaters mortality rate on other islands in the region that are mouse-free (Mackin 2007). The high mortality rate was expected to contribute to the extirpation of Audubon's shearwater on Allen Cay if conditions did not change (W. Mackin, pers. comm.). House mice were successfully eradicated from Allen Cay in 2012 and early observations in 2013 suggest that shearwater mortality has declined substantially (Bahamas National Trust and Island Conservation 2013).

Golden eagles (*Aquila chrysaetos*) colonized Santa Cruz Island in Channel Islands National Park, California, in the mid-1990s, after discovering an abundant food source of feral pigs (*Sus scrofa*). Eagles then began preying upon the rare, endemic island fox (*Urocyon littoralis*), resulting in a catastrophic decline of the island fox population (Roemer et al. 2001). After removal of feral pigs and eagles from Santa Cruz Island combined with fox reintroduction efforts, the fox population recovered quickly to near historic population levels (Coonan 2011). Similarly, island seabird populations experience increased predation pressure by feral cats where feral cat populations are sustained between seabird breeding seasons by introduced rodents (Atkinson 1985) or rabbits (Apps 1983; Courchamp et al. 1999, 2000).

On Santa Barbara Island, barn owls preyed upon and extirpated burrowing owls following a cyclic crash of deer mice (*Peromyscus maniculatus*) (Drost and McCloskey 1992). The deer mice are native but population fluctuations with peaks of up to 500 mice per ha occur every three to four years. The mice attract barn owls, many of which starve to death following the mouse population crash (Drost and Fellers 1991), and also facilitate predation of Scripps's Murrelets (Nur et al. 2013b). Barn owl numbers on Santa Barbara Island are much lower when mouse numbers are low.

In these examples, the presence of invasive prey led to declines in native species populations through hyperpredation. However, removal of invasive prey, as evidenced by the restoration of Santa Cruz Island, can also lead to native population recovery.

1.2.2 House Mouse Impacts on the South Farallon Islands Ecosystem

Invasive house mice are negatively impacting the Farallon Islands ecosystem both directly and indirectly. Some of the impacts have been documented on the Farallones while others have been

inferred based on documented invasive house impacts on other islands. Figure 1.3 demonstrates the house mouse food web on the South Farallon Islands.

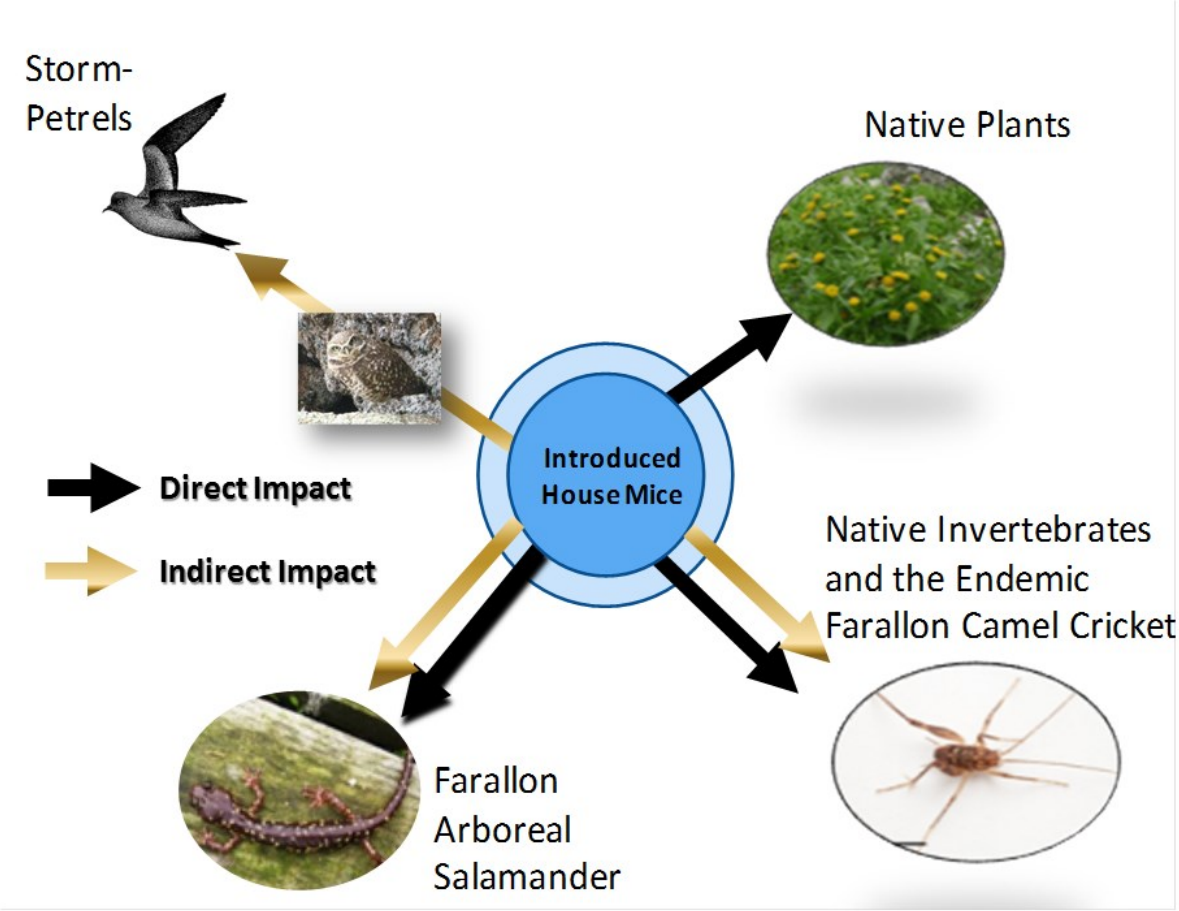


Figure 1.3 – Food web of house mice on the South Farallon Islands.

1.2.2.1 *Impacts of mice on storm-petrels*

House mice primarily impact Farallon ashy and Leach's storm-petrels indirectly. Indirect impacts through hyperpredation consists of a transient burrowing owl population that is initially subsidized by the mice; when the mouse population crashes, the owls switch to preying on storm-petrels (Chandler et al. 2016, Mills 2016). Like many other species of birds, burrowing owls stop at the South Farallon Islands on their fall migration. Most owls arrive at the islands between late September and October (DeSante and Ainley 1980, Richardson et al. 2003), when the mouse population is at its annual peak (Figure 1.4). This high mouse abundance leads to several burrowing owls remaining on the island through the winter instead of continuing on their migration, as most other migrant landbirds reaching the islands do. Intensive studies have shown that burrowing owls feed primarily on mice during the period of October to mid-January. However, as the mouse population naturally declines in the winter months, the owls switch to preying mainly on storm-petrels from February until the time when most owls have departed the islands in April (Chandler et al. 2016, Mills et al. 2016). Chandler et al. (2016) reported that mice and storm-petrels made up 98 percent of burrowing owl diet, with similar proportions of

mice in the early period and storm-petrels in the later period. Figure 1.4 illustrates the temporal changes in prey availability and burrowing owl abundance on the South Farallones.

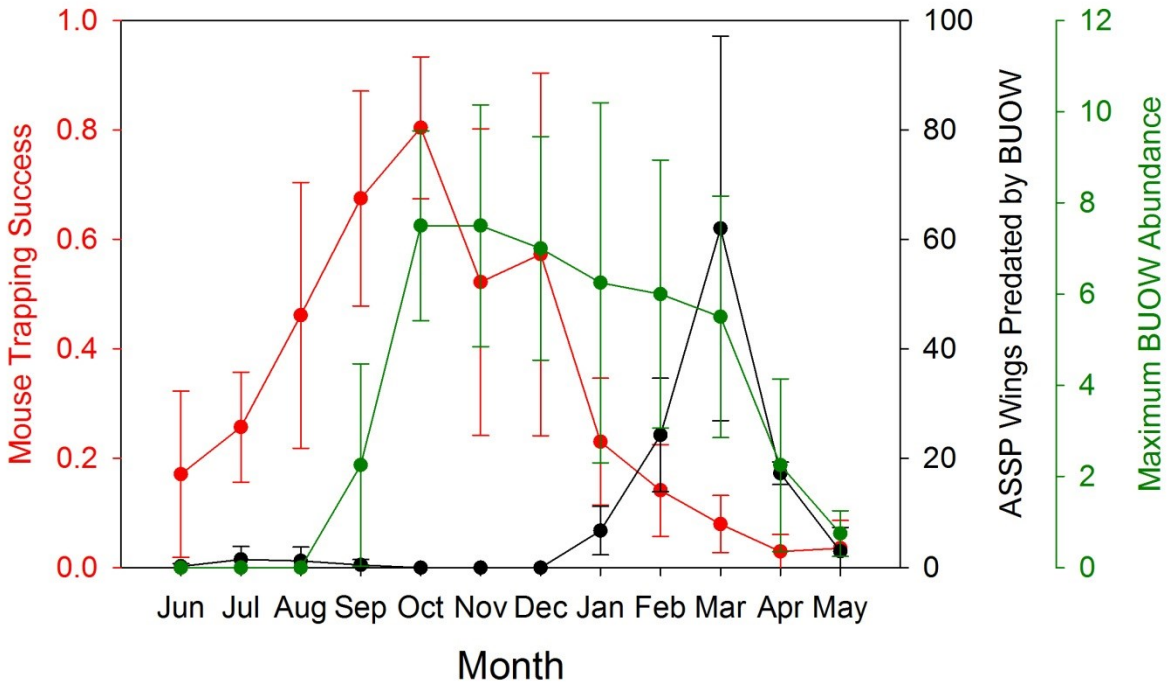


Figure 1.4: Seasonal cycle of house mouse abundance (2001-2004, 2011-2012), ashy storm-petrel predation (ASSP) and burrowing owl (BUOW) abundance on Southeast Farallon Island. Monthly values with standard deviations are shown.

The hyperpredation situation of owls preying on mice then switching to storm-petrels is considered to be one of the primary threats to the Farallon storm-petrel populations (Carter et al. 2008; Nur et al. 2013a, in review). Bradley et al. (2011) estimated that 40% of depredated storm-petrel carcasses found on Southeast Farallon Island in 2003-2011 were killed by burrowing owls. This equated to a minimum of 90-108 storm-petrels depredated by burrowing owls per year, but actual numbers were likely considerably higher because it only included frequently accessed portions of the island (Figure 1.5). However, these totals may underestimate total predation because only easily accessible portions of Southeast Farallon Island were surveyed (Bradley et al. 2011).

Figure 1.5: Ashy storm-petrel remains beneath burrowing owl roost on Southeast Farallon Island.

Photo by P. Pyle.

Nur et al. (2013a, in review) modeled the impacts house mice via burrowing owl predation on storm-petrels from field surveys of owls, mice, owl predation rates on storm-petrels, and storm-petrel mist-net capture rates on Southeast Farallon Island between 2000 and 2012. They found owl predation on storm-petrels to be positively related to burrowing owl abundance and negatively related to house mouse abundance. In other words when owls were more abundant, they preyed on more storm-petrels and when mice were less abundant, owls preyed on more storm-petrels. Indices of burrowing owl abundance and predation on storm-petrels significantly increased in the later years examined, when an average of 6.2 owls (range is two to 11 owls) were known to occur on the islands in mid-winter (Nur et al. 2013a). Capture-recapture analyses of storm-petrel population trends revealed two divergent trends: a strong increasing trend from 2002-2005/6, with a significant change in trend from increasing to decreasing for the period 2006-2012. The declining trend in abundance after 2005 was associated with low rates of adult survival, high abundance of over-wintering burrowing owls and high incidence of owl-killed storm-petrels compared to before 2005. For the period 2000 to 2012, a model including a linear negative effect of burrowing owl abundance best described annual storm-petrel survival (Nur et al. 2013a, in review). In other words, in years with more overwintering burrowing owls, storm-petrel survivorship was reduced.

House mice also have been shown to have at least minor direct impacts to Farallon storm-petrels as well as another small seabird, the Cassin's auklet (*Ptychoramphus aleuticus*). Ainley et al. (1990d) inferred predation by house mice of one ashy storm-petrel chick based upon the remains of a partially eaten carcass. They surmised that mouse predation was likely one factor that affected ashy storm-petrel chick survival. In addition, researchers found mice would chew on decoy eggs made of modeling clay, when they were made available (Point Blue, unpublished data). Chicks of storm-petrels and Cassin's auklets have been found with toes or feet missing as a result of mouse predation (D. Ainley, pers. comm.; P. Pyle, pers. comm.). This information, combined with evidence of house mouse predation on seabird eggs and chicks on other islands around the world (Cuthbert and Hilton 2004; Wanless et al. 2007; Angel et al. 2009; Jones and

Ryan 2010; USFWS 2018), indicates that house mice have at minimum a low level of direct impact on storm-petrels on the South Farallon Islands. However, because of the difficulty in monitoring storm-petrels in their small rock crevice nest sites and nocturnal behavior, it is possible that house mice are imposing a greater impact on Farallon storm-petrels than has been directly observed.

1.2.2.2 *Impacts of mice on salamanders*

Although there have been no studies on the direct effects of invasive house mice on salamanders and other amphibians, likely impacts can be inferred about the impacts of mice on endemic Farallon arboreal salamander by comparing the two species' ecologies. Salamanders feed primarily on insects and other small invertebrates (Lee 2010). Insects have been shown to be a major prey item of house mice on the Farallones and other islands (Rowe-Rowe et al. 1989, Jones and Golightly 2006, Angel et al. 2009). Thus, mice and salamanders compete for the same prey. Given the opportunistic, omnivorous diet of house mice (Berry 1968, Jones and Golightly 2006), it is also possible that mice consume salamander eggs and/or juveniles, especially during periods when mice are food stressed. Farallon arboreal salamanders lay their eggs in summer (Boekelheide 1975), with young appearing in the fall (Lee 2008). Thus, juvenile salamanders begin to emerge to the ground surface when mice are most abundant, increasing their risk of predation by mice.

1.2.2.3 *Impacts of mice on native invertebrates*

Evidence from the South Farallones and other islands (see Sections 1.2.5.4 and 4.5.3.6) suggests that mice impact native invertebrates both directly and indirectly (Rowe-Rowe et al. 1989, Jones and Golightly 2006, Angel et al. 2009). Analysis of mouse diet on Southeast Farallon Island showed high consumption of native invertebrates including the endemic Farallon camel cricket (Jones and Golightly 2006). By means of hyperpredation (see Section 1.2.2.1), mice indirectly impact native invertebrates by encouraging large numbers of burrowing owls to over-winter on the Farallones. These owls consume large numbers of invertebrates, mainly beetles (Coleoptera) and Farallon camel crickets (Chandler et al. 2016, Mills 2016). The combined mouse and owl predation are likely suppressing numbers of the rare cricket and other invertebrates. Reductions in invertebrate populations may have other ecosystem impacts since many invertebrates are important pollinators of plants, help to decompose dead plant and animal matter, and provide food sources for migratory birds stopping to refuel at the islands (e.g., Seastedt and Crossley 1984, Angel et al. 2009, St. Clair 2011).

1.2.2.4 *Impacts of mice on native plants*

House mice likely impact Farallon native plants both directly and indirectly. Seeds and other parts of native plants, especially the ecologically important maritime goldfield (*Lasthenia maritima*; an annual), are major food items of Farallon mice (Jones and Golightly 2006). The large numbers of native seeds consumed by mice likely reduces native plant abundance and may also give more hardy invasive plants (mostly perennials and aggressive European grasses) a competitive edge. For example, on Marion Island, mouse predation on seeds and young shoots of the native sedge *Uncinia compacta* has nearly led to that plant's extirpation, and mice are

thought to be similarly impacting the herbaceous plant *Acaena megellanica* (Angel et al. 2009). Some studies suggest that mice prefer feeding on native plants on islands, possibly because island natives lack the defensive traits (e.g., chemical compounds) that help reduce palatability (Angel et al. 2009). Indirectly, mice may impact native plants by reducing populations of important pollinators (Angel et al. 2009, St. Clair 2011).

1.3 Benefits of House Mouse Eradication

While many studies have focused on the impacts of introduced mammals, most eradications lack the robust, long-term monitoring needed to document ecosystem changes following eradication and most that do focus on breeding seabirds (Buxton et al. 2014, Brooke et al. 2017). This is particularly true for house mice, partly because most successful house mouse eradications have been in fairly recent years. However, most mammal eradication projects with post-eradication monitoring recorded increases in impacted populations (e.g., Buxton et al. 2014, Newton et al. 2016, Brooke et al. 2017, Martin and Richardson 2017, Wolf et al. 2018). In some cases, species not known to have been impacted increased following removal of the mammal invader.

Along with information on documented changes following eradications, the benefits of invasive mammal eradications on island ecosystems are largely assessed by the elimination of their known or suspected impacts. In some cases, those impacts may not be realized until the invasive species is removed. On the South Farallon Islands, the eradication of house mice would result in significant benefits to the Farallon ecosystem. Reduced predation pressure on impacted native species would assist population recovery of several species, help restore the historic ecosystem balance of the Farallones, and help buffer native species against other current and future threats. Additionally, mouse removal would make the Farallones ecosystem more resilient to potential impacts from projected future climate change. For example, if changing weather patterns lead to a change in mouse annual cycle, with more mice in seabird breeding season, they could have a much bigger impact on breeding seabirds and other resources.

1.3.1 Removing the Impacts of Mice on Storm-Petrels

The removal of house mice from the South Farallon Islands is expected to substantially reduce or eliminate hyperpredation of ashy and Leach's storm-petrels by burrowing owls (See Section 1.2.2). The best scientific evidence available to the Service indicates that if mice are removed from the South Farallon Islands, few if any of the burrowing owls that now arrive on the islands in the fall would overwinter. Studies conducted on seasonal fluctuations in owl diet on the South Farallones support the hypothesis that owls depend on mice for survival during the fall (Chandler et al. 2016, Mills 2016). By the time the owls switch from preying on mice to storm-petrels in the winter and spring, most owls have been on the island for several months (Chandler et al. 2016; Point Blue, unpublished data), having settled awaiting their spring departure to the breeding grounds.

While ashy storm-petrels are present at least in low numbers year-round, attendance from February, through October; Leach's storm-petrels are present from late February to mid-October (Ainley et al. 1990d). Storm-petrels are likely most at risk from owl predation when they are in the colony vocalizing and socializing, which is primarily between winter and early summer.

Conversely, in the fall, activity is mainly limited to secretive visits to nest sites to feed chicks. Burrowing owls mainly arrive on the South Farallones in the fall (DeSante and Ainley 1980, Richardson et al. 2003), when house mice provide abundant prey but storm-petrels do not. While owls also consume large numbers of insects, it is believed that insects would not provide adequate prey supplies to sustain the numbers of owls overwintering on the Farallones in recent years (Chandler et al. 2016). Therefore, it is considered highly likely that if mice are removed from the South Farallones, owls would behave similarly to the thousands of other migrant birds that arrive at the islands each fall and only stay for a short stop-over. With mice absent from the islands, storm-petrels would be at reduced risk of predation by owls in the winter and early spring; this predation equates to hundreds of storm-petrels lost to the population in years of high owl abundance.

To assess potential benefits to Farallon ashy storm-petrels from eradication of mice, Nur et al. (2013a, Appendix M) modeled the annual change in ashy storm-petrel population trend as a result of anticipated reductions in burrowing owl predation, as reported in the RDEIS. Although it is less well documented probably because of their much smaller island population size, burrowing owls likely prey on Leach's storm-petrels as well and modelled population scenarios for the ashy likely reflect similar scenarios for the Leach's. That modelling effort showed that even a 50% reduction in owl numbers would have population-level benefits to storm-petrels. More recent analyses utilizing a longer time series have provided even greater insights into owl (and, indirectly, mouse) impacts on storm-petrels (Nur et al. 2018, in review). Nur et al. (2018, in review) considered three future "baseline trend scenarios" for Farallon ashy storm-petrels and developed population models for each, incorporating environmental variability. They used these scenarios to model a range of plausible future population trends and then modeled projected impacts of changes in owl abundance on storm-petrel adult survival and population trajectory: 1) Trend Scenario A was the observed storm-petrel population trend between 2006 and 2012 (4.36% decline per year); 2) Trend Scenario B assumed a "moderate" storm-petrel decline of 2.14% per year (one standard error higher than Scenario A): and 3) Trend Scenario C assumed an approximately stable storm-petrel population trend of 0.12% increase per year (two standard errors higher than Scenario A). For each of these population trend scenarios, expected changes in relative storm-petrel population size over a twenty-year time period were modeled for three levels of projected changes in owl numbers (and, thus, predation on storm-petrels) from the 2009-2012 (4-year average) baseline level: no change, 50% reduction, and 80% reduction (Figure 1.6).

Nur et al.'s (2018, in review) modelling results demonstrated levels of uncertainty in the scenario outcomes. However, under all three trend scenarios, median results displayed a strong projected effect of reduction on Farallon ashy storm-petrel population trends due to owl predation even after just 10 years. Under Scenario A, future storm-petrel trends shift from an expected average 38% decline after 10 years under baseline owl numbers to a 13% storm-petrel decline with 50% owl reduction. An 80% decline in owl numbers leads to an expected 2% increase in storm-petrel numbers. Given that the Farallon colony represents nearly 100% of the regional population (Carter et al. 1992, McChesney et al. 2013), estimates of expected changes for the Farallon colony would extend to the regional population.

Similar effects to Scenario A are seen under Scenarios B and C after 10 years. Not surprisingly, impacts of owl reduction are more marked after 20 years. For example, under Scenario B and no owl reduction, storm-petrels are expected to decline 40% after 20 years. With owl reductions of 50% and 80%, storm-petrels are expected to increase by 6% and 37%, respectively. For Scenario C, the expected values based on median outcomes is a 54% or 89% storm-petrel increase after 20 years with 50% or 80% owl reduction, respectively, compared to median storm-petrel decline of 1.3% with no owl reduction.

In more recent years (2013-2016), numbers of burrowing owls wintering on the Farallones has been lower than most years of the 2005-2012 period. Anecdotal observations suggest that reduced burrowing owl abundance was likely associated with reduced mouse abundance, a possible result of prolonged drought. The reduced owl abundance resulted in reduced owl predation on storm-petrels. In turn, storm-petrel population size was more stable during this brief period (Nur et al 2018, in review). This finding provides further support for the benefits of reducing burrowing owl numbers on the Farallones.

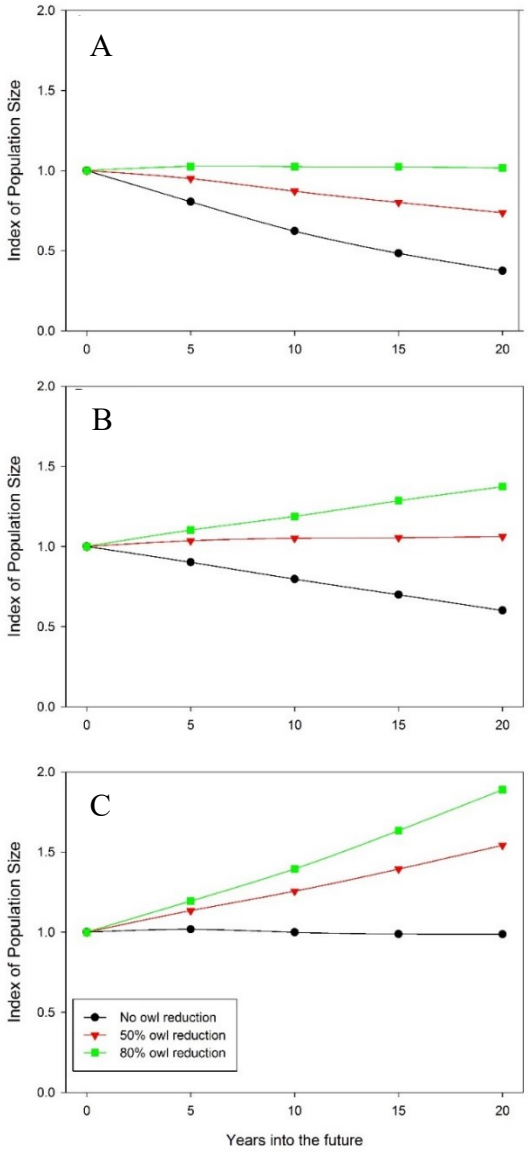


Figure 1.6: Farallon ashy storm-petrel population projections under the three levels of reduction in burrowing owl abundance: 0% reduction (black circles), 50% reduction (red triangles), and 80% reduction (green squares). Median results from simulations (10,000 simulations per trend-owl reduction scenario combination) are shown. Levels of reduction are modeled for each of three baseline trend scenarios: A) "Observed Decline"; B) "Moderate Decline"; and C) "Near-Stable". Depicted are relative population sizes for a 20-year period; the population size index is 1.0 for Year 0. Year 0 corresponds to the year in which burrowing owl reduction is implemented, hence the storm petrel population is assumed to first respond between Year 0 and Year 1. Figure from Nur et al. 2013(in review).

1.3.2 Removing the impacts of mice on wilderness character

With the exception of Southeast Farallon Island, all of the South Farallon Islands were included in the designated Farallon Wilderness in 1974. House mice have degraded the natural character of the Farallon Wilderness. The removal of mice would lead to long-term significant benefit to wilderness character by allowing the wilderness to be more influenced by natural forces (see section 4.4.1). Mouse removal would be consistent with the Service's Wilderness Stewardship Policy, which allows the Service to intervene in ecosystem processes to further refuge purposes or to counteract processes that are unnatural. Examples of unnatural processes include disrupted predator/prey relationships and the spread of non-native species (610 FW 2). The Service's Wilderness Stewardship policy further provides that actions to modify ecosystem processes are justifiable to "maintain[s] or restore[s] biological integrity, diversity, or environmental health of the wilderness area" (610 FW 2). The Wilderness Stewardship Policy further provides that removal of invasive species or pests may take place in wilderness areas to protect biological integrity or diversity through an Integrated Pest Management approach. Consistent with this policy, a Minimum Requirements Analysis (MRA) has been prepared addressing the consistency of the alternatives proposed in the EIS with the requirements of the Wilderness Act (see Appendix G). In discussing the impact of removing mice on wilderness character, the MRA notes that "[t]he influences of house mice has altered the abundance of certain native species . . . and thereby reduced the influence of natural forces on the islands." It further notes that "[t]he removal of mice would allow the wilderness to be more influenced by natural forces" (Appendix G).

1.3.3 Removing the impacts of mice on native invertebrates

Mouse eradication efforts have led to documented increases in naïve invertebrate populations on many islands (Newman 1994, Ruscoe 2001, St. Clair 2011). For example, on Mana Island, New Zealand, the populations of the Cook Strait giant weta (*Deinacrida rugosa*), a native insect in the same order as the endemic Farallon camel cricket, increased noticeably after mouse eradication (Newman 1994). Both mice and burrowing owls, which are attracted to the Farallon islands by the mice, consume large numbers of terrestrial invertebrates on the islands, including the endemic Farallon camel cricket (Jones and Golightly 2006, Chandler et al. 2016). Removing this additional predation pressure will likely benefit the endemic cricket and other species and help restore the diverse Farallon invertebrate fauna to a more natural balance.

1.3.4 Removing the impacts of mice on native salamanders

The eradication of mice on the South Farallones would likely benefit the islands' endemic Farallon arboreal salamander by removing both the presumed predation pressure on salamanders from mice and competition with mice for invertebrate prey. The Farallon arboreal salamander population is expected to benefit as a result of increased productivity, juvenile survivorship, and/or adult survivorship in response to complete mouse removal. For example, after a successful mouse eradication on Mana Island, New Zealand, populations of McGregor's skinks (*Cyclodina macgregori*) and common geckos (*Hoplodactylus maculatus*) increased significantly (Newman 1994). Both of those species are of a similar size to the Farallon salamander and were presumably subject to the same pressures likely supplied by house mice on Farallon salamanders.

1.3.5 Removing the impacts of mice on native plants

The native plants of the Farallones evolved without predation pressure from mammals such as house mice. These mostly annual plants are currently at a competitive disadvantage against the more aggressive invasive plants like New Zealand spinach (*Tetragonia tetragonoides*), narrowleaf plantain (*Plantago coronopus*), and several species of European grasses that have become dominant on large parts of the islands (Hawk 2015, Holzman et al. 2016). Eliminating mouse predation to native plant seeds and shoots will likely increase germination and survival rates of plants like the maritime goldfield, helping to improve the conditions of the native Farallon plant community.

1.4 Past Actions to Reduce Mouse Impacts on the South Farallon Islands

It had been suggested that many burrowing owls that attempt to over-winter on the Farallon Islands starve to death following the cyclic crash of house mice in the winter (Mills 2006). To help protect burrowing owls from potential starvation, the Service experimented with capture and translocation of a small number of owls to sites on the mainland. As a result, translocated owls would be prevented from preying upon storm-petrels on the islands. These attempts proved difficult, and benefits to translocated owls were difficult to ascertain. More intensive studies in recent years have shown that many owls survive the winter on the Farallones, and some individuals have returned to over-winter in subsequent years (Point Blue, unpublished data). Thus, the need for owl translocation to benefit the owls has diminished and translocations were discontinued. Because few owls were translocated, the benefit to storm-petrels was minor.

1.5 Lessons Learned

For the RDEIS, the Service developed action alternatives that incorporated many of the lessons learned from previous eradication projects, including Anacapa Island, Rat Island, Palmyra Atoll, Desecheo Island, Wake Atoll, Henderson Island, and many others). Lessons learned are more often thought of as those that hampered project success, but it also includes those helped project success. However, the RDEIS did not specify how lessons from past projects were applied within the document or how the proposed alternatives would address those lessons. For those reasons, the Service has added lessons learned into three different chapters of the FEIS. Chapter 1 describes the Service's approach to addressing lessons learned from past projects, the overall lessons learned that were accounted for in this project and outlining the Best Management Practices (BMPs) for rodent eradication projects developed by the Service (provide citation here). Chapter 2 incorporates lessons learned from projects that failed to eradicate the target species, a summary of the BMPs developed by the New Zealand Department of Conservation (DOC) for aerial mouse eradications, as well as the specific mitigation measures that have been incorporated into this EIS to address potential impacts. Finally, Chapter 4 incorporates lessons learned from eradication projects where nontarget impacts were greater than expected, as well as how the mitigation measures and contingency planning incorporated into this EIS would minimize the negative impacts to those species most at risk from eradication operations.

1.5.1 Overall Lessons Learned

Careful planning and expert implementation most often result in successful rodent eradications with minimal unexpected results. However, unforeseen scenarios in planning can result in negative consequences during project implementation. A well-known example of this was the 2009 rat eradication on Rat Island in the Aleutian Islands, Alaska. The operation was successful at eradicating the target rat species, but it failed to foresee and plan for non-target impacts that resulted in the deaths of at least 320 glaucous-winged gulls and 46 bald eagles (Ornithological Council 2010). Following the Rat Island project, the Service solicited the Ornithological Council to undertake a third-party review of the project from feasibility to planning and implementation that included recommendations for best management practices and topics for the Service to consider when developing future eradication projects. Section 1.5.2 summarizes the Ornithological Council's findings and recommendations.

With improving eradication methodology and success rates, in the last decade eradication teams have begun to target more islands with increasingly difficult planning environments. This resulted in several projects that failed to eradicate the target species or resulted in unanticipated nontarget mortality, particularly in tropical environments. As a result, an international team of eradication specialists met in New Zealand in 2013 to discuss and examine the factors contributing to eradication failures (Keitt et al. 2015). Ultimately, it was determined that a better understanding of the existing biological structure is imperative to successfully implementing eradication projects on islands. The most likely reasons for eradication failure include nontarget bait consumers that can consume bait intended for the target species, succumb to bait consumption, or act as a secondary toxicant source to their predators; failing to get sufficient bait into every rodent territory to ensure that every target individual can receive a lethal dose; and failure to sufficiently monitor and mitigate impacts to non-target species at a level that is both within permitted levels and socially acceptable (Keitt et al. 2015).

1.5.2 Ornithological Council's Recommendations for Island Rodent Eradications

The Ornithological Council (2010) report on the Rat Island project included four recommendations for future rodent eradication projects conducted by the federal government The four recommendations include, 1) A concerted effort must be made to use first generation anticoagulants or less toxic alternatives whenever possible; 2) Use best practices outlined by the Ornithological Council when planning future eradication projects on federally owned islands; 3) In cases where project implementation differs from the plan, agencies should document the reasons for any changes and discuss the impacts of any changes; and 4) Make planning documents available to the public. The following outlines the Service's effort to address the four recommendations from the Ornithological Council by providing section numbers and reports where the Service has addressed each specific recommendation.

Recommendation 1: A concerted effort is needed to develop effective methodologies for diphacinone and other toxicants with a goal of reducing non-target mortality. The Council also suggested that first generation anticoagulants such as diphacinone be used in cases where rare species could be imperiled by the use of second-generation anticoagulants and where logistical

considerations did not necessitate the use of a second-generation compound. As part of this same recommendation, the Council also suggested using short-term control measures until effective low-toxicity rodenticides could be developed.

The Service included a diphacinone-based alternative in this EIS (Alternative C). As discussed in the EIS, no rare species (e.g., endangered or threatened) are at substantial risk of non-target mortality from either B or Alternative C. The risks of non-target mortality from each alternative are discussed in Chapter 4. The gull species present on the South Farallon Islands are not considered rare by any standards but are at relatively high risk of non-target mortality. As a result, the Service has developed a robust gull hazing program to reduce this risk. As part of the alternative development process, the Service considered a number of non-toxic methodologies, including control. These were rejected from full consideration in the EIS for the reasons explained in Section 2.7.

Recommendation 2: The Council recommended a list of best practices for rodent eradication projects. Each best practice is listed below with corresponding references to the sections of the EIS where the best practice has been addressed.

a) Provide an explanation of why a second-generation rodenticide is being considered (Section 2.6)
b) Conduct site specific studies such as biological surveys and bait uptake (Section 2.8)
c) Determination of bait rate (Sections 2.8, 2.10.5, 2.11, and 2.12)
d) Criteria of applying bait above planned rate (Section 2.10.5)
e) Baiting strategy (Sections 2.8, 2.10.5, 2.11, and 2.12)
f) Use standard terminology and definitions in operational documents (Operational Plan)
g) Full and public documentation of planning decisions (Section 1.7 and Chapter 5)
h) Full and public documentation of external reviews and responses to reviews (Chapter 5 and Public Comment Response Report)
i) NEPA documents should contain specific information:
   The EIS contains all of the specific types of information required by law (Section 1.6) and recommended by the Council. The Service does not anticipate any changes to the project following publication of the FEIS. If changes are made to the project, the Service will assess whether those changes are substantial and relevant to environmental concerns or the impacts of the selected action. A supplemental EIS would be prepared if appropriate.
j) Bait rate reporting (Section 2.11.2 and Section 2.12.2)
k) Mitigation measures, including carcass removal where practical (Section 2.10.7 and Section 2.10.10)
l) Publication and dissemination of results (Chapter 5 and Record of Decision)

Recommendation 3: In cases where project implementation differs from the plan, agencies should document the reasons for any changes and discuss the impacts of any changes.

As a result of public and agency input, the Service has continued to fine tune the alternatives and develop protocols for contingencies. If an action alternative is implemented, the Service will develop contingency plans for unexpected occurrences that jeopardize the success of the project or that may result in significant impacts to non-target resources. Any major changes to a selected

alternative would require approval of a Supplemental EIS. Minor changes, like those used to adaptively manage the project, for example to address weather issues, unexpected discoveries, or to apply additional mitigation measures, do not require a Supplemental EIS but would be documented.

Recommendation 4: The Council recommended that project-related documents, such as feasibility studies, field research reports, operational plans and similar documents, be made available to the public.

The Service has included feasibility studies, site-specific studies, and other reports related to the project in the appendices of the EIS. Responses to public and agency comments are also contained in Appendix P.

1.6 Key Laws and Policies That Guided the Development of the Proposed Project

The Service manages the Refuge in accordance with a number of laws and policies that have guided the development of this project. The primary statute guiding refuge management is the National Wildlife Refuge System Administration Act of 1966, amended by the National Wildlife Refuge System Improvement Act of 1997 and codified at 16 U.S.C. §§ 668dd-668ee. The Refuge Improvement Act provides that the mission of the National Wildlife Refuge System involves the "conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States." § 668dd(a)(2). Furthermore, the Refuge Improvement Act directs the Service to "ensure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans." § 668dd(a)(4)(B).

Another source of guidance for this project is the Presidential Executive Order relating to invasive species. The order directs federal agencies to "eradicate or control populations of invasive species in a manner that is cost-effective and minimizes human, animal, plant, and environmental health risks" (Executive Order 13112 on Invasive Species, February 3, 1999, as amended December 5, 2016). Agencies are further instructed to "provide for the restoration of native species, ecosystems, and other assets that have been impacted by invasive species" (EO 13112).

The Refuge is also managed in accordance with the Wilderness Act of 1964 (16 U.S. C. 1131-1136). The Wilderness Act established a National Wilderness Preservation System composed of federally owned areas designated by Congress as "wilderness areas." An area designated as wilderness must be managed to preserve its wilderness character. All of the Farallon Islands except for Southeast Farallon Island are designated under this system as the Farallon Wilderness.

In order to fulfill its Congressional and Executive mandates, the Fish and Wildlife Service issues policies that must be followed by Service personnel unless the Service Director provides a waiver (see 010 FW 1.4). Following the passage of the Refuge Improvement Act, the Service issued a policy on Biological Integrity, Diversity, and Environmental Health (601 FW 3). This policy provides that refuges in the National Wildlife Refuge System must be managed in a way

that maintains, and, where appropriate, restores the biological integrity, diversity, and environmental health of the Refuge System. The policy "favor[s] management that restores or mimics natural ecosystem processes or functions to achieve refuge purpose(s)" (601 FW 3). In seeking to maintain biological diversity, the policy supports "eliminating unnatural biotic and abiotic features and processes not necessary to accomplish refuge purpose(s)" where elimination would be "appropriate and feasible" (601 FW 3).

With regard to invasive species, the Service implements the Executive Order on Invasive Species by instructing refuge managers to "control populations of invasive species and provide for restoration of native species and habitat conditions in invaded ecosystems" (601 FW 3). Management of invasive species is accomplished through "integrated pest management strategies that incorporate the most effective combination of mechanical, chemical, biological, and cultural controls while considering the effects on environmental health" (601 FW 3). The Service's Integrated Pest Management policy likewise authorizes the use of chemical tools to control invasive species in a way that "minimizes health, environmental, and economic risks" (569 FW 1).

Lastly, the Service carries out its obligations under the Wilderness Act through its Wilderness Stewardship Policy (610 FW 1-2, 2008), which "encourage[s] the restoration and maintenance of biological integrity and wilderness character." The policy allows interference with ecosystem processes when necessary for accomplishing refuge purposes or when these processes "become unnatural." These circumstances may involve the spread of alien species or disrupted predatory/prey relationships. Under the policy, Service action to maintain or restore the biological integrity of a refuge may be justified by a Minimum Requirements Analysis. The Service has conducted such an analysis, included in this EIS as Appendix G.

1.6.1 **Other Applicable Laws, Policies and Plans**

In addition to the laws and policies discussed above, the following legal authorities and plans have also informed the proposed action and its alternatives.

The U.S. Fish and Wildlife Service's mission is to work with others to "conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people."

The Fish and Wildlife Act of 1956 (16 U.S.C. 742a-742j, not including 742 d-l, 70 Stat. 1119), as amended, gives general guidance that can be construed to include alien species control, that requires the Secretary of the Interior to take steps "required for the development, management, advancement, conservation, and protection of fish and wildlife resources."

The Migratory Bird Treaty Act of 1918 (16 U.S.C. § 703 et seq.) implements several treaties protecting birds that migrate across national borders. The Act makes it unlawful to take, capture, possess, or sell protected species, or any product or parts thereof, except as permitted by the Secretary. The MBTA's take prohibitions apply when the purpose of an action is to take migratory birds, their eggs, or their nests. The taking of birds, eggs or nests occurring as a result of an activity, the purpose of which is not to take birds, eggs or nests, is not prohibited by the

MBTA (Department of the Interior Solicitor's Opinion M-37050 and FWS Guidance Memo, April 11, 2018). The purpose of the proposed project is to eradicate mice, not to take birds, eggs or nests. As a result, non-target take of birds as a result of the eradication project would not constitute take under the MBTA and a permit would not be required. Proposed deterrent efforts that involve hazing migratory birds also do not require a permit under the MBTA, however hazing methods have been reviewed and agreed upon by the Service's Regional Migratory Bird Permit Office. Methods involving capture and translocation, or temporary captivity will be done in accordance with the terms of a permit issued by the Regional Migratory Bird Permit Office.

The Coastal Zone Management Act of 1972 (16 U.S.C. § 1451 et seq.) encourages coastal states to develop and implement comprehensive programs to manage and balance competing coastal resource uses. The Act allows states with approved plans to review federal actions that have a reasonably foreseeable effect on any land or water use or natural resources of the state's coastal zone. The California Coastal Commission implements a federally-approved plan for California's coastal waters. The Coastal Commission will determine whether the proposed federal action is consistent to the maximum extent practicable with the enforceable policies of the state's coastal plan. While federal agency actions do not require state approval, a state determination of inconsistency requires federal agencies to follow additional procedures prior to taking action. The Service will seek a consistency determination from the California Coastal Commission prior to issuing a Record of Decision for the proposed project.

The Clean Water Act of 1972, as amended, (33 U.S.C. § 1251 et seq.) is the primary federal law governing water integrity in the United States. Under the Act, pollutants may not be discharged from point sources into navigable waters without a permit. National Pollutant Discharge Elimination System permits are required for the aerial application of rodenticides when the application may cause rodenticides to enter waters of the United States. The Service will seek a NPDES permit from the Regional Water Quality Control Board if one of the action alternatives is selected for implementation.

The Endangered Species Act of 1973, as amended, (16 U.S.C. § 1531 et seq.) provides a program to conserve endangered and threatened species of plants and animals, as well as their habitats. The Act requires the Service to ensure that its actions affecting federally listed species do not jeopardize those species' continued existence or result in the destruction or adverse modification of their critical habitat. The Service has initiated consultation with the Service's Ecological Services Division and the National Marine Fisheries Service regarding the effects of the proposed action on listed species and critical habitat.

The Federal Insecticide, Fungicide, and Rodenticide Act of 1972 (7 U.S.C. § 136 et seq.) regulates the distribution, sale, and use of pesticides by providing a system of registration, labeling, and use of pesticides to protect applicators, the public, and the environment. Use of each registered pesticide must be consistent with use directions contained on the label or labeling. The Act establishes a system of examination and certification for applicators. If use of a rodenticide is approved, the Service will comply with label instructions and follow Service policy regarding the application of rodenticides.

The Marine Mammal Protection Act of 1972 (16 U.S.C. §1361 et seq.) establishes a national policy to prevent marine mammal populations from declining and to protect marine mammals. The Act prohibits, with certain exceptions, the taking of marine mammals in the waters of the United States. "Take" is defined as "harass, hunt, capture, or attempt to harass, hunt, capture or kill any marine mammal." Harassment means "any act of pursuit, torment, or annoyance that (i) has the potential to injure a marine mammal or marine mammal stock in the wild; or (ii) has the potential to disturb . . .by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding, or shelter." (16 U.S.C. § 1362(18)). The Service will consult with the National Marine Fisheries Service and seek an incidental harassment authorization for pinnipeds if either of the action alternatives is selected for implementation.

The National Marine Sanctuaries Act (16 U.S.C. §1431 et seq.) allows for the designation and protection of areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities. The Farallon Islands National Wildlife Refuge is bounded by the Greater Farallones National Marine Sanctuary. The flying of aircraft less than 1,000 feet over specific Special Wildlife Protection Zones of the Sanctuary, including areas surrounding the Farallon Islands, is regulated by the sanctuary to protect seabirds, marine mammals, and sea turtles from disturbance. If the proposed project is approved, the Service will coordinate with the Sanctuary on applicable permitting requirements.

Greater Farallones National Marine Sanctuary regulations CFR Title 15, Subtitle B, Chapter IX, Subchapter B, Part 922, Subpart H, §922.82(a)(2) prohibits "Discharging or depositing from within or into the Sanctuary, other than from a cruise ship, any material or other matter..."

The USFWS's Regional Seabird Conservation Plan lists mouse eradication from the Farallones as a top seabird conservation priority in the region.

Comprehensive Conservation Plan (CCP) for Farallon Islands National Wildlife Refuge. As mandated by the National Wildlife Refuge System Improvement Act of 1997, the Service finalized a CCP in 2009 to guide future management actions on the Refuge to meet the missions and purposes of the Refuge and the Service. The CCP includes mouse eradication from the South Farallon Islands as an objective for the Refuge's management direction of removing invasive species and restoration the native ecosystem of the Farallon Islands.

The Golden Gate Biosphere Reserve includes the Farallon Islands National Wildlife Refuge (Proclamation dated 12 August 1989). The Man and the Biosphere Program has been established by the United Nations Educational, Scientific and Cultural Organization to promote the conservation and wise use of the world's natural resources. The Reserve was determined "…to possess natural resource values of the highest international significance." The purposes include developing "…management methods for the benefit of the resources of the Reserve."

1.7 Scope of the Action Alternatives

The action alternatives focus on three areas:

- Activities necessary to eradicate house mice from the South Farallon Islands and eliminate their negative impact to island resources;
- Activities necessary to prevent the reintroduction of house mice and introduction of other small, non-native mammals to the South Farallon Islands, in the future; and
- Activities necessary to minimize negative impacts to native species and preserve wilderness character on the Farallones during the course of mouse eradication and reintroduction-prevention activities.

1.7.1 Summary of Scoping

Section 1501.7 of the CEQ regulations for implementing NEPA requires that agencies implement a process, referred to as 'scoping', to determine the scope of issues to be addressed in an environmental impacts analysis and identify the major environmental issues related to a proposed action that need to be analyzed. The scoping process included research in published and unpublished literature, consultations with experts in the ecology of the Farallones and in invasive species eradications, consultation with the government agencies that have a stake in the resources of the Farallones and adjacent waters, and invitations for comments from the public. There is a detailed description of the scoping process that the Service conducted for this EIS in Chapter 5. During the scoping process, the Service identified the major environmental issues, or "impact topics," that are described in Section 1.8 below. These issues guided the development of the alternatives in Chapter 2, and the scope and content of the environmental impacts analysis for each alternative found in Chapter 4. An updated Scoping Report (Appendix O) provides a detailed assessment of the comments received during the entire scoping process for both the original Draft EA and the Draft EIS that was subsequently published in 2013.

1.7.2 Summary of EA and EIS Scoping Processes

In 2006 the Service initiated an EA process for the removal of invasive house mice from the Farallon Islands. The Service sent letters out to interested parties and published a press release in local newspapers inviting interested parties to attend the Public Scoping Meeting held in San Francisco, CA on May 17, 2006. Approximately 10 guests attended the EA Scoping meeting with minimal questions or concerns over the projects proposed alternatives or outcomes. After completing an Administrative Draft EA, in early 2011 the Service determined that an EIS was a more appropriate document because of the potential for significant impacts from the project.

A Notice of Intent (NOI) to prepare an EIS was published in the Federal Register on April 13, 2011. In addition, a scoping notice was sent to a variety of interested parties, including those who attended or submitted comments at the initial scoping meeting on May 17, 2006 for the EA, as well as to various federal and state environmental agencies. The notice was also posted on the website of the Farallon Islands National Wildlife Refuge, and to a website established by former project partner Island Conservation (www.restorethefarallones.org).

Furthermore, for both the EA and EIS processes, the Service sent out press releases and published scoping announcements in major San Francisco Bay Area newspapers. The Service also notified other potentially interested constituents of the project and the scoping process.

At both scoping meetings, attendees viewed presentations prepared by the Service and project partners who were readily available to answer questions related to project objectives, methods, and related research. Comments made during the public scoping meetings related primarily to the potential for project success, and concerns regarding the proposed eradication methods. For more detail, see Appendix O.

1.8 Environmental Issues (Impact Topics) Identified

1.8.1 Impact Topic: Physical Resources

Sub-topic: Impacts to water resources

Because the proposed action would include the delivery of a toxicant into the Farallones environment, the potential impacts of the toxicant to local water quality was identified as an important environmental issue.

Sub-topic: Impacts to geology and soils

Because the proposed action would include the delivery of a toxicant into the Farallones environment, the potential for transfer and persistence of the toxicant into soils was identified as an important environmental issue.

Sub-topic: Impacts to wilderness

All of the South Farallones except Southeast Farallon Island are designated as wilderness under the Wilderness Act of 1964 (PL 88-577). Wilderness designation makes the wilderness character of the South Farallones an important environmental issue.

1.8.2 Impact Topic: Biological Resources

Sub-topic: Non-target impacts from toxicant use

Mouse eradication would include the use of a toxicant that is toxic to vertebrates. Toxicants should only be used in the environment if the behavior of that toxicant can be predicted with some accuracy. The impact of the toxicant to species other than mice and the persistence of the toxicant in the environment are important environmental issues related to the impacts of the action to biological resources, because animals other than mice, including birds, could be exposed to the toxicant.

Sub-topic: Disturbance to sensitive species

The Farallones are important habitat for species, such as seabirds and pinnipeds that are especially sensitive to human disturbance. The risk of disturbance to sensitive species from proposed action alternatives and mitigation measures is an important environmental issue related

to the impacts of the action to biological resources, particularly because of the importance of the islands for breeding seabirds and pinnipeds.

1.8.3 Impact Topic: Social and Cultural Resources

Sub-topic: Impacts to Personnel Safety

The impacts to human health and safety from operations are addressed under this impact topic

Sub-topic: Impacts to Refuge visitors and recreation

The Farallones are closed to the public to protect the Refuge's sensitive biological resources, but the animal species that depend on the Farallones are nevertheless important resources for wildlife enthusiasts visiting the nearshore waters and throughout these species' ranges. Additionally, recreational boaters utilize the waters surrounding the islands. Finally, a small number of FWS and Point Blue Conservation Science (Point Blue) personnel, contractors, and visiting researchers utilize the island year-round.

Sub-topic: Impacts to fishing resources

The waters near the Farallones are important recreational and commercial fishing grounds protected under the Magnus Stevens Act to Protect Essential Fish Habitat for species such as Chinook salmon (*Oncorhynchus tshawytscha*), albacore tuna (*Thunnus alalunga*), Dungeness crab (*Metacarcinus magister*), cabezon (*Scorpaenichthys marmoratus*), lingcod (*Ophiodon elongatus*), California halibut (*Paralichthys californicus*), and several species of rockfish (genus *Sebastidae*) (Scholz and Steinback 2006). In May of 2010, the State of California, as mandated by the State's Marine Life Protection Act, established the Southeast Farallon Island State Marine Reserve (SMR) surrounding the South Farallon Islands. The 5.34 square mile "no take" SMR prohibits the take of all living marine resources, including recreational and commercial fishing (California Dept. of Fish and Game 2011a).

Sub-topic: Impacts to cultural and economic resources

The impact of the action to historical and cultural sites, structures, objects and artifacts on the South Farallones that are listed on the National Registry are important environmental issues to assess. The Service will also assess the economic impacts from proposed operations to shark diving other tourism operations in the area that may be directly impacted during the operation.

This page intentionally left blank

2 Alternatives

2.1 Introduction

As part of the analytical process mandated by NEPA, federal agencies are required to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." Based upon the existing site conditions, purpose and need for action, constraints and feedback received during the public scoping process, three alternatives were identified: The No Action alternative (Alternative A) and two action alternatives, Alternative B (preferred alternative) and Alternative C. The No Action alternative is included in NEPA analysis to provide a baseline against which to compare the magnitude of environmental effects generated by the action alternatives. The No Action alternative describes the Service's current management regime on the South Farallones with regard to the mouse population and its impacts on the islands' resources.

The two action alternatives were developed by resource specialists within the Service, experts in island rodent eradications, and experts on the Farallon Islands' resources, as well as input from other applicable government regulatory agencies. In addition, the action alternatives reflect feedback received from agencies and the general public during scoping and the RDEIS public comment period. All individuals, agencies and organizations that provided substantive input are listed in Chapter 5.

In order to be retained for consideration, an alternative had to 1) be consistent with the Service's management guidelines, 2) be feasible to implement, and 3) meet the Service's safety and logistic requirements.

The alternatives are:

- *Alternative A: No Action, which would allow mice to remain on the South Farallon Islands and continue to negatively impact the islands' native ecosystem.*

- *Alternative B (preferred alternative): Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of the rodent bait Brodifacoum-25D Conservation as the primary method of bait delivery.*

- *Alternative C: Eradicate invasive house mice from the South Farallon Islands by aerial broadcast of the rodent bait Diphacinone-50 Conservation as the primary method of bait delivery.*

A number of additional alternatives were initially considered but removed from full consideration after completion of scoping and a quantitative alternatives selection process. A summary of the Alternative Selection Process (Appendix C) is provided in Section 2.2. Action alternatives that were considered and dismissed from detailed consideration are described along with the rationale for their dismissal in Section 2.7. Background information used during the development of action alternatives is provided in Section 2.8. The alternatives are outlined in Sections 2.9 – 2.13, including the No Action Alternative. Because both of the two action

alternatives rely on the aerial application of rodenticide bait, the many features common to both alternatives were grouped into Section 2.10.

The preferred alternative (Alternative B) was identified by the Service after extensive review of both agency and public comments received during the extended public comment period for the RDEIS. In addition, the Service conducted several pre-eradication studies (Section 2.8), reviewed lessons learned from past projects (Sections 1.5, 2.6.5, and 4.5.1.1), and consulted with collaborating agencies including the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA/APHIS/WS), U.S. Environmental Protection Agency (EPA), Greater Farallones National Marine Sanctuary, and California Department of Fish and Wildlife) prior to choosing the preferred alternative for this project.

2.1.1 Integrated Pest Management

Use of either Brodifacoum-25D Conservation or Diphacinone-50 Conservation would be in compliance with applicable Integrated Pest Management policies. Service policy, as reflected in the Departmental Manual, 517 DM 1, and the FWS Manual, 569 FW 1, calls for the use of integrated pest management (IPM) as the decision-making tool for making pest management decisions on refuge lands. The Service's wilderness stewardship policy also adopts the use of IPM for pest eradication efforts in wilderness (610 FW 1 and 2).

Integrated Pest Management is a sustainable approach to managing pests by using tools, including chemicals, in a way that minimizes health, environmental and economic risks. It is a science-based, decision-making process that incorporates management goals, consensus building, pest biology, monitoring, environmental factors, and selection of the best available technology to achieve desired outcomes while minimizing effects to non-target species and the environment and preventing unacceptable levels of pest damage (569 FW 1).

The Service's IPM policy allows the Service to take pest management actions when pests threaten the health of native wildlife, are detrimental to refuge management objectives, and the method for removing pests does not interfere with refuge management objectives. The choice of a pest control method is guided by the following, in order of importance: human safety, environmental integrity, effectiveness and cost. The Alternatives Selection Process (Appendix C) and the analysis in this EIS have been used to inform the Service's IPM decision-making process.

Before pesticides can be used on a refuge, the Service must prepare a Pesticide Use Proposal (PUP). PUPs are reviewed and approved at the regional office or Washington office level. If use of a rodenticide is approved on the South Farallon Islands, the PUP for this project would be reviewed and approved by the National IPM Coordinator and application of the selected rodenticide would comply with the terms and specifications of the PUP.

2.2 Summary of the Alternatives Selection Process

In 2011, the Service commissioned the preparation of an EIS in compliance with the National Environmental Policy Act to assess the most appropriate action alternatives for removing all

mice from the Farallon Islands. To decide which action alternatives to include in the EIS, the Service utilized a Structured Decision Making (SDM) approach known as the Alternatives Selection Process (Appendix C). This report documents the findings of that process and describes the decision-making structure and resources that the Service relied upon to assess and compare potential alternatives. The methods analyzed were gleaned from public and agency comments received during an extended public scoping period, as well as from a thorough review of past mouse and, similar and more numerous, rat eradication efforts world-wide.

In total, 49 different potential mouse removal methods were assessed including mechanical, theoretical, biological, and chemical methods applied using three different delivery techniques. The methods analyzed were first assessed to determine if they met the Minimum Operational Criteria, which required that each method:

A. Be consistent with select management and policy guidelines required of all proposed projects within the National Wildlife Refuge System, including:
    a. Mission of the Farallon Islands National Wildlife Refuge;
    b. Farallon Comprehensive Conservation Plan;
    c. U.S. Department of the Interior Policy on Introduced/Invasive Species;
    d. Wilderness Act Minimum Requirements;
    e. Endangered Species Act Jeopardy Requirements;
    f. Migratory Bird Treaty Act;
    g. Marine Mammal Protection Act;
B. Be feasible to implement; and
C. Meet human safety and logistical guidelines.

A second parallel analysis, conducted simultaneously with the Minimum Operational Criteria analysis, scored and ranked each potential method for likely environmental impacts to the islands' resources and operational considerations associated with implementing the method at the Farallon Islands. The scoring and ranking of methods were done within a series of matrices to provide a quantitative comparative analysis of potential alternatives. This approach was intended to allow decision-makers to readily compare the potential environmental impacts and operational consideration of each method on island resources in a quantifiable manner. Each method was analyzed for its potential impact to island resources (biological, physical, and social), its availability for use, and its potential for successfully eradicating mice from the South Farallon Islands. Thirty-five resources in total were scored and analyzed for each method.

Based on the information reviewed, assessed, and scored the Service selected the two action alternatives stated above to be developed and analyzed in the EIS. The two action alternatives selected for analysis in the EIS met all of the Minimum Operational Criteria and were ranked among the top ten methods within the matrix analysis. The two alternatives also include the only rodenticides legally available and registered for island rodent eradication use in the United States: Diphacinone-50 Conservation and Brodifacoum-25D Conservation. The assessments and conclusions reached in this report were thoroughly researched, discussed, and reviewed by a wide range of experts and are based on the best scientific information currently available.

2.3 A Comparison of Rodent Control and Eradication Strategies

Table 2.1: Comparison of the key characteristics of eradication and control operations.

	Eradication on Islands	Control on Mainland
Location	Rodent eradications are primarily conducted on islands where an invasive species is impacting the native species and natural ecological processes, as well as where rodents cannot easily recolonize after the eradication.	Rodent control efforts are primarily attempted on the mainland in urban, residential, or agricultural areas where rodents impact people or commercial endeavors. Rodent control is also undertaken to benefit native species, agriculture, and human health.
Goal	Restoration of an island ecosystem by complete removal of the target species. One hundred percent removal of all individuals is required, as failure to remove an individual from an island could result in repopulation.	Reduction of the rodent population in a confined management area for economic, human health or conservation benefit. Generally, eradication is impossible because rodents can recolonize from adjacent areas.
Successful Methods	On all but the very smallest of islets, the only technique that has been used successfully to remove rodents from islands has been the distribution of bait containing a rodenticide.	A variety of toxic, non-toxic, mechanical and biological methods are available to control rodents. It is not necessary for control operations to remove every individual.
History of Success	Rodent eradications have been successfully conducted on more than 692 islands world-wide. Without exception, successful eradications have resulted in the recovery of native biota.	Control operations are often successful at reducing rodent populations with demonstrated economic benefit and benefits to biodiversity. However, unless active control is sustained, rodent populations will return to pre-control levels within a short period of time.
Length of Operation	Rodent eradications are typically one-time operations that usually take a few days or weeks to conduct.	Depending on the nature of the infestation, control efforts must be sustained for long periods or revisited periodically in perpetuity.
Extent of Positive Impact	The positive impacts to ecosystems and native species are measurable and permanent.	Positive impacts are limited in extent, degree, and duration; however, some benefits to native species can occur.

	Eradication on Islands	Control on Mainland
Extent of Negative Impact	While eradications have been known to have non-target effects, these unintentional impacts have largely been short-term and have not impacted native species at the population level. The majority of impacts can be avoided, minimized or mitigated. Most have a limited extent and are confined to a relatively closed island ecosystem.	Negative impacts of rodent control efforts have occasionally resulted in direct and indirect impacts to non-target species, primarily predatory birds and mammals. Because of the open ecological system on the mainland, a toxicant can be distributed widely through a variety of pathways by a range of scavengers and predators. Repeated use of toxicants in urban and agricultural settings extends the period of time in which exposure can occur.
Risk of Failed Operation	Because of the high cost and logistical complexity of conducting a rodent eradication, there is a reduced likelihood of implementing follow-up eradication attempts. A failed operation would not generate the anticipated ecological benefits to native species and resources.	Because of their relatively low short-term cost and low logistical complexity, unsuccessful rodent control efforts can be followed up with additional techniques to increase the chance of success.
Extent of Regulatory Oversight	In the U.S., island eradications are permitted after extensive planning and a review of potential impacts are assessed under NEPA, in addition to the federal, state, and local permits that are required.	For some compounds, pesticide applicator licenses and permits are not required for purchase and use. Often their use is allowed without the need for a NEPA analysis.

There are many similarities between the techniques used for rodent control and eradication. For example, both often include the use of rodenticides. However, the goals and impacts of control and eradication efforts are often very different (Cromarty et al. 2002). Control efforts aim to reduce a rodent population to an acceptable level, whereas the goal of an eradication effort is the complete removal of a target species from the operational area (Bomford and O'Brien 1995). Rodent control efforts require ongoing management to maintain a low population level. The net conservation gains achieved by rodent control (i.e. reducing and maintaining rodent populations at low levels) are temporary, generally more expensive in the long-term, and less beneficial than the lasting benefits of complete eradication (Pascal et al. 2008). Control operations can also pose long-term risks to non-target species. Sustained rodent control can also be immensely challenging, especially on islands such as the Farallones where topography, safety, and disturbance to native wildlife make access difficult and, in some areas, impossible.

On the Farallones, thousands of personnel hours would be required on an annual basis to sustain a successful control operation for mice. Activities associated with a control program would result in repeated disturbance to sensitive breeding seabirds, marine mammals, and habitats. If rodenticides were used as the control method, control operations would pose a low but ongoing risk to non-target wildlife from exposure to toxicants. Should the control operation be interrupted or ineffective, mice would quickly reproduce and rapidly re-populate the island reaching former

population densities relatively quickly (Witmer 2007). A control effort, even if possible, would pose an ongoing safety risk to staff, have repeated impacts to native species, be less cost-effective, and would not generate the desired permanent island-wide conservation and restoration benefits to the native flora and fauna on the Refuge.

In contrast, the eradication of mice on the South Farallon Islands would entail an intensive but short-term effort to completely remove mice. The risks posed by an eradication program would be more significant in the short-term; however if reinvasion can be prevented, eradication would result in greater long-term benefits for native species of the South Farallon Islands, as evidenced by other eradication projects (Pascal et al. 2008). However, an eradication operation requires a different philosophy and more extensive consideration of risk (Cromarty et al. 2002). Robust and meticulous planning would be required to ensure the success of the project (Cromarty et al. 2002).

In contrast to a control program, five principles are inherent to any eradication attempt (Parkes 1990, Bomford and O'Brien 1995). Every eradication project should be able to address all of the principles listed below before an operation is undertaken. These principles include:

- All target individuals are able to be put at risk by the eradication technique(s);
- Individuals are able to be eliminated faster than the population's rate of increase;
- The probability of the pest re-establishing can be managed so that reinvasion is unlikely;
- The project is socially acceptable to the community involved;
- The benefits of the project must outweigh the risks and costs.

Based on the history of past mouse eradication successes (MacKay et al. 2007) it is believed that the first three principles can be met for the removal of mice from the South Farallon islands. Based on public comments received during scoping and on the FEIS, eradication of house mice from the South Farallon Islands is socially acceptable to many but not all of community involved. Based on the Service's assessment, the benefits of the project outweigh the risks and costs. A detailed comparison of control and eradication programs is presented in Table 2.1.

2.4 Comparison of Mouse and Rat Ecology Relevant to the Removal of Mice from the South Farallon Islands

As of the writing of the RDEIS, house mice had been successfully eradicated from 60 islands, with six more either pending confirmation or in progress, and four whose success is unknown (Samienago 2016 and DIISE 2015). All of the successful house mouse eradications used rodent bait containing a rodenticide. While there are many similarities between mice and rats, there are several differences in behavior and physiology that are important to consider when designing an eradication project. Eradication methods effective for some rat species may not be effective for house mice due to differences between mice and rats in their foraging ecology, movements, density, and physiology (Clapperton 2006). The following discussion summarizes the most important differences between rats and mice relevant to the removal of introduced house mice from the South Farallon Islands.

All commensal rodent species are opportunistic omnivores that readily consume seeds, plants, invertebrates, and bird eggs and chicks (Veitch et al. 2011). However, house mice tend to consume more invertebrates than rats do (Sheils 2010) and are considered more selective and intermittent

feeders than rats (Crowcroft and Jeffers 1961). Some rat species may consume up to 1.5 oz (43 grams) of food per day, while house mice on average only need to consume approximately 0.1 oz (3-4 grams) of food per day (Mackay et al. 2011). Thus, it can require more careful planning to ensure that each mouse has access to and ingests sufficient bait and rodenticide.

In addition, home range size is a factor that must be considered in planning an eradication attempt. Rats generally have much larger home ranges than house mice. The average home range size for most rats is typically greater than 2.47 acres (1 ha) and can be as large as 27.2 acres (11 ha) (Sheils 2010), whereas house mouse home ranges are typically 0.62 acres (0.25 ha) or less (Pickard 1984). Such small home range sizes accentuate the need for ensuring comprehensive bait or devise coverage to guarantee that every individual has access to the required amount of bait or rodent removal devices.

As with most rat species, house mouse populations typically show cyclical changes in population density (Ruscoe and Murphy 2005), especially in the higher latitudes when food and weather are variable (Mackay et al. 2011). Rodent eradication operations must be designed and timed to consider these cyclical population fluctuations. Targeting a population when it is in decline, food stressed, and not breeding provides the greatest chance for eradication success (Howald et al. 2007).

Adult house mice generally range from 0.5 oz to 0.9 oz (15 g to 25 g). Of 250 mice captured on SEFI the average weight recorded was 0.5 oz (15 g). In contrast, invasive rat species can be as much as 80 times heavier (King 2005). House mice also differ from rats in their physiology and consequently can react differently to toxicants. For example, the LD_{50} (the amount required to kill 50 percent of tested individuals) recorded for first-generation anticoagulants such as diphacinone is 1.75 ppm (mg/kg) for Norway rats whereas for laboratory house mice the LD_{50} is over four times higher, 7.05 ppm (Erickson and Urban 2004). Another study lists the LD_{50} for diphacinone for mice to be 350 times higher than for rats (O'Connor and Booth 2001). Like rats, resistance by mice to first-generation toxicants such as warfarin and diphacinone has been recorded (Buckle and Prescott 2012). The physiology of mice is sufficiently different to rats to suggest that an eradication method or toxicant, proven effective for rat eradication, may not be directly transferable.

2.5 History of Rodent Eradications

As a consequence of pioneering rodent eradication efforts in New Zealand in the 1970s (Samaniego 2016, DIISE 2015, Howald et al. 2007), as of 2016 rodent eradications have been attempted 944 times and rodents have now been removed from 692 islands in more than 50 countries around the world including the U.S. (DIISE 2015, Samianiego 2016). These successes have invariably resulted in species and ecosystem recovery and almost certainly saved some species from extinction (Bellingham et al. 2010; see additional references in Chapter 1). For example, the eradication of black rats (*Rattus rattus*) on Anacapa Island (California, Channel Islands) resulted in increased abundance of several native species such as the Scripps's murrelet (*Synthliboramphus scrippsi*), deer mouse (*Peromyscus maniculatus*) and intertidal algae as well as re-colonization by Cassin's auklets (*Ptychoramphus aleuticus*) (Newton et al. 2016). Eradication of rodents and other invasive species has subsequently become a powerful tool to prevent extinctions and restore ecosystems (Howald et al. 2007).

Steady advances in planning and methodology, including the development of second-generation anticoagulants, and access to accurate satellite navigational guidance (Bellingham et al. 2010) have contributed to an accelerating rate of eradication success and has resulted in the removal of rodents from increasingly larger and more biologically complex islands. The systematic application of bait containing rodenticides, particularly second-generation anticoagulants, has been central to this record of success (Howald et al. 2007).

Of 944 rodent eradications examined by the Database of Island Invasive Species Eradications (DIISE 2015) and Samaniego (2016), 86 targeted house mice and 61 (four islands were subsequently reinvaded) were successful (Mackay et al.. 2007, Samaniego 2016, DIISE 2015). Success rates have improved over time and since 2007, 28 of the 30 mouse eradications undertaken have been confirmed as successful (Samaniego 2016). House mice have now been removed from islands as large as the interconnected islands of Rangitoto and Motutapu (9,523 acres or 3,854 ha) in New Zealand. All but one of the successful mouse eradications that used a rodenticide used brodifacoum or another closely related second-generation anticoagulant (Table 2.2). Bait stations were used as the primary method in 30 of 86 mouse eradication attempts on 48 islands. Hand broadcasting was used in two attempts, and aerial broadcast was used in 55 attempts.

Table 2.2. Summary of House Mouse Eradication Attempts Utilizing Rodenticides with Documented Results and Methods *(* Samaniego 2016, DIISE 2015, Mackay et al. 2011*)**.

Toxicant used		Eradication attempts	Successful	Failed
1st Generation anticoagulant rodenticides	Diphacinone	1	1	0
	Pindone	1	0	1
	Warfarin	1	1	0
2nd Generation anticoagulant rodenticides	Brodifacoum	70	48	22
	Bromadiolone	5	5	0
	Flocoumafen	3	2	1
	Flocoumafen and brodifacoum	1	1	0
Mixed 1st and 2nd generation anticoagulant rodenticides	Pindone and brodifacoum	3	3	0
Acute rodenticides	Sodium monofluoroacetate (1080)	1	0	1
TOTAL		86	61	25

*Only eradication attempts with known methods and known results were included in this table.

A total of 29 mouse eradication attempts were undertaken on islands where another mammal pest species was present; thirteen of these operations failed. These operations may have been complicated by inter-specific competition and the presence of another more dominant rodent species. Equally the design of the eradication project may not have accounted for the presence of mice. However, Mackay et al. (2007) assessed all mouse eradications undertaken up until 2007 and could not determine any single underlying cause of success or failure for the operations assessed. While MacKay et al. (2007) found no significant trends in the data, it was suggested that gaps in coverage leaving some individuals unexposed to bait may have been a cause of failure in some mouse eradications. Several operations that relied upon bait stations used a spacing design appropriate for rats, but not for the small home range sizes of mice (Witmer 2007). When house mice were the only target species on the island, the eradication success rate was 90 percent.

2.6 Anticoagulant Rodenticides

Rodenticides are a category of toxicants that were developed specifically to be used for the control or eradication of rodents. They include anticoagulants, metal phosphides, calciferols (Vitamin D), and other toxicants. Naturally occurring anticoagulants were discovered in the 1940s in moldy sweet clover hay following the discovery of bleeding disorders in cattle (Stahmann et al. 1941). Related compounds were then synthesized between the 1940s and 1980s to produce a range of anticoagulant rodenticides. Anticoagulant toxicants act by interfering with vitamin K metabolism in the liver. By inhibiting vitamin K-dependent clotting factors blood clotting time increases until the point where no clotting occurs (Hadler and Shadbolt 1975, Eason and Ogilvie 2009). In order for an anticoagulant to incur a lethal response, levels in the liver must reach a critical threshold; this level can vary widely between species and even between individuals within a species. Anticoagulants are classified as either first-generation (e.g. diphacinone) or second-generation (e.g. brodifacoum) compounds. Examples of first generation rodenticides include warfarin, chlorophacinone, and diphacinone, and they require multiple feeds to cause death in rodents; their use resulted in the emergence of genetic resistance in rats and house mice. Examples of second generation rodenticides, also known as "superwarfarins", include brodifacoum, difethialone, bromadiolone, and difenacoum, and were developed to overcome resistance by rats and mice.

Following exposure to an anticoagulant rodenticide, there is a lag period of one to several days before coagulopathy (impaired blood coagulation) becomes observable in the exposed organism. This is because clotting factors, which have half-lives from 6 to 120 hours, support the slowing or stopping of bleeding, but once cleared clotting becomes impaired. The lag period can be useful for eradication efforts because the onset of coagulopathy is often well-established prior to an organism sensing its deteriorating health condition. Coagulopathy can be resolved in a matter of days to weeks assuming the rodent is not further exposed to rodenticide. The latent period between time of ingestion and the onset of symptoms (Littin et al. 2000) makes anticoagulants an extraordinarily effective tool for pest eradication particularly when targeting rodents.

2.6.1 Rodent bait products currently registered in the U.S. for conservation purposes

Currently, four rodenticide-based products are registered by the U.S Department of Agriculture Animal and Plant Health Inspection Service (USDA/APHIS) with the U.S. Environmental Protection Agency (EPA) and available for use in the United States and in U.S. territories for conservation purposes:

- Diphacinone-50 Conservation (USDA/APHIS, EPA Reg. No. 56228-35)
- Brodifacoum-25W Conservation (USDA/APHIS, EPA Reg. No. 56228-36)
- Brodifacoum-25D Conservation (USDA/APHIS, EPA Reg. No. 56228-37)
- Ditrac D-50 Conservation (USDA/APHIS, EPA Reg. No. 12455-147)

Each bait product is designed to be attractive and palatable to rodents, such that rodents are more likely to choose the bait product over natural food sources. The predominant ingredients in these bait products are inactive, non-germinating grains (either sterile or crushed). Brodifacoum-25W

Conservation was designed for use in wet environments where a lot of rainfall is expected, whereas Brodifacoum-25D Conservation was developed for drier conditions like the Farallon Islands. Ditrac D-50 was developed for the purpose of controlling or eradicating Polynesian rats on islands or vessels. This compound was used for the Lehua Island Ecosystem Restoration Project to eradicate non-native rats (USFWS 2017).

2.6.2 **Diphacinone**

Diphacinone is a first-generation anticoagulant of the indandione class, structurally similar to pindone and chlorophacinone (Figure 2.1). Developed in the 1950s, it is used for rodent and other vertebrate pest control and has been used as a therapeutic drug for heart patients in the USA. Like other anticoagulants, diphacinone inhibits the formation of vitamin K-dependent clotting factors in the blood. Similar to other first-generation anticoagulants, diphacinone is readily metabolized and rodents are far more susceptible to lethal poisoning if the toxicant is ingested over several consecutive nights rather than through a single dose. Diphacinone is the approved common name; other names for diphacinone include: 2-Diphenylacetyl-1,3-Indandione; 2-(diphenylacetyl)-1H-Indene-1,3(2H)-dione; diphacin; and diphenadione. The empirical formula for diphacinone sodium salt is $C_{23}H_{15}O_3Na$ and the molecular weight is 340.4. It has low water solubility (30 ppm at 25° C); ((EPA 1998).

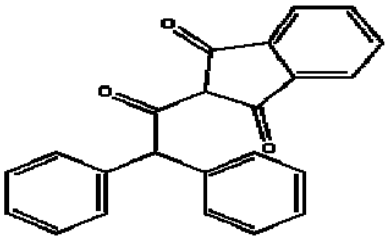


Figure 2.1. Chemical structure of diphacinone

Diphacinone is most effective if ingested over several consecutive nights. Acute single dose LD_{50} figures are typically higher than doses administered over several consecutive days. Swift (1998) found in a study of wild caught ship (black) rats (*Rattus rattus*) that an uninterrupted supply of toxic bait must be provided for a period of at least 7 days or until feeding has stopped to reach an LD_{80} using 'Ramik Green' compressed cereal baits with 0.005 ppm diphacinone in bait stations. House mice are less susceptible than Norway rats to repeated doses of diphacinone (Ashton et al. 1987) and appear to be generally more tolerant of diphacinone with acute oral LD_{50} values reported between 28 ppm and 340 ppm (Kusano 1974, Kosmin and Barlow 1976, RTECS 1980, Hayes and Laws 1990). Repeat-dose oral LD_{50} values for house mice were reported as 0.42 ppm/day for males and 2.83 ppm/day for females for five days (Ashton et al. 1987).

The primary advantage of diphacinone as a rodenticide for island eradication purposes is the lower risk it poses to non-target organisms relative to second-generation anticoagulants. Diphacinone has comparatively low persistence in animal tissues, which reduces but does not eliminate the risk to non-target vertebrates (Fisher 2009). Laboratory trials have also indicated that diphacinone has a lower toxicity to birds when compared with brodifacoum (Erickson and

Urban 2004, Eisemann and Swift 2006) and other second generation anticoagulants, although recent research suggests that the toxicity of diphacinone to some birds, particularly raptors, may be higher than previously thought (Eisemann and Swift 2006, Rattner et al. 2010, Rattner et al. 2001, Rattner et al. 2012). See Chapter 4 for a discussion of the potential impacts of diphacinone on the Farallon Islands environment. Appendix F, Western Gull Risk Assessment, contains a brief review, including LD_{50} values, of the toxic effects associated with brodifacoum or diphacinone exposure in birds. The lowest lethal dose of diphacinone in birds has been reported in the literature as 7.1 mg/kg (Long et al. 1992).

2.6.3 **Brodifacoum**

Brodifacoum is a second-generation anticoagulant of the coumarin class (Figure 2.2). Its properties were first described in the early 1970s. Brodifacoum, like other anticoagulant toxicants, acts by interfering with the synthesis of vitamin K-dependent clotting factors. This increases the clotting time of blood and leads to death from hemorrhaging. Brodifacoum is absorbed through the gastrointestinal tract. It can also be absorbed through the skin. Brodifacoum is not readily metabolized and the major route of excretion of the unbound compound is through the feces (Erickson and Urban 2004). A proportion of any ingested dose of brodifacoum is bound in the liver, kidney, or pancreas where it remains in a stable form for some time and is only very slowly excreted (Weldon et al. 2011).

The precise chemical name for brodifacoum is 3-(3-(4'-Bromo-(1,1'-biphenyl)-4-yl)-1,2,3,4-tetrahydro-1-napthalenyl)-4-hydroxycoumarin. The empirical formula for brodifacoum is $C_{31}H_{23}BrO_3$ and its molecular weight is 523.4. It has a very low solubility in water (less than 10 ppm or mg/L at 20ºC and pH 7) and is stable at room temperature.

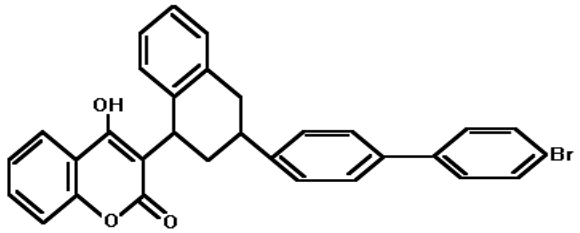


Figure 2.2. Chemical structure of brodifacoum

Brodifacoum is a very potent second-generation anticoagulant, which is used in many countries to control commensal rats and house mice including rodent populations that have exhibited resistance to first-generation anticoagulants (Rennison and Hadler 1975). It has been the toxicant most frequently used for successful rodent eradications undertaken around the world (Howald et al. 2007, Samienago 2016, and DIISE 2015). Brodifacoum was made a restricted-use pesticide in 2008 by EPA. Due to their potential risk to non-target species, several second-generation anticoagulant rodenticides, including brodifacoum, are no longer registered for use in the United States in products geared toward consumers and are registered only for the commercial pest control and structural pest control markets, as well as for conservation purposes such as those aimed to protected islands from invasive rodents.

The LD_{50} value for brodifacoum for house mice is 0.52 mg/kg, with house mice needing to eat 0.43- 0.65 g of bait containing 20 ppm brodifacoum to ingest a median lethal dose (Fisher 2005). A single dose of 0.4 mg brodifacoum / kg body weight is equivalent to the oral LD_{50} in house mice (Eason and Ogilvie 2009). To ingest a median lethal dose a mouse would need to eat from 0.8-2.1 percent of its body weight in rodent bait containing brodifacoum at 25 ppm, which is the same as 0.0025 percent. House mice eat up to 20 percent of their body weight daily (Berry 1970). The time to death for house mice after ingesting a lethal dose is generally four to five days, but mice have survived for up to 21 days in laboratory trials (Morriss 2007). Brodifacoum is considered to be highly toxic to rodents and other mammals, birds, and some fish (Erickson and Urban 2004, Pitt et al. 2012). The LD_{50} for birds is highly variable, ranging over nearly two orders of magnitude from 0.26 mg brodifacoum/kg body weight for the mallard to 20 mg brodifacoum/kg body weight for the Paradise shelduck, although mortality could result at lower doses since one study did not produce definitive values for Canada goose and southern black-backed gull (Godfrey 1986). The lowest lethal dose of brodifacoum in birds reported in the literature is 0.2 mg/kg (Ross et al. 1980).

2.6.4 Rationale for Proposing the Rodent Bait Products and Toxicants

From extensive research we determined that the broad-scale application of rodenticide bait products is the only available and proven method of eradicating house mice on islands as large and rugged as the South Farallones. Howald et al. (2007) reported that brodifacoum was the toxicant used in more than 71 percent of rodent eradication campaigns and in 91 percent of the total area treated. Of the 61 confirmed successful island mouse eradications, 48 of them used brodifacoum and one relied on diphacinone (Samaniego 2016). Between the years of 2005 and 2015, 100 percent of all mouse eradication attempts on islands (30 in total) used brodifacoum; 93 percent of these attempts were successful at removing mice from islands Samaniego 2016). Among the second-generation anticoagulant rodenticides, brodifacoum and bromadiolone appear to be the most effective compounds (Bhattacharyya and Borah 2016). Brodifacoum has been successfully used for mouse and rat eradications worldwide because of its toxicity to rodents and the fact that a lethal dose can be readily consumed in a short period of time. The specific product Brodifacoum-25D Conservation outlined in Alternative B has been used successfully to eradicate rodents on five islands. Brodifacoum-25D Conservation is similar to the bait CI-25, which was specifically developed for rodent eradication and used successfully on Anacapa Island in 2001 to remove black rats. The product was initially developed for use in dry California coastal island environments like the Farallon Islands.

At least 28 successful island rat eradications have been undertaken using diphacinone as the primary toxicant (Howald et al. 2007, Keitt et al. 2011, Samaniago 2016), including one aerial application on Mokapu Island, Hawaii (4 ha). However, only one house mouse eradication has been successfully conducted using diphacinone as the primary toxicant (Samaniego 2016). On Buck Island-USVI, the project implementers used diphacinone where mice were present, successfully removing ship rats but unsuccessfully removing house mice (Witmer 2007). Since house mice were not the target species on Gough Island, the spacing of bait stations (40m x 40m) was greater than that recommended for mice (Mackay 2011), and as a result bait was likely inaccessible to all individuals within the population. However, other factors such as bait palatability could also have contributed. In a laboratory setting, Pitt et al. (2011) found that

Ramik Green®, the diphacinone bait product used on Buck Island, had lower consumption and acceptance rates for mice than the other bait products assessed in the same study. The diphacinone product did not meet a threshold of at least 80 percent mortality in two-choice tests after seven days of exposure. The result was attributed to low product toxicity, limited exposure times, and low palatability relative to the other products tested (Pitt et al. 2011). The lower acceptance rate directly affected efficacy and fewer animals succumbed to the diphacinone product under the test conditions compared with several other products (Pitt et al. 2011).

The lack of a demonstrated record of eradication success for diphacinone as the primary toxicant in house mouse eradications creates a number of uncertainties associated with its use. Recent research and discussion on other products or methods in development are reviewed in published literature (Witmer et al. 2014; Campbell et al. 2015; Ferencz and Muntean 2015. However, an action alternative relying on diphacinone as the primary eradication tool was being considered because:

- Diphacinone-50 Conservation is EPA-approved and registered by USDA/APHIS for conservation purposes in the U.S. for the eradication of mice on islands, and can be aerially applied;
- Rodent bait containing diphacinone has been used successfully to eradicate other rodent species from islands;
- Diphacinone has a lower toxicity than brodifacoum, reducing the potential risk to non-target species (Parkes et al. 2011).

The uncertainties associated with the proposed use of diphacinone are reflected in the prescribed parameters for its use on the Farallones (Section 2.12.2). A conservative approach was taken in setting proposed application rates and timing between applications.

2.6.5 **Best Management Practices for Rodent Eradications**

Lessons learned from past rodent eradication projects was discussed in Section 1.5, including the Ornithological Council's recommendations for improving the successful implementation of rodent eradications (Ornithological Council 2010). In addition, the New Zealand Department of Conservation (DOC) recently released a list of Best Management Practices (BMPs) specifically designed for mouse eradications in New Zealand (Broome et al. 2017). Incorporating mouse specific BMPs will allow us to increase the likelihood of successfully eradicating mice from the Farallon Islands. A review of the DOC BMPs found that the actions specified in the alternatives for this FEIS were largely consistent with those in the DOC BMPS. The DOC BMPs for house mouse eradications on islands in New Zealand (Broome et al. 2017) included:

- Conduct island specific feasibility studies,
- Eliminate knowledge gaps through research and trials,
- Identify biosecurity risks and implement biosecurity protocols,
- Obtain DNA samples of target individuals to identify the exact target and determine the potential resistance to bait, as well as to compare with future incursions that may occur,
- Determine where and when alternative food sources are present and adjust baiting strategies to increase baiting success,
- Use aerial broadcast or bait stations that are close enough together to intercept every mouse territory. Monitor for success,

- Identify non-target bait consumers and determine methods to compensate for secondary bait consumption (e.g. hazing, using more bait, etc.),
- Use sufficient bait in every mouse territory that will be available for several days to expose every mouse,
- For aerial broadcast, use two applications of brodifacoum 20 ppm or higher concentration bait at 8 kg/ha separated by 14 days. Use GPS to guide flight lines and overlap swaths by 50% to prevent baiting gaps.
- Apply bait along the coastline to ensure every mouse territory is baited.

In order to minimize the likelihood of operational failure, the Service has incorporated the following actions into the planning and implementation processes for the Farallon mouse eradication project that are based on the recommendations from the Ornithological Council, the mouse specific BMPs developed by DOC, lessons learned from other successful eradications, as well lessons learned from recent projects that either failed to eradicate the target species or failed to mitigate impacts to non-target species, including Wake Atoll, Desecheo Island, Rat Island and Henderson Island.

a) The Service has prepared a detailed plan (EIS) that assesses the expected impacts and allows for adaptive management during implementation so that the Service can respond in real-time to unexpected outcomes without violating permits or jeopardizing success;
b) The Service will prepare contingency plans as part of the operational planning phase (Section 2.10.11);
c) The Service will seek to obtain permits that would allow operators to successfully eradicate the target species while minimizing and mitigating impacts to non-target resources;
d) The Service, working with the USDA/APHIS in consultation with EPA, will obtain a supplemental bait label if deemed necessary to ensure that 100% of the target species will be receive a lethal dose of rodent bait without violating the conditions of the label. (Section 2.11 and 2.12).
e) Pre-eradication trials to help determine appropriate application rates were conducted on the South Farallon Islands for both broadcast and bait station methods All structures and caves have been documented for determining the best baiting method for each. (Section 2.8).
f) Secondary bait consumers like the gulls found on the South Farallon Islands can impact bait availability or suffer from sublethal or lethal impacts from consuming bait or toxic mice. Mitigation measures, including gull hazing, have been evaluated and included in in action alternatives to minimize impacts to gulls and assure that adequate bait is available to mice for uptake. (Section 2.10.5).
g) Bait availability will be monitored during implementation to ensure that bait is available at sufficient quantities for the required timeframe to ensure eradication success. Details will be provided in the Operational Plan (Section 2.10.10).
h) The Service has committed to ensuring that the eradication operation is fully staffed for the duration of the implementation. The detailed Operational Plan would determine the

exact number of personnel needed for each position type, a description of the responsibilities for that position, and the duration of time that position will need to be staffed.

i) The Service has committed to allow the operational team the opportunity to fully review the operational plan, ask questions, and suggest revisions prior to initiation. Additionally, key personnel would be given the opportunity to approve the operational details and make minor modifications, if necessary and permissible, prior to implementation.

j) The Service will develop a detailed and clearly laid out command structure to be utilized during the operation. Each position's job description would be outlined and included in the command structure conceptual model that would be included in the operational plan. As much information as possible regarding who to contact during an incident would be included in the operational plan and outlined in relevant contingency plans. This will streamline on the ground decision-making, allow for real-time adaptive management, and reduce confusion and "on-the-fly" decision-making during the operations. It is critical to work through any unresolved planning details prior to initiating operations.

2.7 Alternatives Considered but Dismissed

2.7.1 Use of Toxicants other than Diphacinone or Brodifacoum

Other rodenticides that have been used in rodent eradications or are thought to be effective at controlling rodents were considered for inclusion in this EIS. The following rodenticides that are not registered with the EPA for conservation use on islands (sodium fluoroacetate (1080), cholecalciferol, chlorophacinone, difethialone, bromadiolone, warfarin, zinc phosphide, bromethaline, and strychnine) or are not registered with EPA for any purpose (pindone, Eradibait®, flocoumafen, and coumatetralyl) were considered in the Alternative Selection Process but dismissed from further consideration for one or more of the following reasons: 1) the time to trial and register a product, if successful, for conservation purposes was a minimum of three to five years away; 2) there was potential for mice to develop resistance to the toxicant; 3) the product lacked an effective antidote (in case of human or non-target wildlife exposure); 4) the product was currently unavailable in a usable format to conduct an island eradication and this situation was unlikely to change in the foreseeable future; or 5) the product had never been tested in a rodent eradication.

2.7.2 Control as the Primary Method

On the South Farallones, thousands of personnel hours would be required on an annual basis to sustain a control operation for mice. Activities associated with a control program would result in repeated disturbance to sensitive breeding seabirds, marine mammals, wilderness character, and habitats. If rodenticides were used as the control method, control operations would pose a low but ongoing risk to non-target wildlife from exposure to toxicants. Should the control operation be interrupted or ineffective, mice would quickly reproduce and rapidly re-populate the island reaching former population densities relatively quickly (Witmer 2007). A control effort, even if possible, would pose an ongoing safety risk to personnel because of the island's rugged topography, would cause repeated impacts to native species, be less cost-effective, and would not

generate the desired permanent island-wide conservation and restoration benefits to the native flora and fauna on the Refuge that the Service desires. Consequently, this alternative would not meet the project objective to eradicate mice from the South Farallones, nor does it satisfy safety requirements.

2.7.3 Bait Stations as the Primary Method

Enclosed bait stations provide a means of making toxic rodent bait accessible to mice but inaccessible to most other non-target species. Bait stations must be placed by hand, anchored to the ground, baited, checked regularly (i.e., initially every two days) to ascertain if bait is still available (and re-bait as necessary), and removed upon project completion. The use of bait stations as the primary method is not being considered for the following reasons: 1) many areas of the South Farallon Islands, because of the island's steep and rugged terrain, are inaccessible on foot or pose a significant risk to personnel. As a consequence, targeting 100 percent of mouse territories could not be accomplished using this technique, which is a necessary prerequisite for a successful rodent eradication (Bomford and O'Brien 1995, Broome et al. 2017); 2) even if all parts of the South Farallon Islands were accessible, bait stations would need to be deployed on a 2 m x 4 m grid and more than 61,000 bait stations would be required. Installing and maintaining more than 61,000 bait stations across the entire island for several months is infeasible. In addition to frequent initial checking, bait stations should be maintained for at least one month after the last evidence of rodent bait take is observed, which can take up to 2 years. Even if plausible, the human presence associated with maintaining such a large number of bait stations would likely cause large-scale, unacceptable impacts to nesting seabirds and their habitats, breeding and resting marine mammals, other sensitive species, wilderness character, and habitats on the islands. Consequently, this alternative would not meet project objectives, would not be technically feasible to implement, and would pose unacceptable safety hazards to personnel.

2.7.4 Hand Broadcasting Rodent Bait as the Primary Method

Reasons for not considering a hand broadcast operation as the primary bait delivery method are similar to those outlined for a bait station approach above. Access to all mouse territories is not possible or would put personnel at extreme risk because of the islands' terrain. The method would pose the same risks to non-target species as an aerial application of rodent bait, would require extensive effort and result in potentially unacceptable impacts to island habitats and non-target species as a consequence of trampling and disturbance. The chance of a successful eradication would be extremely low. For these reasons, a hand baiting operation as the primary method was dismissed from further consideration.

2.7.5 Trapping

Reasons for not considering trapping as the primary eradication method are similar to those outlined for a bait station approach above. Access to all mouse territories is not possible or would put personnel at extreme risk because of the islands' terrain. The method would pose an unacceptable level of risk to non-target species because it would require extensive effort and likely result in unacceptable impacts to island habitats and non-target species as a consequence of trampling and disturbance. The use of live traps to remove mice from an area is also a strong

selection agent in favor of mice that are 'trap-shy' and avoid capture in traps. Thus, after extensive trapping, mice that are wary of traps would remain and these mice would be very difficult to remove without the introduction of alternate methods such as toxicants. For these reasons, trapping was eliminated from further consideration.

2.7.6 Use of Disease

While there is ongoing research focused on the development of taxon-specific diseases that can control populations of invasive species (such as by the Australian agency CSIRO, www.cse.csiro.au/research/rodents/publications.htm), there are no pathogens presently available with proven efficacy at eradicating rodents (Howald et al. 2007). Even a highly lethal mouse-specific pathogen would likely be ineffective at removing all mice, because the population would decline to a point where further transmission of disease between individuals was unlikely (Bomford and O'Brien 1995). As a result, the introduced disease would likely disappear before fully infecting the entire mouse population. The introduction of novel diseases into the environment carries unknown risks to non-target species. Consequently, the use of disease would fail to meet project objectives to eradicate mice and minimize risk to non-target species.

2.7.7 Biological Control

The possibility of introducing a biological control agent for mice such as snakes or cats was dismissed because, as evidenced by other biological control programs, mice would be reduced in number but not fully eliminated as a consequence (Fagan et al. 2002). Additionally, there are no known effective biological control agents for mice that would not result in irreparable damage to the South Farallon Islands environment. As illustrated by numerous examples, the introduction of a predator to the South Farallon Islands, such as cats or snakes, would result in significant and likely devastating impacts to seabirds (Atkinson 1985, Courchamp et al. 1999, Wiles et al. 2003). Therefore, this alternative was eliminated from further consideration.

2.7.8 Fertility Control (Immunocontraception and Genetic Mutation)

Fertility control has been used with limited success as a method of pest management for a few invasive species but has never been applied in an eradication setting. Experimental sterilization methods include chemicals and proteins delivered by vaccine, genetically-modified viral pathogens, and genetically modified mice that produce only male offspring (Quammen 1996, Tobin and Fall 2005, Campbell et al. 2014). However, the effectiveness of these experimental techniques in the wild, as well as their impacts to non-target animals, is unknown. The lack of information and a history of success coupled with the extended time period (a minimum of a few years, according to Campbell et al. 2014) required to trial and register the technology disqualified the use of fertility control from detailed consideration.

2.7.9 Burrowing Owl Translocation Only

The capture and translocation of wintering burrowing owls from the South Farallon Islands in lieu of eradicating mice was considered as a method to reduce owl predation, and thus the indirect impacts of mice, on ashy and Leach's storm-petrels. In the absence of mouse

eradication, the relocation of burrowing owls would be expected to benefit storm-petrels on the South Farallon Islands. However, translocating burrowing owls away from the South Farallon Islands does not address the many other threats that mice pose to the Farallon Islands ecosystem, and thus does not address the purpose of this project; that is, to meet the Service's management goal of eradicating invasive house mice from the Farallon Islands National Wildlife Refuge in order to eliminate their negative impacts on the native ecosystem of the Farallon Islands. Thus, translocation of burrowing owls in lieu of eradicating mice was not considered as an alternative.

2.8 Pre-Eradication Studies Conducted on the Farallones

To advise the development of alternatives for this FEIS, several studies were conducted to examine potential strategies to effectively and safely remove house mice from the South Farallon Islands. A summary of this research is provided below in Section 2.8.1.

2.8.1 Farallon Mouse Eradication Trial Studies (2010-2012)

Field trials to guide the selection and development of potential action alternatives were conducted on the Farallon Islands in 2010, 2011, and 2012. These trials were conducted to collect site-specific information to support the design of a mouse eradication operation. The majority of successful island based mouse eradications around the world have relied upon the use of a rodenticide (Keitt et al. 2011); therefore, the field trials conducted for the eradication on the Farallones focused on the use of a rodent bait containing rodenticide. These trials had three objectives: 1) determine the parameters necessary to eradicate mice, 2) evaluate risks to non-target native species, and 3) identify and develop measures to avoid, minimize, and mitigate any potential impacts. A complete account of these studies is provided in Appendices A and D.

2.8.2 House Mouse Density Estimate Study

In November 2010, a mark-recapture study was conducted on Southeast Farallon Island to assess mouse abundance and reproductive condition. The trial was conducted during the fall season when an eradication operation would most likely be undertaken because of declining mouse populations and relatively low abundance of other wildlife on the islands (Appendix A). Trapping conducted as part of the bait exposure study (Section 2.8.4) revealed a variable density of mice across the island.

Closed capture modeling in the program MARK 6.1 (White and Burnham 1999) on data from a mark-recapture study completed in one area of Southeast Farallon Island provided a density estimate of 1,297 ± 224 mice per ha (95 percent confidence interval 799-1,792), which is possibly the highest reported house mouse density estimate for any island in the world. Commonly, house mouse densities range from 10 to 50 per ha (Mackay et al. 2011).

The high mouse density also is supported by anecdotal observations. Hundreds of mice can readily be seen on the Farallon Islands foraging throughout the day and night in the late summer and fall, across most areas of the island (Table 2.3). Despite the remarkably high abundance, this study found little evidence of mouse breeding activity during November, although mice in reproductive condition have been trapped year-round on the Farallon Islands. November also

marks the start of the annual, cyclic mouse population decline, likely because of declining food resources and the onset of the rainy season. Both reduced breeding activity and reduced food resources are important indicators for best timing to conduct a successful mouse eradication.

Table 2.3: Monthly index (trap success rate) of house mouse abundance on Southeast Farallon Island, 2010-2012.

Year	Month	Raw success	Number of traps	Trap success
2010	December	84	99	0.85
2011	January	36	132	0.27
2011	February	27	99	0.27
2011	March	9	99	0.09
2011	April	7	99	0.07
2011	May	N/A	N/A	N/A
2011	June	28	96	0.29
2011	July	31	96	0.32
2011	August	78	96	0.81
2011	September	89	99	0.90
2011	October	98	99	0.99
2011	November	32	99	0.32
2011	December	9	99	0.09
2012	January	4	99	0.04
2012	February	13	99	0.13
2012	March	0	99	0.00

2.8.3 **Bait Palatability and Preference Trials**

In November 2010, a bait palatability trial was undertaken on Southeast Farallon Island with 0.035 oz (1g) non-toxic Brodifacoum-25D Conservation bait pellets containing only the fluorescent dye tracer (or, biomarker), pyranine. Using standard methods (Grote and Brown 1971), ten mice from the Farallones were presented with an eight-day standard two-choice test in a lab environment to assess the relative palatability of the non-toxic bait pellet. Local dietary items such as invertebrates and vegetation were selected as the alternative food choice, based on Farallon mouse diet described by Hagen (2003). Results indicated that the non-toxic 1g bait pellet was highly acceptable to house mice present on the Farallones with mice showing a higher affinity for rodent bait than the local food items presented. All mice in the trial consumed the equivalent of a lethal dose of bait containing a second-generation anticoagulant within 48 hours, and bait palatability appeared to increase over time. For additional information on this study see Appendix A.

2.8.4 **Bait Exposure Rates (Efficacy)**

In order to determine the likelihood of all mice being exposed to bait during an eradication operation, a trial was undertaken on Southeast Farallon Island in November 2010 with non-toxic

bait pellets containing the tracer (or, biomarker) pyranine (see Appendix A). The trial design followed methods developed for other rodent bait acceptance trials (Wanless et al. 2008a). Bait was hand broadcast in two discrete applications, initially at 18 kg/ha and then at either 18 kg/ha or 9 kg/ha across easily accessible areas of Southeast Farallon Island. Live-trapping within the areas of bait spread was undertaken to determine the percentage of mice exposed to the bait.

A total of 162 of 167 mice trapped within core areas showed exposure to the bait, as indicated by the presence of the fluorescent dye. The five mice that displayed no evidence of pyranine were all trapped in one trap area on the last night that trapping was undertaken. Several factors could explain the small number of negative results observed. The most likely scenario is that due to the extremely rapid disappearance of bait following the second application, some mice did not have access to bait or had consumed bait but were trapped too late to detect the fluorescent dye. Captive trials showed that detection of pyranine could only be guaranteed within 48 hours of bait consumption. Bait is expected to remain available for a longer period after a subsequent application in an actual operation because consumption by mice would be eliminated or greatly reduced and consumption by western gulls would be reduced through hazing activities. It is also possible that the mice moved into trapped areas from areas more than 164 ft (50 m) away that were not baited during the trial. The possibility that some mice chose not to eat the bait is considered less likely based on results from the palatability trial undertaken (Appendix A) and previous eradication successes.

Interpretation of results from exposure trials such as the one undertaken on Southeast Farallon Island is challenging and confounded by the unbounded nature of the study. However, the results are indicative that at the application rates tested would ensure exposure of all individuals within the population. For additional information on these studies, see Appendix A.

2.8.5 **Bait Availability**

A successful house mouse eradication relies upon a sufficient amount of toxic bait being delivered to all mice on the island, and bait being available for a sufficient period of time to allow for the ingestion of a lethal dose. To better understand the expected rates of bait disappearance in the environment of the South Farallon Islands and the resultant availability of bait to mice over time, a trial was undertaken in November 2010. After an initial application of the non-toxic bait at 18 kg/ha, bait remained on the ground within the majority of bait uptake plots for at least four nights, but bait was gone from some plots by the fourth day. Bait disappearance rates ranged from 1.6 kg/ha/day to 6.3 kg/ha/day and were much higher after the second application with bait disappearing from some plots in both areas within one day. Increased uptake by both gulls and mice was considered the most likely factor contributing to the increase in bait disappearance after the second application. Mice are not expected to be a factor influencing bait availability during subsequent applications in an eradication operation. Additionally, gull hazing and the potential use of bait stations in certain areas are expected to reduce the likelihood of bait consumption by gulls.

Results of the trial indicate that an application of the rodent bait Brodifacoum-25D Conservation (Alternative B) at current label rates for aerial broadcast in most areas of the island is likely sufficient to provide four nights of exposure for all mice, although a supplemental label may be

needed for baiting certain areas (see Sections 2.10, 2.11 and 2.12). Four nights of exposure after each application is considered a suitable exposure period for bait containing a second-generation compound like brodifacoum (Alternative B), as a lethal dose can be ingested within a short period (Fisher 2005). A higher bait application rate would be required for first-generation compounds like Diphacinone-50 Conservation (Alternative C) to ensure a longer period of bait availability that relies on multiple consecutive days of feeding for lethal effects to occur.

2.8.6 **Bait Station Field Test**

Two bait station designs were tested on the Farallones in November 2011. Bait stations were tested for their practicality and durability, to confirm they would be used by mice, and assess their effectiveness at excluding potential non-target consumers of bait such as gulls. Bait stations could be used as an alternative method of bait application to aerial broadcast in and around structures on the island, and possibly in areas where gulls may persistently roost in an effort to reduce the likelihood of bait uptake by gulls. Both a standard commercially available mouse bait station (Protecta) and a handmade PVC tube design proved successful at providing mice access to bait, prohibiting bait uptake by gulls, and were sturdy enough to withstand interference by pinnipeds. For additional information, see Appendix A.

2.8.7 **Mapping of Accessible and Sensitive Wildlife Areas**

During eradication-related research undertaken between 2010 and 2012, areas safely accessible to ground personnel and containing sensitive wildlife were mapped. Figure 2.3 is a topographical map of the Farallones that illustrates the large areas of steep terrain that would be difficult or impossible for personnel to access without increasing safety concerns for operations personnel. Mapping of these areas was important to identify which areas would be easily accessible for non-target mitigation activities. Mapping of caves and other areas that may require special treatment was also conducted. For a discussion of the results of these surveys, see Appendix A.

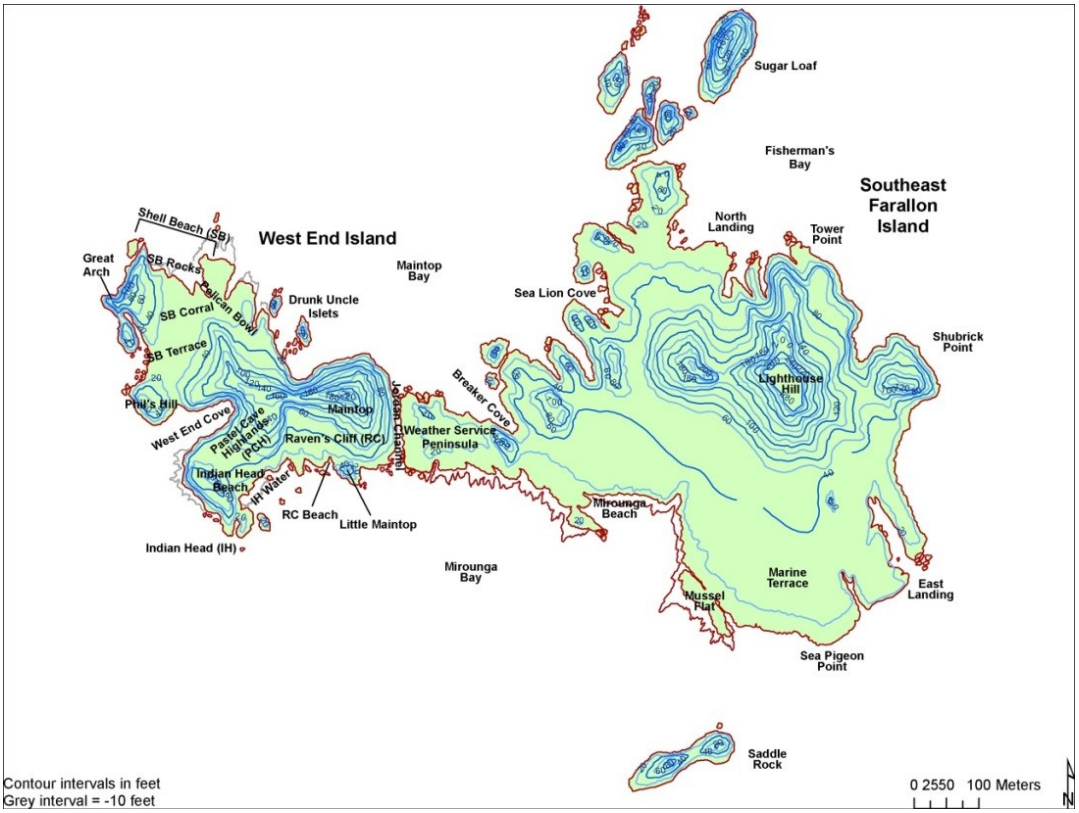


Figure 2.3. Topographic map of the South Farallon Islands showing steep areas that have limited or no safe access.

2.8.8 Commensal Habitat Assessment

Because EPA labels prohibit bait containing rodenticide from being applied by helicopter in and immediately surrounding areas of human habitation, the two residences and other man-made structures on Southeast Farallon Island were surveyed by a National Park Service pest control professional in November 2010 to identify what preventative actions may be required prior to house mouse eradication. Some minor maintenance and some changes to food disposal practices were recommended (Badzik 2010). Because the absence of mice from within structures cannot be guaranteed, bait stations containing rodent bait would be used to target mice in and around areas of human habitation.

2.8.9 Collection of Mouse Samples and Genetic Analysis

Over 100 house mouse tissue samples were collected in November 2010 and November 2011 from the South Farallon Islands. Samples were collected for future DNA analyses should mice be detected on the islands post-eradication. If mice are found on the islands after the eradication, samples would be used to determine if a re-colonization event occurred or the eradication failed to remove all of the mice from the islands. Fifty tail-tip samples were collected from both Southeast Farallon Island and West End Island and are being stored if future analysis is required.

Genetic analysis was also conducted on tissue samples from 25 house mice (11♂, 14♀) collected from Southeast Farallon Island to determine the subspecies present, their geographic origin, and to determine the presence or absence of any potential genetic resistance to anticoagulants. Analysis was conducted by researchers at the University of Northern Carolina and North Carolina State University. The subspecies of mouse was confirmed as *Mus mus domesticus*, with the likely source populations being from the United Kingdom and Mediterranean regions. The Farallon house mouse genome was compared using a Mouse Diversity Array and was referenced to a set of genotypes from 200 wild caught and wild-derived strains of *M. m. domesticus*, *M. m. musculus* and *M. m. castaneus*. Diagnostic alleles assigned the subspecific origin of the Farallon mice to be overwhelmingly of *domesticus* origin (Didion et al. 2012, Morgan et al. 2018).

In addition to identifying the origin of the Farallon house mice, researchers compared the protein (Vkorc 1) that determines if species are resistant to anticoagulants. Vkorc1 encodes a protein that is critical for blood clotting. Mutations in Vkorc1 in rodents are associated with resistance to warfarin, an anticoagulant rodenticide. Several species of rodents are known to have resistance alleles, including some mouse species. This analysis showed that Farallon mice are of Mediterranean ancestry in the region containing Vkorc1. Sequencing of Vkorc1 in all Farallon mouse samples revealed no evidence of resistance alleles. Therefore, it was concluded that there is no known genetic barrier to eradicating mice on the South Farallon Islands with the use of an anticoagulant (Didion et al. 2012, Morgan et al. 2018).

2.8.10 **Bait Degradation Trials**

In 2011 and 2012, bait degradation trials were undertaken on Southeast Farallon Island using non-toxic pellets to determine how fast rodent bait would degrade if pellets are not consumed (Appendix D). In the first trial both Diphacinone-50 Conservation and Brodifacoum-25D Conservation bait degraded to a condition not considered available or palatable to western gulls after a period of 101 days. These trial results were confounded by an extreme drought. A second trial was undertaken beginning in November 2012 under wetter conditions. Degradation of Brodifacoum-25D Conservation in the second trial was rapid and bait degraded to an inedible state within seven days. For unknown reasons, Diphacinone-50 Conservation persisted in an edible condition despite the higher rainfall until the conclusion of the second trial (15 weeks). Reasons for the difference in bait degradation rates for these bait types in the 2012 trial are unknown.

Bait degradation did not differ greatly between sites, but significant variation was found between substrates (baits broke down more rapidly on soil and in vegetation than on a rock substrate) and years. Other studies (e.g. Merton 1987, Howald et al. 2001) testified to the impact of rainfall on the rate of bait degradation and data from our trial supported the existence of a relationship between bait degradation and rainfall. On this basis, predictions of the time bait may be available and palatable to susceptible non-target species such as western gulls were made using three different rainfall scenarios. Assuming rainfall during the operation is similar to the average that has been observed over the last 30 years, it is anticipated that Brodifacoum-25D Conservation bait (Alternative B) would remain available and palatable to western gulls for a period of about five weeks after the last bait application. Diphacinone-50 Conservation (Alternative C) is

anticipated to remain available and palatable to non-target wildlife for about 15 weeks after the last bait application.

2.8.11 **Bird Mitigation Trials**

Hazing of gulls has been recommended as a means of isolating gulls from rodent bait and reducing their potential risk of exposure. To evaluate the potential techniques available for hazing gulls from the South Farallon Islands, two gull hazing trials were undertaken; the first was in January 2011 and the second in November and December 2012. In 2011, numerous hazing techniques were tested over the course of three days to gauge their efficacy, and the 2012 trial was structured based on the lessons learned from the 2011 trial. The 2012 hazing trial was much larger in scale and scope than the 2011 trial, and successfully demonstrated the ability to keep the majority of western gulls off the South Farallon Islands for an extended period of time. The trial successfully prevented gulls from contacting areas where non-toxic rodent bait was available and the results from the trial provide a high degree of confidence that a well-planned and executed hazing operation would keep gull mortality to an acceptable level during a mouse eradication (Appendix E, Warzybok et al. 2013).

Hazing activities caused low levels of disturbance to non-target species. Most birds besides gulls did not respond to hazing techniques. However, relatively small numbers of several bird species were flushed by hazing operations, including Brandt's cormorants, common murres, brown pelicans (*Pelecanus occidentalis*), black oystercatchers, black turnstones, whimbrels, and willets. Impacts observed to these species were small and short-term. The hazing trial also had little impact on pinnipeds hauled out on the islands. Pinniped responses varied depending on the hazing tool employed and the species present, but only rarely did hazing activities result in pinnipeds being flushed into the water (Appendix E).

As described in Warzybok et al. (in prep), gull hazing effectiveness in the trial appeared to be greater than many other reported studies which showed that initial response to hazing may be great, but that habituation arises, quickly leading to a reduction in the effectiveness of scaring devices (Belant 1997, Blackwell et al. 2002, Stevens et al. 2000; Baxter and Allan 2007; Gagliardi et al. 2006; Ronconi and St. Clair 2006, Soldatini et al. 2008). However, these other studies were conducted at locations such as landfills where abundant food resources produced a high motivation for birds to return to the site (Soldatini et al. 2008, Cook et al. 2008, Lecker et al. 2015). This "high feeding motivation" (described by Kimball et al. 2009) likely produces an incentive for gulls to continue to visit the site and adapt to hazing methods. This differs from most gulls visiting the South Farallones in fall and early winter, when attendance at the islands is mainly to roost and not to feed. If gulls were visiting the islands to feed, hazing effectiveness may have been much lower. Likewise, if hazing were conducted during the breeding season, it may be more difficult to keep birds from attending breeding sites. Another key difference between this and other studies is the use of a large suite of hazing methods and frequently varying the stimuli. Two recent studies have demonstrated deterrence results more similar to those we observed. These studies were able to maintain a high level of deterrence, even in the presence of attractive food resources, for extended periods by using multiple scaring devices in conjunction with each other and combining the effects of visual and auditory stimuli (Castege et

al. 2015, Lecker et al. 2015). These approaches, similar to what is proposed for this project, helps to reduce the bird's predictability of hazing treatments and prevent (or at least delay) habituation.

2.8.12 **Salamander Toxicity Study**

In 2018, USDA/APHIS/WS-National Wildlife Research Center completed an investigation of the acute toxicity of anticoagulant rodenticides (Brodifacoum-25D Conservation and Diphacinone-50 Conservation) to three species of Plethodontid (lungless) salamanders (Witmer 2018; Appendix Q). The objective of this study was to assess the potential hazards of the rodenticides brodifacoum and diphacinone to Farallon arboreal salamanders using conspecifics from another population of closely related salamanders as surrogates because of the Farallon population's relatively small and endemic status. Three closely related species of salamanders were used in the study: yellow-eyed ensatina (*Ensatina eschscholzii xanthoptica*), arboreal salamander (*Aneides lugubris*; mainland variety), and California slender salamander (*Batrachoseps attenuatus*). Salamanders were exposed to rodenticides through two routes: 1) oral exposure, and 2) direct dermal exposure. The study was designed to maximize rodenticide exposure.

Results from the study suggest elevated hazard to salamanders that were dermally exposed to rodenticide bait for up to 14 days, as evidenced by mortality in two of three test species (arboreal and slender salamander) and skin abnormalities. Skin sloughing and sores on the undersides of some salamanders exposed to rodenticide as well as some controls left it unclear whether or not the rodenticide caused this effect. Investigators did not note the sub-lethal effects of weight loss or reduced food (cricket) consumption that has been observed in studies of other taxa. Data also suggest that salamanders have the potential to quickly recover from exposure to rodenticides after being removed from a contaminated environment.

Accumulation of brodifacoum in salamanders was generally low, with concentrations ranging from 42.7 - 226 µg/g in arboreal salamanders and 48.3 - 101 µg/g in yellow-eyed ensatina. Diphacinone residues in salamanders were also generally low, ranging from 10.8 - 174 µg/g in arboreal salamanders, but not detected in yellow-eyed ensatina. Low brodifacoum accumulation (< 100 µg/g) was also observed in slender salamanders exposed to brodifacoum through either exposure route; diphacinone was not detected in any slender salamanders following the exposure period. Because of the low residue levels in salamanders, it appears that the hazard to animals preying or scavenging on salamanders would be low.

Caution should be used when interpreting the study results since the experimental design optimized salamander exposure to rodenticides to simulate a worst-case scenario, typical of introductory acute toxicity studies for which no existing species-toxicant data are available. The study author concluded that while diphacinone and brodifacoum pose some hazards (both lethal and sub-lethal) to salamanders, the level appears to be relatively low, especially given the very high exposure rates applied in the study compared to the exposure salamanders would encounter in an aerial broadcast of rodenticide baits in an invasive rodent eradication project. A report describing details of the study is provided in Appendix Q.

2.9 Alternative A: No Action

Analysis of the No Action alternative is required under NEPA to provide a benchmark for comparing alternatives. If this alternative was selected, mice would not be eradicated from the South Farallon Islands. Low-intensity mouse control, primarily snap-trapping, currently occurs within and around the residences and buildings on Southeast Farallon Island. These localized control efforts would continue under the No Action alternative, although they have little effect mouse abundance. Efforts to reduce the likelihood of new rodent introductions would also continue.

In addition, the Service currently attempts to manage invasive plants through manual control and the selective application of herbicides. Native plant seeds are also occasionally distributed to improve native plant populations. Vegetation on the islands is monitored so that new invasions can be responded to and populations of current invasive species can be contained. These efforts would continue under the No Action alternative.

The Service would also continue management activities focused on protecting storm-petrels and their habitat on the islands, including nest habitat protection, maintenance, construction, and possibly predator management when feasible.

If mice were allowed to remain on the islands, ongoing negative impacts are anticipated to affect seabird, plant, arboreal salamander, and terrestrial invertebrate populations. The population decline seen in ashy storm-petrels is expected to continue, and negative impacts to Leach's storm-petrel are likely to continue. Continued suppression of the islands' invertebrate populations is anticipated and potential increases in the abundance and distribution of endemic Farallon arboreal salamanders and endemic Farallon camel crickets would not likely be seen. Native plant species including the maritime goldfield would continue to be affected. Mice would continue to degrade the natural quality of the Farallon wilderness.

While currently there is very little evidence for mouse predation on Farallon seabirds and their eggs, potential changes in dynamics of island species- particularly the timing of mouse abundance, in vegetation, climate or inter-species interactions, could have major future impacts. For example, on Marion Island after the recent eradication of feral cats left mice as the only invasive mammal on the island, researchers recorded several wandering albatrosses (*Diomedea exulans*) killed by mice for the first time (Figure 1.2) (Wanless et al. 2007, Angel et al. 2009). On Midway Atoll in the tropical Pacific Ocean, an eradication of black rats (*Rattus rattus*) in 1996 has left house mice as the only mammalian predator. In 2015, house mice were first documented attacking and killing adult Laysan (*Phoebastria immutabilis*) and black-footed (P. *nigripes*) albatrosses and the behavior increased the following year, leading to mouse control efforts. Other potential causes for this change in mouse behavior include eradication efforts for an invasive plant (possible mouse food source) and a change in the annual rainfall pattern (USFWS 2018; B. Flint, USFWS, pers. comm.). Given the high density of Farallon mice at their peak abundances, shifts in their seasonal cycle that lead to increased abundance during the seabird breeding season could result in much greater direct mouse predation on seabirds, their eggs or chicks.

It is believed that the continued presence of house mice on the Farallones would compromise the effectiveness of future ecosystem restoration efforts. Mice present an obstacle to the Service facilitating ecological adaptation in the face of accelerated global climate change (Burgiel and Muir 2010). Biosecurity measures planned to prevent the arrival of other invasive vertebrates would be hampered by the presence of mice since they can mask the ability to detect other rodent species arriving on the islands, leaving the South Farallon Islands at risk of additional invasions. Taking No Action to address the effects of non-native mice would be contrary to the purpose of the refuge and other USFWS policies for conservation and restoration of natural biodiversity and management of designated wilderness.

2.10 Features Common to both Action Alternatives

2.10.1 Introduction

The purpose of the proposed action is to meet the Service's management goals of protecting and restoring the ecosystem of the Farallon Islands, removing invasive house mice, and eliminating their negative impacts on seabirds and other native species of the Farallon Islands National Wildlife Refuge. Eradicating invasive house mice depends on meeting all of the principles for eradication success as specified above in Section 2.2. Because of the steep and rugged terrain of much of the South Farallones, the presence of sensitive wildlife and the inaccessibility of parts of the island to ground based staff, the aerial application of bait is the primary delivery method being proposed for the South Farallon Islands mouse eradication. Hand baiting, bait stations, and traps may be used as a secondary means of bait delivery in some selected areas that would be identified in the final operational work plan as well as through adaptive management during project implementation based on bait application and uptake monitoring (Section 2.10.5).

2.10.2 Adaptive Management

Based upon the Department of the Interior (DOI) 2008 Adaptive Management Implementation Policy (522 DM 1, Feb. 1, 2008), refuge staff shall use adaptive management (AM) for conserving, protecting, and, where appropriate, restoring lands and resources. The DOI defines AM within section 43 CFR 46.30 as a system of management practices based upon clearly identified outcomes, where monitoring evaluates whether management actions are achieving desired results (objectives). The DOI Adaptive Management Technical Guide (2009) also defines AM as a decision process that "promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood" (Williams et al. 2009). Adaptive Management accounts for the fact that complete knowledge about fish, wildlife, plants, habitats, and the ecological processes supporting them may be lacking. The role of natural variability contributing to ecological resilience also is recognized as an important principle for AM. It is not a "trial and error" process, but rather AM emphasizes learning while doing based upon available scientific information and best professional judgment considering site-specific biotic and abiotic factors on Refuge lands.

Adaptive management in the context of the proposed action alternatives would include operational decisions such as: at what time within the operational window should bait application be undertaken; which of the proposed baiting methods should be used to address gaps in bait

application if they occur; and when to begin and conclude mitigation actions. If unanticipated mortality in any non-target species is recorded following the first bait application, a management decision on whether to proceed with subsequent applications would need to be made. Such a decision would be based on past risk analyses but would also encompass observations made during the operation and is outlined in Section 2.10.11.

A Supplemental label would outline the specific activities approved for implementation of the project. The Service would apply bait at or below the specified rate(s) on the supplemental label and would employ adaptive management protocols within the framework of the supplemental label. Adaptive management would allow the Service to include the potential need to broadcast bait at higher rates in specific areas, such as steep cliffs, to ensure adequate bait coverage to expose every mouse to rodent bait. In those cases, bait application rates in certain other areas may need to be reduced so that the average application rate remains within the approved supplemental label rate. While the operational plan will cover most needed adjustments to site-specific application rates, some adjustments will likely be needed depending on conditions during implementation. Any such changes will remain within the parameters of the supplemental label.

2.10.3 **Environmental Concerns Considered**

In developing an operational plan to remove house mice, many environmental concerns were considered in an effort to minimize potential impacts to native species and resources on and around the South Farallon Islands. The environmental issues that received significant consideration are outlined in Chapters 3 and 4 and include minimizing disturbance impacts to wildlife, minimizing the risk of non-target species exposure to toxicants, minimizing impacts to wilderness character, minimizing bait drift into the marine environment, and minimizing impacts to cultural and recreational resources.

2.10.4 **Operational Timing**

Three factors were considered in selecting the proposed timing for an eradication operation to remove house mice from the South Farallon Islands. These were the annual reproductive and population cycle for house mice, typical weather patterns, and seasonal attendance patterns of native wildlife. How these factors influence project timing is illustrated in Table 2.4 below.

Demographic information on mice is important because the best time to target a rodent population for eradication is at a time when the population is low or declining and food-stressed (Cromarty et al. 2002). The likelihood of success is also increased when rodents are targeted at a time when they are not breeding. On the South Farallon Islands, the majority of annual precipitation falls between December and March; these weather patterns drive a cyclical pattern in the house mouse population, which is directly tied to the availability of food resources and weather patterns. With the boom and bust cycle of available food resources on the Farallon Islands, the mouse population typically increases dramatically in the summer and early fall and then rapidly declines as food resources become more scarce and colder winter storms commence in the late fall and winter (Irwin 2006, Grout and Griffiths 2012).

Mice in reproductive condition have been trapped on the South Farallones throughout the year, indicating that breeding may never completely cease. However, the lowest incidence of mouse reproduction appears to be in the late fall and winter (Appendix A). During November 2010 and 2011, mouse trapping revealed few juveniles, no pregnant females, and very few scrotal males from over 800 trapped mice. Consequently, to maximize the likely success of a mouse eradication on the South Farallon Islands it is recommended that an operation be undertaken in the late fall or winter after the beginning of October.

The Farallon Islands are known for their Mediterranean climate with the majority of annual precipitation and winter storms falling between late December and March (Null 1995; see Section 3.3.1 for detailed weather information). The action alternatives (Alternatives B and C) have been designed with the assumption that bait application would occur near the onset of the winter rainy season with sufficient contingency time incorporated to wait out any bad weather such as heavy rainfall, rough seas, or high winds that could preclude bait broadcast or logistical/supply operations. Wind speeds of less than 30 knots (35 mph) are required for bait application to minimize bait drift. Rough seas could also result in delays in accessing the island by boat.

To maximize the quality and longevity of bait on the ground it is advisable that bait application be undertaken during a period of little to no precipitation. The likelihood of getting a long enough period of dry weather to complete the application of bait (up to three applications depending on the alternative) would be more uncertain during the winter months than earlier in the fall season.

While the late fall is considered the best time for a mouse eradication based on the combination of weather and mouse population considerations, it is also important to independently assess what time of year might pose the lowest risk to sensitive native species on the islands. A thorough analysis of potential environmental impacts can be found in Chapter 4, but the key biological issues and the non-target species considered to be at risk that might influence the timing of implementation are summarized here. The potential impacts to native wildlife from the proposed operational activities associated with mouse eradication fall into two major categories: 1) disturbance as a result of activities on island; and 2) exposure to a toxicant following the application of rodent bait.

The Farallones' seabird population reaches an annual low during the months of August to January (See Table 2.4). The time of year with the fewest breeding pinnipeds is October to December and mid-March to April. A more detailed description of seabird and pinniped residency patterns on the Farallones is given in Chapter 3.

Table 2.4: Overall Project Timing Considerations.

Issue or Constraint	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Mouse numbers increasing		X	X	X	X	X	X					
Increased likelihood of mouse breeding	X	X	X	X	X	X	X					
Seabirds breeding	X	X	X	X	X	X	X[1]	X[1]			X	X
More than 5,000 Gulls present (avg)	X	X	X	X	X	X			X	X	X	X
Pinnipeds breeding	X	X	X	X	X	X			X	X	X	X
Average rainfall >2"							X	X	X	X	X	X
Proposed Timing for Implementation								X				

[1]In October and November the only seabird species still breeding on the Farallon Islands is the ashy storm-petrel. Because ashy storm-petrels nest underground in small rock crevices and are nocturnal, they would be nearly unaffected by proposed eradication activities.

Specific timing considerations for birds include the following:

- Seabirds generally breed on the South Farallones between mid-March and October, depending on the species. After the breeding season many species are virtually absent from the colony, with some starting to return in highly variable numbers in October or November. The peak breeding season for most species lasts from late April to early August. The relative abundance of many of the seabird species on the South Farallones declines after the breeding season, which reduces the number of seabirds that could be exposed to rodenticide or disturbed by operations.

- Migrant land birds and shorebirds stop frequently on the South Farallones during the spring and fall, but most stay for only a few days before resuming migration (DeSante and Ainley 1980, Pyle and Henderson 1991). However, between November and February only a small number of overwintering and visiting birds are typically present on the island with a daily average of around 30 land birds and around 60 shorebirds between mid-November and mid-December (Point Blue unpubl. data).

Specific timing considerations for pinnipeds include the following:

- Pinniped breeding seasons on the South Farallones vary dramatically between species but range from late December to September. This encompasses the breeding seasons for California sea lion (*Zalophus californianus*), northern elephant seal (*Mirounga angustirostris*), harbor seal (*Phoca vitulina richardsii*), northern fur seal (*Callorhinus ursinus*), and Steller sea lion (*Eumatopias jubatus*).

- Northern elephant seal pups are born on the South Farallones between late December and late February. Pups are weaned at about four weeks old and remain onshore in groups for up to 12 weeks before departing to sea. All pups should have dispersed from the island by the end of June (Le Boeuf and Laws 1994). The remaining four species breed in spring or summer.

- Both harbor seals and northern elephant seals undergo an annual molt and use the South Farallon Islands as a haul-out site during that time. Molt occurs at the end of the breeding

season for harbor seals, from July to mid-September (Daniel et al. 2003). Northern elephant seals molt season is stratified by gender and age class. Immatures and females molt starting in March, followed by sub-adult and then adult males, which molt through July. A smaller-scale peak of immatures molting occurs in late September through November (Le Boeuf and Laws 1994). During molt periods, pinnipeds undergo a short period of rapid hair loss during which time they may be more reluctant to enter the water.

From the perspective of minimizing risks to native wildlife, the most acceptable time period for the eradication would be between early October, when seabird and pinniped breeding seasons have largely concluded, and the end of December before the first northern elephant seal pups are born (Table 2.4). Undertaking the eradication operation outside of these sensitive periods would substantially reduce the potential for harm to seabirds and pinnipeds from disturbance and to seabirds from exposure to rodenticides.

When all of the above factors are taken into consideration, the best timing for a mouse eradication project on the South Farallones would be during the mid- to late fall between October and December (Table 2.4), which is the proposed period for implementing both action alternatives. Because mouse populations typically peak in October, implementation would best be delayed until November when mouse populations begin to decline. Both action alternatives could be completed during this window if weather conditions are conducive. At this time the vast majority of the islands' seabirds would not be breeding, would be absent or near their lowest annual abundance. The fall period is after sea lion and fur seal pupping has ended, and before female northern elephant seals start giving birth. Baiting during the late fall would also maximize the chance that normal heavy seasonal rainfalls arriving in December and January (or possibly in November) would rapidly degrade rodent bait, reducing the duration over which non-target species would be exposed to risk.

2.10.5 **Operational Specifications**

While the two action alternatives involve the use of different rodent baits, a different number of applications, and different application rates (See Sections 2.11 and 2.12) they share many similar operational elements. Operational specifications common to both action alternatives are described below.

2.10.5.1 ***Operational Area***

Rodent bait would be applied to all areas above Mean High Water Spring (MHWS) on the South Farallon Islands of the Farallon Islands National Wildlife Refuge, which includes Southeast Farallon Island, West End (or, Maintop) Island, and the smaller associated offshore islets including Saddle Rock, Sugarloaf, Chocolate Chip, Arch Rock, Finger Rock, Aulon Islet, and Sea Lion Islet. The MHWS mark would be the boundary of the operational area such that areas beyond this point would not be targeted for baiting. Areas of the island above MHWS but excluded from aerial bait application are still considered within the operational area but would be treated via hand broadcast, bait stations and/or traps. The operational area totals approximately 121 acres (about 49 ha) based on current Service estimates. Prior to application for a

supplemental bait label, the Service may need to recalculate the operational area based on 3-dimensional surface area.

2.10.5.2 *Bait Type*

Although bait type is specific to the action alternative, there are some similarities in their composition. Both Brodifacoum-25D Conservation and Diphacinone-50 Conservation are grain based rodent baits weighing about 0.02 to 0.07 oz (0.5 to 2 g) and contain an anticoagulant rodenticide. All other ingredients in the bait pellets are non-germinating grains (either sterile or crushed) and other non-toxic additives. Pellets would be dyed blue or green, which has been shown to make them less attractive to some birds, including western gulls (Pank 1976, H. Gellerman unpubl. data, Tershy et al. 1992, Tershy and Breese 1994).

2.10.5.3 *Bait Application*

Bait application would be undertaken in accordance with the Federal Insecticide Fungicide Rodenticide Act of 1972 (FIFRA) and, if necessary, EPA-approved supplemental bait label issued to the USDA/APHIS, which define the legally allowable use and restrictions of the specific pesticide under FIFRA. All bait application activities for the two action alternatives would be conducted under the supervision of a certified pesticide applicator holding a Qualified Applicator Certificate from the State of California. Additionally, a supplemental bait label would be obtained prior to implementation to outline the specific permitted operational protocols for the project.

2.10.5.4 *Bait Application Rate*

The bait application rate is also specific to each alternative. However, both action alternatives would apply rodent bait at a rate that would ensure that all individual mice have access to sufficient bait to ingest a lethal dose. If necessary, an EPA approved supplemental bait label issued to the USDA/APHIS would be obtained prior to implementation to outline the specific permitted operational protocols for the project. Any bait not initially consumed by mice would likely remain attractive to mice for several weeks, although bait pellets are designed to degrade after sufficient rain (Figure 2.4).

Figure 2.4 Brodifacoum-25D Bait Pellets before and after Exposure to Moisture: The image on the left is an intact pellet, while the pellet on the right has been degraded from rain and weathering.

Photos courtesy of Island Conservation

2.10.5.5 *Aerial Bait Application*

Aerial bait broadcast would be conducted in strict accordance with the current EPA-approved label or Supplemental Bait Label (if necessary) issued to the USDA/APHIS. Using a helicopter

guided by GPS, bait would be applied from a specialized bait spreading bucket (Figure 2.5), slung beneath the helicopter. The bait spreading bucket would be composed of a bait storage compartment (the hopper), a remotely-triggered adjustable gate to regulate bait flow out of the storage compartment, and a motor-driven broadcast device (the spinner). The bait spreading bucket would be used in three different configurations (Figure 2.6). The standard configuration would be used to apply bait to most of the operational area. With the spinner on, this configuration would be used to broadcast bait over a predetermined swath width. With a bait deflector installed and a skirt attached, the bucket would be used to provide a directional (120° rather than 360°) broadcast of bait out to a predetermined distance. This configuration would be used to apply bait along the island's coastline and around areas excluded from aerial bait application. The final configuration would be with the spinner removed and a deflection cone added. With this set up, the bait bucket would trickle bait at a low rate on a precise point or along linear or small features.

Figure 2.5: Bait-spreading bucket.

Prior to bait application, the bait spreading buckets would be calibrated using a non-toxic bait product to ensure consistent and accurate bait application. The calibration would occur at a test site in conditions similar to those on the South Farallones. Exact swath widths and application rates to be used during the operation would be determined through this trial.

Aerial broadcast would comprise a series of low-altitude flights by helicopter to most parts of the South Farallon Islands except for areas excluded from aerial application (Figure 2.6). The baiting regime would follow common practices based on successful rodent eradications completed in the U.S. and elsewhere. Each flight swath would overlap the previous by approximately 50 percent to ensure no gaps in bait coverage. During each application, most parts of the South Farallones would be subject to multiple helicopter passes. To compensate for topography, slopes over 45 degrees may be flown a second time to ensure bait application rates across the island are consistent. It has been well established that slopes over 45 degrees increase land area surfaces or planar areas by 41 percent. An EPA-approved supplemental bait label would be obtained prior to implementation to outline the specific permitted operational protocols for the project.

Bait pellets would be applied according to a flight plan that would take into account:

- The need to apply bait as evenly as possible to prevent gaps in coverage or excessive overlap;
- Island topography;
- The need to minimize bait drift into the marine environment;
- The need to avoid bait broadcast in other exclusion zones such as areas of human habitation; and
- Weather conditions.

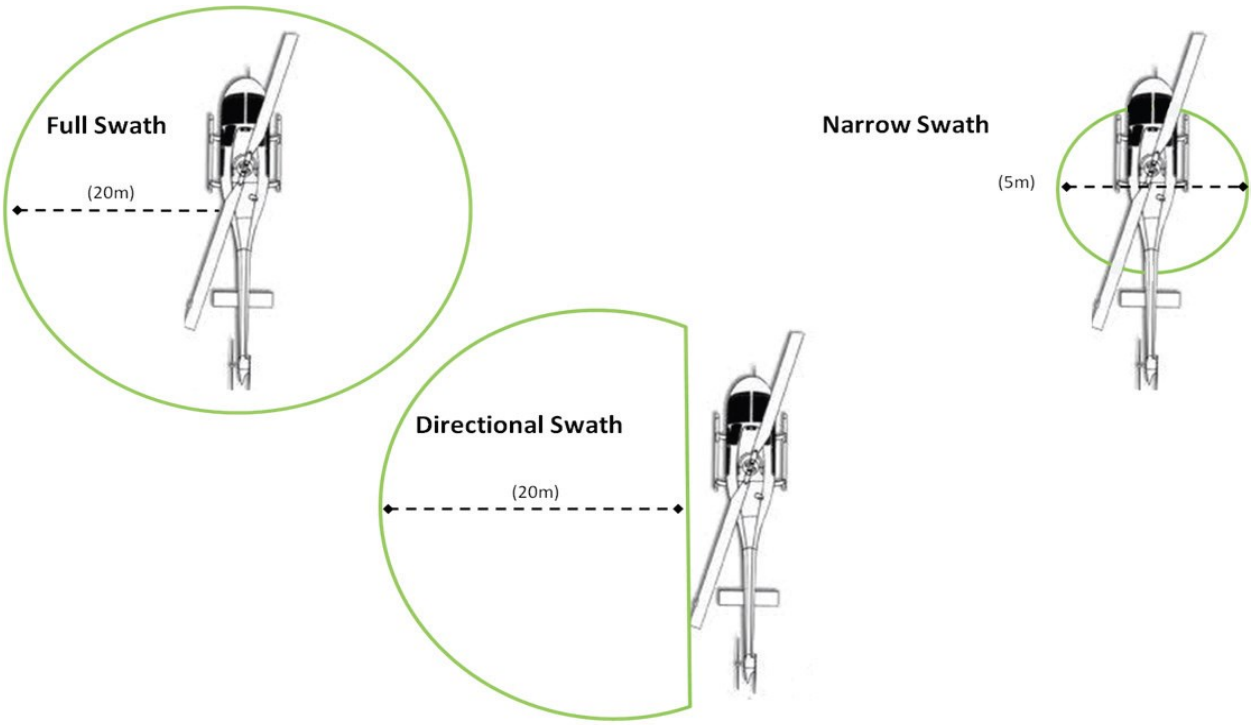


Figure 2.6: Aerial bait applications types *(Swath widths shown are not specific to this project).*

To ensure thorough application of rodenticide:

- The flight path flown by the helicopter would be monitored using an onboard global positioning system (GPS) and a navigation bar to guide bait application and avoid gaps and unanticipated overlaps (Figure 2.7). Flight lines would be mapped prior to bait broadcast and followed by the pilot during the operation.

- Throughout the operation the application rate would be monitored by calculating the area covered versus the quantity of bait used. More in depth analysis of application rates across the island would be undertaken periodically during the operation using Geographic Information System (GIS) software.

- Adjustments in bait flow rates, helicopter speed, and flight lines would be made as needed to achieve the bait application rate while remaining within legal limits set by the EPA approved supplemental bait label.

Figure 2.7: Aircraft GPS navigation bar.

While spatial variability in mouse density across the island was recorded during site trials (Appendix A) it would be nearly impossible to stratify bait application rates and achieve operational success. In a rodent eradication operation, bait

must be placed in every rodent territory so that all individuals are exposed. Without knowing exactly where each individual territory is located, bait must be applied everywhere to ensure eradication success. Aerial application strategies similar to that proposed were employed successfully during a rat eradication operation on Anacapa Island (Channel Islands National Park) (Howald et al. 2010), California and many other rat and mouse eradications worldwide (see Section 2.5).

It is estimated that bait could be applied by helicopter at a rate of approximately 660 lb/hr (300 kg/hr). For Alternative B involving an aerial broadcast of Brodifacoum-25D Conservation, up to 6 hours of flight time would be required to complete the two bait applications required, or roughly three hours for the first application at 16 lb/acre (18 kg/ha) and 3 hours for the second application at 8 lb/acre (9 kg/ha). An additional five hours would be required for helicopter transport, reloading, and other flight-related logistics, bringing the total flight time for Alternative B to about 11 hours. For Alternative C, involving the broadcast of Diphacinone-50 Conservation, an estimated total of up to seven hours of helicopter time would likely be required to complete up to three bait applications, or a little more than two hours for each of the three applications at 12.5 lb/acre (13.8 kg/ha). An additional nine hours would be required for helicopter transport, reloading, and other flight-related logistics, bringing the total flight time for Alternative C to approximately 16 hours.

2.10.5.6 *Additional Air Operations*

In addition to applying bait, helicopters may be used to transport equipment and personnel to and from the island, to monitor gulls in otherwise inaccessible areas, to gently flush pinnipeds off the islands prior to bait application, and/or to support gull hazing operations. Helicopters would use a helicopter pad to land on Southeast Farallon and, if necessary, would either hover for brief periods over land or land on level, safe terrain to drop off personnel and equipment in other otherwise inaccessible areas.

Figure 2.8 – Helicopter with bait spreading bucket.

2.10.5.7 *Staging for Aerial Bait Application*

The helicopter that would be used to broadcast rodent bait may be staged from the island, the mainland, or from a boat or barge anchored offshore (Figure 2.8). The staging area would not be located within any designated Wilderness Area. Logistically, staging from the mainland may be the simplest and safest approach, even though a greater amount of time would be spent commuting over marine waters. A number of recent rodent eradication projects (e.g. Desecheo, Puerto Rico, and Taranga, New Zealand) have employed this approach without incident (Hawkins 2011, Island Conservation 2012). If the operation is staged from the mainland, precautions would be taken to minimize the risk of bait entering the marine environment while on route to the island. The design of the bucket prevents bait from being lost or blown out of the bucket while in transit.

Staging on Southeast Farallon Island may be the next easiest method of completing the operation. However, this would require that bait be airlifted from a ship or barge to a staging site on the islands, an additional step that would increase the risk of bait entering the marine environment. Lifting loads from an unstable platform is an inherently risky activity. Staging from a ship or barge would be logistically the most complex and would mean the operation was more dependent on favorable weather and sea conditions. Although loading bait into bait spreading buckets on a ship or barge has proven to be an effective method (e.g. Henderson 2011 and Pinzon 2012), this approach would also increase the risk of bait entering the marine environment.

During the bait application phase, the helicopter would land at the designated staging area, where staff would refill the bait spreading bucket, refuel the helicopter, and conduct other necessary preparations. The staging area would be adequately stocked with fuel and other supplies and equipment to support the helicopter for the entire bait application process.

2.10.5.8 *Areas to be excluded from Aerial Bait Application*

Areas excluded from aerial bait application may include sites of human habitation, any shoreline areas where the risk of bait drift into the marine environment is considered excessively high, and caves. The only inhabited area on the South Farallon Islands is the site containing the two island residences. An exclusion zone around these buildings may be established during the aerial bait application. The power house and other outbuildings are not considered to be areas of human habitation and bait likely would be applied aerially over these buildings. Bait likely would also be applied aerially over the concrete water catchment pad, but this site would be protected as described in Section 2.10.6 to prevent contamination of the island's water supply.

2.10.5.9 *Hand Baiting*

In both action alternatives up to 12 acres (5 ha) of the islands may require hand-baiting to fill gaps in aerial baiting such as within caves (Appendix A) or around areas of human habitation. Personnel would also hand broadcast bait across all land areas excluded from aerial bait application (i.e. using the bait spreading bucket) except for those areas being treated with bait stations, such as the inside of buildings that are in use. In areas to be hand baited, project staff would distribute rodent bait by hand at the same application rate as it is applied aerially. It is estimated that selected land areas could be hand-baited by crews on foot at a rate of approximately three acres/person/day (1.25 ha/person/day). This estimate of productivity includes assessing GIS maps of bait spread, as well as carrying and broadcasting bait to these areas. Hand baiting would be conducted on foot, from a boat, or from a helicopter. All personnel participating in supplemental hand broadcasts would be trained in systematic bait application at the target application rates.

2.10.5.10 *Bait Stations*

Both action alternatives would involve the use of bait stations as a method of delivering bait to mice in specific areas of the island such as in and under all buildings and enclosed structures on

the island. Buildings on the Southeast Farallon Island, especially residences, provide high-quality habitat for mice because they provide shelter from the elements and alternative food sources.

Bait stations provide a means of containing rodent bait that provide rodents with access to the bait while making bait less accessible to non-target species such as birds (Figure 2.9). Bait stations would be used in accordance with EPA label requirements. Project staff would install bait stations according to guidelines outlined in an operational plan. The bait used in bait stations would be identical to the bait pellets used for broadcast. Bait stations would need to be deployed at a minimum density of 2 to 4 m spacing to ensure that all mice have access to bait within their home ranges. Approximately 50 bait stations are estimated to be required to apply bait within the islands' two occupied houses and four out-buildings. Bait stations would need to be checked and refilled on a regular basis during the operation, with refill rates varying between the two action alternatives. A team of at least four personnel stationed on the island would install, arm, and maintain bait stations. The exact number of bait stations that would be used during the operation would be identified in the operational plan should the Service move forward with this project.

Figure 2.9 Bait Station

Bait stations may also be used in other selected sites on the islands to minimize bait consumption by non-target species (Appendix A). Bait stations can reduce the risk of rodenticide exposure for non-target species by making bait less accessible and reducing the total amount of bait introduced into an ecosystem. However, the use of more than one bait application technique in adjacent areas could result in a greater risk of eradication failure because it adds complexity to the operation and creates greater potential for gaps in bait distribution.

Two bait station designs were tested for use on the South Farallon Islands, and both are considered acceptable for use during an eradication operation (Appendix A). Both bait stations were effective at excluding non-target consumers such as gulls, while providing ready access to mice. They were also resistant to damage from pinnipeds. Bait stations located outside of buildings would be secured to the ground with anchors, placed into the soil, or drilled into rock or a wooden board as appropriate. Bait stations will be placed in a manner that will prevent them from accidentally entering the marine environment.

To establish bait stations in designated areas throughout the islands, access routes may need to be created in sensitive habitats such as those areas with burrows and/or crevices for breeding seabirds. Wherever possible, access routes would be diverted around sensitive biological habitat. If necessary, temporary platforms or boardwalks may be installed to avoid trampling of sensitive habitats. Rappel, boat, or helicopter access may be required to deploy some bait stations. Bait stations would need to be checked and refilled on a regular basis, with refill rates varying between the alternatives. All bait stations except those that are proposed to be left for biosecurity

purposes would be removed one month after the last evidence of mouse consumption of bait on the islands.

2.10.5.11 *Treatment of Structures*

Ensuring that mice are excluded from all alternative food sources during project implementation is critical to the success of a mouse eradication attempt. A preliminary assessment of the structures on the Farallones was conducted in October 2010 to identify steps necessary to exclude mice from the island's structures (Badzik 2010). The island's recycling system and treatment of food waste was subsequently modified in an effort to exclude mice from accessing commensal food sources. Throughout the course of the operation, personnel on-island would be required to adhere to strict protocols to reduce the availability of food for mice within residences and on the island in general.

Although the structures report identified actions to exclude mice from structures, during the eradication all buildings would be treated as though mice were present. Bait stations would be used to present bait to mice both inside and outside of any building that is in use. Water from the water catchment system would be tested for the presence of rodenticide pre- and post-implementation to prevent potential contamination of the drinking water supply. In addition, the water catchment pad would be covered with a tarpaulin prior to application to prevent bait from entering the water catchment system. Immediately after bait application, any bait that incidentally landed on the tarpaulin would be swept and cleaned off. The tarpaulin would remain in place until the aerial bait application component of the operation is complete.

2.10.5.12 *Schedule for Bait Application*

The exact schedule of operations for bait application is unique to each action alternative. However, many aspects of the aerial operation are identical for both Alternatives B and C. Exact dates for bait application would be weather dependent, but if weather conditions are conducive, it is anticipated that all aerial bait application and hand baiting activity could be completed in the late fall. Assuming a bait-spreading bucket capacity of 661 lb or 300 kg the turn-around time for each bucket load would be between 20 minutes and one hour depending on the location of the loading site. The greatest turn-around time would occur if operations were conducted from the mainland, although the actual flight time over the island would be only 15-20 minutes for bait application.

Two to three applications of bait across the islands would be required depending on the action alternative, with each application lasting up to two days subject to weather and sea conditions or logistical delays. Applications would be approximately 7-21 days apart depending on weather conditions, and possibly other factors, and each would require from three to ten bait bucket loads per application. Areas to be hand baited would be treated on the same schedule as aerial bait application. Pre-placement of unarmed bait stations would occur six weeks prior to aerial operations to ensure bait stations were in place prior to the implementation of the eradication, as well as to minimize any risk of neophobia by mice. Pre-placement of bait stations is recommended as good practice for all bait station operations (Broome and Brown 2010). Bait stations would be loaded with rodent bait on approximately the same schedule as bait is applied

aerially. In addition, bait stations would be continually checked and replenished for at least one month after the last evidence of consumption by mice is observed (Broome and Brown 2010).

2.10.5.13 *Follow-up bait application*

If fresh mouse signs are detected after the initial eradication operation is completed, and the sign is localized, follow-up bait application may be undertaken. Depending on the area's accessibility and whether it is within an area of human habitation or not, aerial application, hand spreading and bait stations, or a combination thereof would be used. Rodent bait would be applied to an area approximately 200 m in diameter around the site or sites where signs are observed. This distance is based on documented movements by individual mice in the absence of conspecifics (Nathan 2011). Bait would be applied at the rates specified previously for both action alternatives. If possible, other methods such as trapping and the use of indicator dogs to locate surviving individuals may also be used. Prior to any action, the FWS with the help of USDA/APHIS and EPA would identify and include specification for follow-up bait application within a Supplemental Label for this project.

2.10.5.14 *Response to a spill of rodent bait or helicopter fuel*

Prior to project implementation, a spill response plan would be prepared. The spill response plan would outline the response that would be taken in the event of a spill of rodent bait or helicopter fuel. More than two pounds of rodent bait discharged at a single point would be considered a spill. Spills within accessible land areas would be recovered with negligible impacts. However, spills of loose bait may not be able to be recovered from inaccessible land areas or the marine environment. These spills, should they occur, would be documented and their details forwarded to the USDA, EPA, GFNMS, and other appropriate agencies. If rodent bait is shipped to the islands for the operation, it would be packaged in sealed containers weighing approximately 300 kg each. If one or more of these containerized loads of rodent bait were spilled into the sea or on land, it is likely that it would be recovered.

If fuel were spilled onto surface waters, immediate notification would be given to the U.S. Coast Guard 11th District spill response center, the FWS Regional Environmental Compliance Coordinator, and the California Emergency Management Division and standard response protocols followed. If a spill occurs on the island, the Refuge's Spill Prevention and Response Coordinator would be notified immediately, and the Refuge's Spill Prevention and Response Plan would be followed.

The Service has developed a contingency plan in case of a bait spill, outlined in Section 2.10.11 and Appendix R.

2.10.5.15 *Use of Traps*

Traps may be utilized in caves or within structures as a secondary eradication method for this project. Traps would be used in areas that are unlikely to have mouse territories in addition to having minimal exposure to the elements, such as caves, to ensure that toxic bait doesn't linger

for an extended period of time. The exact trap protocol would be outlined in the Operational Plan and will comply with all permitted activities.

2.10.6 **Protecting Human Health and Safety**

All of the Farallon Islands are closed to the general public and access is only granted under permit, contract, or agreement issued by the Service. Access is generally restricted to those conducting natural resource research and monitoring or facility maintenance and repairs. The waters surrounding the islands are productive fishing grounds, but most adjacent waters are within either the Southeast Farallon Island State Marine Reserve or the Southeast Farallon Island State Marine Conservation Area, which prohibit or restrict the take of living marine resources. The Southeast Farallon Island Special Closure under subsection 632(b) (32) (D) of the California code restricts all vessels from operating or anchoring at any time from the mean high tide line to a distance of 300 feet seaward of the mean low tide line of most of the islands' shorelines except in cases of emergency or as authorized under permit by the California Department of Fish and Wildlife (https://www.wildlife.ca.gov/Conservation/Marine/MPAs). However, waters outside of the state marine protected areas and special closures do provide recreational opportunities for fishing, whale and bird watching, shark cage diving, and other tour boat operations from the nearby San Francisco Bay Area.

During an eradication operation, the Farallon Islands NWR would be closed to all non-essential access for about two months following bait application. Personnel required to be present at these locations would be experienced or qualified for the roles they will perform. All bait application activities (aerial broadcast, hand broadcast and servicing of bait stations) would be conducted by or under the supervision of one or more pesticide applicators licensed by the State of California.

Prior to implementation of an action alternative, notifications would be made to inform other agencies, known researchers, other stakeholders, local recreational and commercial boat owners, and the general public of the timing of the eradication and the potential hazards posed by the activity. Information describing the eradication actions taking place on the South Farallones would be distributed to tour boats that visit the islands, as appropriate, to ensure public safety. Boat patrols may also be undertaken on a regular basis during the period that bait would be applied.

Communication materials would describe the characteristics of rodent bait and provide guidelines to avoid contact with the rodenticide. Approved pesticide warning and informational signs would be posted in the island's research housing and at all typical access points to the island. All island visitors would receive these materials and signs would remain visible until the risk of exposure has declined to negligible. on the islands.

The air space below an altitude of 1,000 feet above ground level over the waters within about one nautical mile of the islands are within overflight regulation areas administered by the Greater Farallones National Marine Sanctuary (NOAA 2014), but additional temporary closures might be needed to ensure the safety of the pilots and personnel during implementation operations and during gull hazing operations, which could potentially last for up to about three months after bait application.

To preclude direct exposure to the toxicant, all staff and volunteers involved in the project would wear appropriate personal protective equipment (PPE) and receive task-specific trainings and briefings on managing the risks. PPE would meet or exceed all requirements by the EPA.

The seven stage filtration system in place to protect the island's water supply is expected to be an effective barrier against anticoagulant contamination (Howald et al. 2003). However, the water catchment pad would still be covered with a tarpaulin or a plastic sheet during aerial bait spread to eliminate any possibility of rodent bait or toxicant entering the water cistern. Water from the cistern would be tested prior to and after the application of rodent bait to confirm the absence of anticoagulant residues.

2.10.7 **Mitigation Measures to Protect Biological Resources**

The majority of the native species on the South Farallon Islands are expected to be at minimal risk from the two action alternatives because the operation would take place when most breeding seabirds and migratory birds are not on the islands. Marine mammals that would be present will not be breeding in the late fall. Of the seabirds, only a small proportion of the crevice-nesting ashy storm-petrels would still be breeding during the period proposed for the application of rodent bait. Most invertebrates are not susceptible to anticoagulants (Spurr 1996), and due to their low solubility, anticoagulants are unlikely to be taken up by plants (Weldon et al. 2011).

Most of the seabird species that might be present during the fall period feed at sea. Consequently, they are not considered to be at risk of ingesting rodent bait (See Chapter 4). However, some non-target species such as western gulls and other migrant gulls that would likely be on the islands during the operation may be directly exposed to the toxicant by consuming bait pellets, or indirectly by consuming mice and other organisms that have eaten the bait.

Gulls and migrant raptors present on the islands during the operational window are considered to be the species most at risk of exposure to the toxicant. A number of mitigation measures have been identified to protect these species that are described below. Brodifacoum-25D Conservation (Alternative B, preferred alternative) is more toxic than Diphacinone-50 Conservation (Alternative C). Consequently, Alternative B poses a greater risk to non-target species. However, the same mitigation measures would be employed for both alternatives because lethal exposure to diphacinone (Alternative C) is still possible and consumption of rodent bait by non-target species, especially gulls, could pose a risk to the success of either action alternative by reducing the amount of bait available that is intended for house mice.

2.10.7.1 ***Gull hazing***

2.10.7.1.1 *Hazing Trial*

Western gulls and a few other migrant gull species including California (*Larus californicus*), herring (*Larus argentatus*), and glaucous-winged gulls (*Larus glaucescens*) are known to roost on the islands in relatively small but variable numbers during the fall. Because gulls could consume bait and/or poisoned mice, hazing gulls would be incorporated into both action

alternatives to minimize the numbers of gulls landing on the islands. The goals of hazing would be two-fold: 1) to reduce non-target rodenticide exposure and mortality of gulls, and 2) to maximize the amount of bait available to mice. Gull hazing would begin shortly prior to the application of rodent bait and continue until exposure risk is determined to be reduced to negligible (Appendix E).

A hazing trial undertaken in 2012 on the South Farallon Islands successfully deployed a range of hazing techniques and demonstrated the ability to keep all but a few western gulls off the islands for an extended period of time. The trial also prevented gulls from contacting areas where non-toxic rodent bait was available. Results from the trial provide a high degree of confidence that a well planned and executed hazing operation could keep gull mortality to an acceptable level during a mouse eradication (Appendices E and F). Hazing of laughing gulls (*Leucophaeus atricilla*) was also conducted successfully during a mouse eradication on Allen Cay, Bahamas in 2012 (Alifano 2012).

The 2012 hazing trial caused only a low level of disturbance to non-target species. Some bird species were affected including Brandt s cormorants, common murres, brown pelicans, black oystercatchers, black turnstones, and willets, but the impacts observed to these species were short-term. The hazing trial also had little impact on pinnipeds (seals and sea lions) hauled out on the islands. Responses of pinnipeds varied depending on the hazing tool employed and the species present but, only rarely did hazing activities result in pinnipeds being flushed into the water (Appendix E).

Hazing effectiveness was well over 90 percent for the majority of the trial (Appendix E). The effects of hazing are summarized below; for a full summary of impacts to non-target species from hazing see Appendix E. There was very little impact to non-target birds as a result of the hazing activity. The hazing trial was designed to be conducted during the time of year when the majority of seabirds are not present on the island. Overall numbers of non-target species were not determined as part of this trial. Common murres only attended the colony on four days during the trial period and only small numbers of cormorants and pelicans were observed roosting on the island during the day. Of the 493 active hazing events during phases three and four of the trial, only 37 caused disturbance to non-target birds (about seven percent). For shorebirds, cormorants and pelicans, the disturbance usually caused the birds to take flight and then return to their roosts. Murres on the other hand typically went to sea and did not return to roost on land again that day.

Similarly, the impact of gull hazing activities on overall pinniped abundance was minimal (Appendix E). Pre-trial counts for all species were statistically similar or higher than numbers observed during the same period in the previous five years. Fur seals in particular were present in greater numbers than the prior five-year average owing to their recent and continuing rapid population growth. Comparing one month of surveys pre and post gull hazing trial, three pinniped species showed no significant differences in numbers before and after the trial: harbor seals, Steller sea lions, and California sea lions. The other two species showed declines in their populations: northern elephant seals and northern fur seals. However, these declines were consistent with regularly observed seasonal declines as juvenile elephant seals and most fur seals depart the islands at this time. The post-trial numbers for both elephant and fur seals were not

significantly different from their number during this period for the previous five years. Thus, it was concluded that there were no major impacts to pinniped abundance from the trial (Appendix E, Warzybok et al. 2013).

2.10.7.1.2 *Hazing Plan*

Gull hazing efforts would be conducted for both Alternatives B and C to reduce the risk of non-target mortality, and to reduce the risk of eradication failure by reducing pellet consumption by non-target species. While the risk of gull mortality from rodent bait consumption is less for Alternative C than for Alternative B, it is anticipated that a similar amount of gull hazing would be required for both alternatives. Gull hazing for both action alternatives would need to continue as long as the risk of exposure remains elevated (i.e. bait remains available and palatable as defined in Appendix D). Rodent bait is expected to continue to pose a high risk until it has disappeared or degraded beyond a certain threshold (Appendix D). Mice that have consumed bait and die in accessible locations would also pose a hazard for the length of time that the carcass remains palatable.

Based on bait disappearance and degradation trials (Appendix D), Brodifacoum-25D Conservation pellets should degrade within just three weeks after the last application of bait under what are considered to be normal rainfall conditions; Diphacinone-50 Conservation pellets can take over 100 days to degrade based on available data in Appendix D. Under conditions unfavorable to bait degradation, brodifacoum and diphacinone bait could pose a risk non-target wildlife for up to 101 days and 105 days, respectively, after date of last application. Although rodent bait is unlikely to persist for this length of time, resources will be in place to maintain hazing efforts for additional time, if needed. Assuming normal weather conditions, bait is expected to pose a risk to gulls for between approximately five weeks (Alternative B) and 15 weeks (Alternative C) (see Section 2.8.10). Mouse carcasses are expected to be sparsely distributed across the surface of South Farallon Islands, and thus mostly unavailable for consumption by scavengers, since the clear majority of rodents tend to retreat to burrows to succumb following onset of symptoms stemming from exposure to brodifacoum (Taylor, 1993; Howald, 1997; Buckelew et al., 2008). Monitoring of bait availability and for mouse carcass availability would be undertaken and used as a guide to determine when to cease hazing efforts (See Section 2.6).

A team of hazing personnel would deploy a range of hazing techniques including lasers, spotlights, pyrotechnics, biosonics, predator calls, air cannons, effigies, and kites to haze gulls off the islands. The use of trained falcons and bird-hazing dogs are also possible but would only be deployed if deemed absolutely necessary. However, the availability of these resources would be confirmed so that they could be deployed quickly if needed. A small reciprocating engine (piston) helicopter, such as a Robinson R22, may be used to transport personnel to otherwise inaccessible areas, monitor gull presence and haze gulls in conjunction with other techniques. To minimize the potential for gulls habituating to hazing techniques, the hazing program would be adaptively managed based on real-time monitoring of efficacy. Based on the trials completed, hazing activities would be concentrated along the islands' coastline and hazing tools would be used sporadically and only where needed. Consequently, only small areas of the South Farallon Islands should be affected at any one time.

In preparation for the possibility of unexpectedly low success of gull hazing or other non-target mitigation measures, a contingency plan was developed to outline the triggers that would be used to identify the need for a response action to minimize nontarget impact (see Section 2.10.11).

2.10.7.2 *Carcass removal*

Carcasses of mice or other species exposed to rodenticide pose a threat to potential scavengers such as gulls or owls. Thus, carcass removal will be implemented to reduce this threat, following the best management practices established in (USFWS 2013). Prior to project implementation, efforts will be made to remove all carcasses of species considered to be at moderate to high risk of rodenticide effects if exposed. The intent of such an effort is to allow for operations personnel to discern between mortality of non-target wildlife before and after eradication operations. Following the start of eradication efforts, systematic searches of all accessible areas would be made to remove dead mice and any other carcasses suspected of containing anticoagulant residues. Details of this activity would be outlined in an operational plan. The biodegradation of a sample of collected mouse carcasses may be monitored to help determine when mouse carcass searches may be discontinued. Collection of non-target species carcasses will be continued until it is determined that the risk of rodenticide exposure has declined to a negligible stage. All discovered carcasses found during the operational window would be carefully identified, recorded, labeled, and stored for further analysis if found in suitable condition.

2.10.7.3 *Manually Reducing Bait Availability*

Retrieving, moving, or crushing rodent bait so that it is inaccessible to gulls may be conducted to reduce their risk of exposure and the length of time that gull hazing is required in areas where bait is likely to persist for a longer period of time, such as on rocky substrates (Appendix A). Although, this measure would be limited to accessible locations, it will be considered as an adaptive management strategy as a means of reducing risk to non-target species. Unless non-target risk is determined to be unacceptably high, retrieving, moving or crushing rodent bait would be initiated no sooner than 10 days after the final application of bait to ensure that all house mice have sufficient access to bait.

2.10.7.4 *Raptor Capture, Captive Management and Release*

To minimize risk to raptors, attempts would be made to capture raptors present on the island prior to and during bait application. These efforts would continue as long as the risk of exposure remains high (i.e., bait or carcasses remain available and palatable). If present, resident peregrine falcons would be held off island and in a captive facility until it is determined safe to return them to the islands. Migrant species including burrowing owls would be transported off the island released into suitable habitat on the mainland. Methods involving capture and translocation or temporary captivity will be done in accordance with the terms of a Special Purpose Miscellaneous Permit issued by the Regional Migratory Bird Permit Office.

Capture techniques have been utilized effectively for island rodent eradications elsewhere. For example, on Anacapa Island, Howald et al. (2010) reported that about 68% of the known raptors

(37 birds, including eight peregrine falcons *Falco peregrinus*, nine red-tailed hawks *Buteo jamaicensis*, four barn owls *Tyto alba* and six burrowing owls) were captured prior to rodenticide applications. Most were released on the mainland, but peregrine falcons were held and released back onto Anacapa 3 weeks after rodenticide applications. Some raptors not captured, including a burrowing owl, survived the rodenticide applications. On Palmyra Atoll, 13 of about 80 (16% of known birds present) bristle-thighed curlews (*Numenius tahitiensis*) and one Pacific golden plover (*Pluvialis fulva*) were live captured prior to rodenticide applications; all survived captive holding and were released after the risk of exposure ceased. On Pinzon Island in the Galapagos Archipelago, 60 captured Galápagos hawks (*Buteo galapagoensis*) were held successfully in captivity and released 12-14 days after the last bait application on a rat eradication project. When it was found that hawks continued to receive secondary exposure to rodenticide, 10 hawks were recaptured and held successfully for three more years. Within three months of release, hawks were breeding (Rueda et al, in press).

2.10.7.5 *Captive Management of Salamanders*

Although (Appendix A) the risk to salamanders from both action alternatives appears to be low (Witmer 2018; Appendix Q), endemic salamander individuals would be collected prior to bait application on Southeast Farallon Island and held in terrariums or similar on the island until the risk of exposure is deemed negligible or monitoring of wild salamanders shows that the operation has had no effect on the population. Captive holding of Plethodontid salamanders can be done successfully following established protocols (Witmer 2018; Appendix Q; V. Vredenburg, San Francisco State University, pers. comm.). About 40 individuals would be collected and housed in captivity in order to retain sufficient genetic diversity in the population (Foose et al. 1986) should an unexpected, large mortality event occur. Individual salamanders would not be collected from under cover boards in an effort to minimize impacts to the long-term monitoring program that is currently in place. As animals are extremely territorial, they would be returned to their same location of capture.

2.10.7.6 *Reducing Disturbance*

Timing the eradication in the fall is ideal since the operation would be implemented outside of the breeding season for seabirds and pinnipeds, in addition to being the most effective strategy for minimizing disturbance to wildlife. However, it is expected that a range of tens to thousands of birds and a few thousand pinnipeds would be present on any given day during the operational window. Also, the islands are sensitive habitat to many resident and breeding species on the Farallon Islands. Prior to the eradication, personnel would be briefed on strategies and techniques for minimizing wildlife disturbance, and these techniques would be implemented during eradication operations and during monitoring periods for both action alternatives. Briefing and training requirements would include the following:

- All staff would be briefed and provided with a map detailing area with sensitive wildlife and habitats such as nesting burrows and crevices.
- All staff would be trained on how to avoid disturbance to wildlife and avoid impacts to sensitive habitats.
- Staff would move slowly in sensitive wildlife areas to avoid frightening marine mammals and birds unnecessarily.

- Staff would travel carefully by foot to avoid sensitive areas when possible to reduce unnecessary impacts to native vegetation, burrows, crevices and intertidal areas.
- Avian hazing operations would be conducted in a manner that minimizes disturbance to marine mammals and other wildlife.
- All staff will document disturbance effects to pinnipeds as required under the MMPA.

Sensitive wildlife areas are fully described in Chapter 3. For more on the topic of wildlife disturbance impacts and mitigations, see Chapter 4.

2.10.7.7 *Preventing Bait Drift into the Marine Environment*

A number of mitigation measures would be employed to minimize the risk of incidental bait drift into the marine ecosystem. These are as follows:

- The coastal boundary for the operation, Mean High Water Spring (MHWS), would be flown and mapped prior to bait being applied.
- Helicopter flight lines for spreading bait would be confined to areas above the MHWS mark.
- Bait application by helicopter would be guided by GPS.
- Rodent bait aerially broadcast along the coast would be applied using a bait spreading bucket configured with a deflector providing a 120-degree swath pattern.
- A trickle bucket with a narrow (<33 ft or <10m) swath would be used to complete linear features and sections of coastline considered too challenging for deflector and full swath bucket configurations.
- Bait application would not be conducted in wind speeds exceeding 30 knots.

Consideration of the following additional measures would also be made:

- Reducing the swath width of all bait spreading bucket configurations to provide for more precise placement of bait.
- Reducing helicopter flight speed to ensure more precise placement of bait.

These adaptive management measures would require more careful consideration prior to being implemented during the eradiation because they add complexity and risk to the proposed operation.

The use of bait deflectors and trickle buckets has been shown to be effective at reducing the extent of bait drift into the marine environment during aerial broadcasts (Wegmann 2011). A recent analysis of bait drift, completed on Palmyra Atoll by Pitt et al. (2015), found bait at densities of up to 14 percent of the targeted application rate 7m from shore and the authors considered that bait may have drifted past this point. Pitt et al. (2015) noted that a number of factors including a malfunction of the bait deflector, a dense forest canopy hanging over the coastline, an irregular coastline, and strong winds could have exacerbated the extent of the bait drift observed at Palmyra. Corrective action to permanently fix the deflector was made on Palmyra and this knowledge would be incorporated into operational planning for the Farallones project. There is no vegetation overhanging the shoreline at the Farallones, thus pilot visibility would not be an issue as it was at Palmyra Atoll. Operating limits for wind speed and helicopter

flight speed would be set during operational planning to further minimize the possibility of bait drift into the marine environment.

2.10.7.8 *Use of bait stations for mitigation purposes*

In addition to the use of bait stations in and around structures, bait stations may also be installed in small areas where the risk of bait drift into the marine environment from aerial application is considered to be high or easily accessible areas that are determined to have particularly high numbers or persistent concentrations of roosting gulls.

2.10.8 **Minimizing Impacts to Wilderness**

To address the special management regulations in place for the wilderness areas on West End Island and other islets of the South Farallones, the Service would use the minimum tools necessary to eradicate house mice from the South Farallones while minimizing impacts to wilderness character including trammeling, development, natural, as well as for providing solitude and primitive and unconfined recreation. As required when one or more of these wilderness qualities will be negatively impacted as part of wilderness management, a wilderness minimum requirements analysis, in the form of the Minimum Requirements Decision Guide (MRDG), as prepared and is available in Appendix G.

2.10.9 **Protecting Cultural Resources**

All known sites with important cultural resources would be clearly identified in a manner that would be recognizable to all field personnel. Personnel would be briefed on the locations and identification of archaeological and historical resources that are present on the island and methods to avoid impacts to those resources. Field personnel would be prohibited from disturbing any sites of historical or cultural importance. Due to the presence of historic buildings and other features on the island, the Service would conduct consultation with Service cultural resources staff and the State Historic Preservation Office (SHPO) to ensure that planned activities would be compatible with protection of cultural resources on the island. Personnel would not dig into the ground or alter the physical environment except at discrete locations for the installation of bait stations and associated necessary equipment.

2.10.10 **Monitoring**

In addition to long-term monitoring programs already in place on the South Farallon Islands, monitoring of operational, mitigation, and ecosystem restoration objectives would be conducted before, during, and after the proposed mouse eradication operation. Monitoring plans would be prepared to guide the monitoring activities outlined below prior to the project being implemented. Monitoring would be conducted in accordance with the best management practices established in USFWS 2013 and based on protocols described in recent monitoring plans, such as those for Palmyra Atoll (Pitt et al. 2015), Antipodes Island (2015) and Desecheo Island (Shiels et al. 2017).

2.10.10.1 *Operational Monitoring*

Operational monitoring would be undertaken in addition to the ongoing monitoring programs already in place on the South Farallones and the non-target biota ecosystem monitoring described below. Operational monitoring would encompass tracking a range of parameters necessary to ensure project success, which is the complete eradication of all house mice from the South Farallon Islands. These efforts include checking bait quality, ensuring the application rate is appropriate, ensuring that there is sufficient bait coverage to expose every mouse on the Farallones, ensuring that bait is available for a sufficient amount of time, and monitoring bait breakdown over time. Information gained from operational monitoring would be used to adaptively manage latter stages of implementation within the constraints of the project such as the interval between bait applications.

Monitoring to determine the presence or absence of mice and the outcome of the eradication operation would be undertaken for approximately two breeding seasons or up to two years after the operation. A range of rodent detection devices such as traps and tracking tunnels would be deployed in an attempt to detect surviving mice.

2.10.10.2 *Monitoring of Mitigation Objectives*

The Council on Environmental Quality issued guidance[1] on January 14, 2011, regarding mitigation monitoring to determine if mitigation was implemented or effective. Mitigation is defined in the CEQ regulations (40 CFR 1508.20) to include: 1) Avoiding the impact altogether by not taking a certain action or parts of an action; 2) minimizing impacts by limiting the degree or magnitude of the action and its implementation; 3) rectifying an impact by repairing, rehabilitating, or restoring the affected environment; 4) reducing or eliminating the impact over time, by preservation and maintenance operations during the life of the action; and 5) compensating for the impact by replacing or providing substitute resources or environments. The CEQ regulations require a monitoring and enforcement program to be adopted and summarized in the Record of Decision (ROD) where applicable for any mitigation. Monitoring can improve the quality of agency decision-making by providing feedback on the effectiveness of proposed and implemented mitigation techniques. Monitoring can be particularly important in the context of proposed actions that involve an adaptive management approach to resource management. Mitigation monitoring is also important in this case because of the high degree of public interest in the proposed project. Mitigation monitoring procedures described in this Final EIS incorporate recommendations from the public and agencies received during either scoping or during public comment on the RDEIS.

Mitigation monitoring including island-wide surveys of certain wildlife species would be undertaken prior to, during, and immediately after the mouse eradication operation to determine the presence, location, and abundance of potential non-target species (such as gulls requiring hazing and other migratory bird species requiring capture and translocation) and gauge the

[1] Guidance on Appropriate Use of Mitigation and Monitoring and Clarifying the Appropriate Use of Mitigated Findings of No Significant Impact issued January 14, 2011, issued in accordance with NEPA, 42 U.S.C. § 4321 et seq., and the CEQ Regulations for Implementing the Procedural Provisions of NEPA (CEQ Regulations), 40 CFR Parts 1500-1508.1

effectiveness of mitigation techniques to reduce impacts to natural resources. Principles of adaptive management would be applied to subsequent mitigation activities and information gained from monitoring would guide how best to minimize risk to non-target species. During and immediately after the eradication, periodic surveys and searches would be conducted for poisoned or incapacitated birds (such as gulls, raptors, and other bird species). Periodic assessments of marine mammal haul-outs would also be completed during implementation to gauge the level of disturbance from operational activity. Marine mammals would be monitored to gauge responses to helicopter operations, bait station installation and maintenance, and other project tasks to ensure compliance with the Marine Mammal Protection Act (MMPA).

2.10.10.3 *Monitoring of Non-target Mortality*

Within one week of the start of project implementation, all safely accessible areas of the islands will be searched for bird and other animal carcasses. Bird and other small animal carcasses will be recorded and collected. The locations of marine mammal or other large animal carcasses will be recorded. Within three days of rodenticide bait being first applied, daily carcass searches and removal would be conducted for assessments of non-target biota mortality and to reduce the opportunity for secondary exposure of non-target scavengers to the toxicant. All non-target species carcasses found would be carefully identified, recorded, labeled, and if in suitable condition stored for further analysis, if appropriate. The location of any non-target species carcasses recovered would be noted. Also, regular, standardized surveys of mainland Gulf of the Farallones beaches may be conducted to search for dead birds that could have been exposed to rodenticide. Surveys would be conducted following standardized protocols of the Greater Farallones National Marine Sanctuary's Beachwatch program and would include collection of carcasses. Recorded mortality during the implementation period would be compared to long-term baseline values to determine if numbers of beached birds were significantly above average. If unanticipated mortality of any non-target species is recorded following the first bait application, a management decision on whether to proceed with subsequent bait applications would be made.

A monitoring plan describing the collection and processing of abiotic samples (soil and water) and biota (mentioned in following sub-sections) as well as analysis of rodenticide residues will be developed in consultation with select permitting agencies, island rodent eradication experts, and toxicologists. The monitoring plan will assist in tracking the environmental fate of rodenticide in the environment, characterizing the extent and period of exposure to non-target biota, and determining when it is safe to release captured and held native wildlife (e.g., Farallon arboreal salamanders) back onto the islands.

2.10.10.4 *Monitoring of Ecosystem Restoration Objectives*

The eradication of house mice is expected to benefit many native species on the South Farallones, including ashy and Leach's storm-petrels, endemic Farallon arboreal salamanders, Farallon camel crickets, other island invertebrates, and native plants.

Monitoring with the intention of documenting changes to species likely to benefit from mouse eradication has already begun and will continue (depending on funding and staffing) for at least two years after the removal of mice to determine positive or negative changes to native biota and

ecosystem function. Biological monitoring on the South Farallon Islands has been an integral part of the management of the islands for nearly 50 years. Current monitoring efforts include ongoing daily, weekly, monthly and seasonal studies and counts of marine mammals, breeding seabirds, migrant birds, plants, bats, migrant butterflies and dragonflies, arboreal salamanders, Farallon camel crickets, and white sharks (http://www.pointblue.org/our-science-and-services/conservation-science/oceans-and-coasts/farallon-islands-research; See Section 4.8.3 for a summary of current monitoring and research activities). In addition, the Greater Farallones National Marine Sanctuary conducts periodic monitoring of intertidal algae and invertebrates (Roletto et al. 2014).

2.10.10.4.1 Bird Monitoring

It is expected that efforts will continue to monitor the numbers of burrowing owls that over-winter on the islands along with the number of ashy-storm petrels killed by owls and other predators each year. Annual surveys of breeding population sizes, seabird productivity, storm-petrel population and survivorship trends and other techniques are expected to be continued to monitor the potential impacts of mouse eradication on seabird species. These actions would be carried out by the Service, Point Blue, and/or other contracted or partnering individuals or organizations. The Service, Point Blue and its partners would also continue to actively monitor resident and migrant bird populations.

2.10.10.4.2 Salamander and Camel Cricket Monitoring

Current studies on salamander life history characteristics are planned to continue. Other studies to examine both salamander and cricket distribution and abundance have been developed and are being conducted to detect potential changes resulting from the proposed mouse eradication and other factors.

2.10.10.4.3 Vegetation Monitoring

A vegetation monitoring plan has been developed and monitoring of vegetation changes are planned to continue post-eradication in an attempt to detect and track changes to the islands plant community.

2.10.10.4.4 Intertidal Monitoring

Intertidal monitoring would include monitoring intertidal algae and invertebrate communities before and after implementation of the project. NOAA has established long-term intertidal study plots around the islands for monitoring changes over time (Roletto et al. 2014). It is expected that this monitoring program could detect long-term impacts of the eradication on the relative abundance and diversity of intertidal algae and invertebrates.

If greater than negligible bait drift into the marine environment is detected, additional monitoring intertidal areas would be conducted after bait application. Samples of fish and marine invertebrates from the intertidal and/or nearshore subtidal zone would be collected during the operational period while bait persists on the islands and submitted for determination of

rodenticide residue concentration. Similar studies have been conducted during and after other rodent eradications (e.g. Howald et al. 2001, Fisher et al. 2011, Pitt et al. 2015, Masuda et al. 2015). Species to be sampled would be determined in consultation with NOAA and CDFW.

2.10.11 Contingency Plans

To prepare for unexpected events that could jeopardize the success of the project or cause significant impacts to the environment, contingency plans will be developed as part of the final operational plan. At a minimum, contingency plans addressing the possibility of a major bait spill or major impacts to non-target resources will be fully developed.

Due to the potential of a spill of rodenticide bait into the South Farallon Islands environment, the Service has begun development of a Bait Spill Contingency Plan that will address the risks associated with the storage, transport and use of rodenticide bait, and identifies appropriate response actions in the event of a spill. At a minimum, the Bait Spill Contingency Plan will outline the following types of information: 1) natural resources at risk; 2) response strategy; 3) precautions that will be taken to minimize risk of a marine or terrestrial bait spill; 4) the response activities, including discovery and control, assessment, notification procedures, and disposal of spilled material; 5) necessary response resources and appropriate preparedness activities; 6) description of Incident Command System (ICS) structure, ICS contacts; and other relevant information necessary to help respond to an unforeseen spill; and 7) appropriate response activities in designated wilderness areas. As part of Bait Spill Contingency Plan development, the Service will consult or coordinate with relevant federal, state, and local agencies and organizations for input and assistance. Depending upon the method selected for transport of bait to the island in the operational plan, scenarios that may be addressed in the Bait Spill Contingency Plan include:

- A shipping accident or incident during the transfer of bait by helicopter from ship to shore results in bait entering the marine environment;

- A bait spreading bucket with a partial or full load of bait is lost into the marine environment; and

- A bait spreading bucket with a partial or full load of bait or container of bait being stored on Southeast Farallon Island is spilled into the terrestrial environment.

In addition to the Spill Contingency Plan, the Service has begun development of a Contingency Plan for Non-Target Impacts to Terrestrial or Marine Biota of the South Farallon Islands ("Non-target Contingency Plan"). Despite planned mitigation measures, there is potential risk of exposure to and subsequent unexpected, adverse impacts from rodenticide bait in non-target fish and wildlife of the South Farallon Islands. At a minimum, the Non-target Contingency Plan will address the risks associated with non-target fish and wildlife exposure to rodenticide bait, particularly western gulls, pinnipeds, raptors, and marine fish; disturbance to pinnipeds as a result of rodenticide bait application and hazing activities; and response of operation personnel in the event of an incident. The Non-target Contingency Plan will also outline the triggers the Service will use to identify the need for response action and the contingency responses that will

be put in place to minimize the consequences of eradication activities to non-target biota. Other similar types of information provided in the Spill Contingency Plan, such as a description of the ICS with contacts, and essential response equipment and supplies, will be included. Like the Spill Contingency Plan, the Service will consult or coordinate with relevant federal, state, and local agencies and organizations for input and assistance. Scenarios that will be addressed in the Non-target Contingency Plan include:

- Potential failures or deficiencies of the hazing program to reduce risk of western gulls and other congregating bird species at risk of exposure to rodenticide; and

- Monitoring results indicate that significant impacts to a species' population or exceedance of allowable take by permit appear likely to occur under current conditions.

2.10.12 **Biosecurity Measures**

In order to mitigate the risk of future rodent reinvasion on the Farallon Islands National Wildlife Refuge, the Farallon Biosecurity Plan (Appendix B) would be implemented by the Service prior to the proposed mouse eradication project to prevent and detect potential future rodent incursions. Southeast Farallon Island hosts a biological research station that is operated year-round by the Service, Point Blue, and other personnel that require a steady influx of supplies in order to maintain operations. The primary pathways by which a rodent incursion might occur include marine vessels, helicopters and their associated cargo. Another potential pathway would be from vessel wreckage on or near the island. Biosecurity measures will focus on the packaging, inspection, and quarantine of all cargo transported to the island, on-island surveillance, and contingency responses in the case of rodent detection on the island. Pre-departure and post-arrival biosecurity measures might include the storage of cargo in quarantine facilities, reduction and re-packaging of supplies, packaging in rodent-proof containers, the visual inspection of all cargo at multiple stages, and the careful unpacking of cargo inside buildings.

In order to inform visitors of biosecurity measures, informational briefings, contract and Special Use Permit language, and public outreach will be a component of the biosecurity plan. Surveillance measures will include the regular deployment and maintenance of rodent control and detection devices around landing areas and buildings. If evidence of a rodent incursion is encountered, contingency response measures would be implemented that may include treating the area with rodenticide applied by bait stations, live trapping, snap trapping, sticky pads, or by a combination of methods. The biosecurity measures that are outlined in the plan would continue and refined as needed by all staff, volunteers, cooperators, contractors, and other visitors, in perpetuity, and would include appropriate staff training. As part of the Refuge's Biosecurity Plan, all station staff would be trained in the detection of rodent signs (See Appendix B). A specific quantity of rodent bait would be stored on the island for use as a rapid rodent response in the event of a rodent sighting due to a re-invasion.

2.11 Alternative B: Aerial Broadcast of Brodifacoum-25D Conservation (Preferred Alternative)

2.11.1 Bait Product: Brodifacoum-25D Conservation

Alternative B encompasses the aerial application of Brodifacoum-25D Conservation rodent bait, manufactured by Bell Labs Inc., as the primary application method. The bait proposed under Alternative B, Brodifacoum-25D Conservation, is a compressed cereal grain pellet that weighs approximately 0.35 oz (1g). The pellet contains 25 ppm or 0.0025 percent brodifacoum, a second-generation anticoagulant. Pellets are dyed green, to make them less attractive to birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). The specific bait product used for this alternative is registered with the EPA (EPA Reg. No. 56228-37) and would be applied in compliance with EPA and the Federal Insecticide, Fungicide and Rodenticide Act bait label. As described in Section 2.10 and elsewhere in this FEIS, a supplemental label will be acquired, in consultation with USDA/APHIS and EPA, to allow the Service to adopt bait label specifications to suit specific needs of this project. For additional discussion of this product, see Section 2.6.

Brodifacoum-25D Conservation is considered a more appropriate bait type for use in this action alternative than Brodifacoum-25W Conservation because Brodifacoum-25D Conservation was developed by Bell Laboratories for dry temperate climatic conditions similar to the Farallones. In contrast Brodifacoum-25W Conservation was developed specifically for wet environments such as Palmyra Atoll (Buckelew et al. 2005). Based on trials completed on SEFI (see Appendix D) and elsewhere (Howald et al. 2004), breakdown of Brodifacoum-25D Conservation is anticipated to be more rapid than Brodifacoum-25W Conservation on the South Farallon Islands, reducing the duration that non-target species would be exposed to risk.

2.11.2 Bait Application Rate and Number of Applications

Bait would be broadcast at or up to the specified rates on the current EPA bait label (Reg. No. 56228-37); a supplemental bait label may be needed for baiting certain areas (see Section 2.10). Rates specified in the existing bait label are 16 lb/acre (18 kg/ha) for the initial application and 8 lb/acre (9 kg/ha) for subsequent applications. Based on trials conducted on Southeast Farallon Island, in which bait disappeared at rates of up to 5.7 lb/acre (6.4 kg/ha) per day (see Appendix D), rates approximating label rates are considered sufficient to expose all invasive house mice on the Farallones to rodent bait and ensure that bait is available for a suitable period to achieve eradication. The rate of bait disappearance following a second application is expected to be less during an eradication because bait consumption by mice will be reduced to nearly negligible levels shortly after the first bait application (due to mouse mortality) and potential consumption by western gulls will be minimized by proposed hazing activity (Section 2.10.7.1).

To ensure uniformity in the application rate across the islands, steep areas may be flown a second time because steep areas increase the island's surface area; a supplemental label for this baiting method may be needed. Current label application rates would be used for any areas where bait is applied by hand. These areas may include caves, sensitive shorelines, or other areas excluded from aerial bait application. Bait stations would be initially filled with up to 4.2 oz (120g) of bait and kept topped up at this level for the duration of their deployment. Much of the

bait deployed in bait stations is expected to be recovered. In areas where bait stations are deployed (such as in or near housing), they would be spaced at least two to four meters apart to ensure that bait is available to all mice. Exact application rates and methods that will be used would be determined during the development of the detailed operational plan and supplemental bait label application process.

Brodifacoum-25D Conservation bait would be applied in two applications, each separated by an interval of 10 to 21 days. There is a small chance that some mice may not be exposed to the bait applied during the first application because of competitive exclusion or if juveniles had not yet been weaned. Conducting a second application 10-21 days after the first would maximize the likelihood that these individuals are exposed to the rodenticide. In no-choice laboratory trials, mice survived for up to 21 days after ingesting a lethal dose of brodifacoum (Morriss 2007). Time to death is likely to be shorter in the wild (Morriss 2007), but it is possible that juvenile mice, still within the nest, could remain isolated from bait for a period of up to three weeks (Griffiths 2008). Brodifacoum poisoning in mammals can cause fetuses to be aborted (Weldon et al. 2011), but too little brodifacoum appears to be passed on through lactation (O'connor and Booth 2001, Gabriel et al. 2012) to cause toxicosis.

Assuming the operation uses current EPA label application rates for the majority of broadcast operations, the total amount of bait needed would be 2,917 lb (1,323 kg). This amount of rodent bait contains between 1.16 oz (33g) of brodifacoum, in total. Approximately 1,945 lb (882 kg) of bait pellets would be delivered during the first application and approximately 972 lb (441 kg) during the second application. The first application would utilize approximately three bucket loads of rodent bait and require approximately three hours of helicopter flight time over the islands. The second application would be completed with just two bucket loads but still require approximately the same amount of flight time as the first bait application. If bait spreading buckets were loaded on the adjacent mainland approximately 30 miles away, the turn-around time for each load would be approximately one hour. Each aerial application operation would still likely be completed within half a day.

The specific bait product used for this alternative is registered with the EPA. However, the proposed application regimen would require consultation with USDA/APHIS and EPA to determine if a supplemental label would be necessary to provide the greatest chance of successfully removing mice.

2.11.3 **Bait Application Timing and Schedule**

The optimal time for bait application would be in the late fall based on several factors including weather, seabird and pinniped breeding periods, mouse population dynamics, and others. Brodifacoum-25D Conservation bait would be applied in two applications, each separated by an interval of 10 to 21 days. The timing of the bait broadcast operation would occur on separate days, between October and December. Both aerial and hand bait application and the filling of bait stations would begin as early as possible during the day to ensure the operation can be completed and any gaps in bait application addressed within one day.

Pre-placement of unarmed bait stations would occur six weeks prior to aerial operations to ensure bait stations were in place prior to the eradication taking place and minimize any risk of neophobia. Pre-placement of bait stations is recommended as good practice (Broome and Brown 2010). Bait stations would be loaded with rodent bait on approximately the same schedule as bait is applied aerially and stations would be continually checked and replenished for at least one month after the last evidence of consumption by mice is recorded (Broome and Brown 2010).

Weather or other factors outside the control of the project may require that operations be altered in order to maximize the project's likelihood of success. For example, if an unexpected rain event occurred immediately following bait application, some back-baiting (baiting of areas previously baited) may be required to prevent potential gaps in coverage. Any changes in the schedule of bait application or other project actions would utilize an adaptive management and decision-making approach to determine the most appropriate measures to take. The potential need for a supplemental label for back-baiting would be done in consultation with the USDA/APHIS and EPA during development of an operational plan.

2.11.4 **Alternative B: Summary**

In summary, bait delivery methods for this alternative would primarily consist of aerial broadcast of Brodifacoum-25D Conservation rodent bait by helicopter using a bait spreading bucket. Hand baiting and the deployment of bait stations would also be undertaken in designated areas. Bait would be systematically applied to all land areas above the MHWS mark on the South Farallones. For potential deviations from the current label, USDA/APHIS and EPA will be consulted to determine the need for a supplemental label and to apply for a supplemental label.

2.12 Alternative C: Aerial Broadcast of Diphacinone-50 Conservation

2.12.1 **Bait Product: Diphacinone-50 Conservation**

Alternative C calls for the aerial broadcast of Diphacinone-50 Conservation, manufactured by Hacco Inc., as the primary bait application method. The rodenticide Diphacinone-50 Conservation is a cereal grain pellet available in approximately 0.35 oz to 0.70 oz (1-2 g) pellets with an added fish flavor. The bait contains 50 ppm or 0.005 percent diphacinone, a first-generation anticoagulant. Pellets are dyed dark green, which has been shown to make them less attractive to birds and reptiles (Pank 1976, Tershy et al. 1992, Tershy and Breese 1994). The specific bait product used for this alternative is registered with the EPA (EPA Reg. No. 56228-35) and would be applied in compliance with the EPA and FIFRA bait label; a supplemental label will be required if desired bait application rate(s) would exceed EPA label rates. For additional discussion of this product, see Section 2.6.

2.12.2 **Bait Application Rate and Number of Applications**

The lack of a history of mouse eradication success using bait containing diphacinone means that no model exists upon which to build an operational prescription for the eradication of mice with a diphacinone based product. Consequently, a conservative approach was taken in the development of this alternative and a number of factors considered. A study by Swift (1998)

using wild caught ship (black) rats (*Rattus rattus*) found that an uninterrupted supply of toxic bait must be provided for a period of at least 7 days or until feeding has stopped to reach an LD_{80} using 'Ramik Green' compressed cereal baits with 0.005 ppm diphacinone in bait stations.). Based on the study by Swift (1998), it is concluded that an uninterrupted supply of rodent bait containing diphacinone must be provided for at least this period of time to effectively target house mice on the Farallones. However, several other considerations suggest that the period of bait availability for mice should be extended further.

Firstly, house mice appear to be more tolerant of diphacinone than rats. Reported acute oral LD_{50}'s for mice lie between 28.0 ppm and 340 ppm (Kusano 1974, Kosmin and Barlow 1976, RTECS 1980, Hayes and Laws 1990) and repeat-dose oral LD_{50} values for mice are 0.42 (male); 2.83 (female); and 1.41 (mixed sex) ppm/day for five days (Ashton et al. 1987). These LD_{50} values are 4-350 times higher than those recorded for rats (Erickson and Urban 2004). There is also some evidence to suggest that females are less susceptible than males to repeated doses (Ashton et al. 1987). In planning for a greater tolerance by mice and intra-population variability, bait may need to contain a higher concentration of diphacinone, be applied at a higher rate, or be broadcast in an increased number of applications to raise the chance of eradication success.

Secondly, trapping of mice on the Farallones indicates that some mice could be in reproductive condition throughout the year (Appendix A). Although breeding is less likely during the fall (the proposed time of the eradication), if it occurs, young mice may not immediately be exposed to bait because they have not yet emerged from the nest. As indicated by experiments on rats (*Rattus* spp.) and rabbits (*Oryctolagus cunicula*), anticoagulant poisoning in mammals can cause fetuses to be aborted (Weldon et al. 2011). However, evidence from experiments with sheep and monitoring of fishers (*Martes pennant*) suggests that little if any anticoagulant is passed on through lactation (O'connor and Booth 2001, Gabriel et al. 2012). Consequently, bait must be available for a longer period of time to ensure all individuals are sufficiently exposed. In 'no choice' laboratory trials using a second-generation anticoagulant, mice survived for up to 21 days after ingesting a lethal dose (Morriss 2007). Time to death is likely to be shorter in wild individuals (Morriss 2007), but it is possible that juvenile mice, still within the nest, could remain isolated from bait for a period of up to three weeks (Griffiths 2008).

Bait disappearance rates as high as 6.34 kg/ha per day were recorded during trials conducted on Southeast Farallon Island (see Appendix D). Consequently, it is considered that bait containing diphacinone would be applied in three applications at a rate of up to 12.5 lb/acre (13.8 kg/ha) in each application; this is the current bait label rate. Applying Diphacinone-50 Conservation at the stated intervals and application rate would be expected to provide continuous availability of bait to mice for a period of at least 21 days. The total amount of bait that would be applied over the course of the operation would be at least 37.5 lb/acre (41.4 kg/ha) or approximately 4,482 lb (2,032 kg) in total. The total amount of diphacinone that would be applied would be 3.6 oz (101.6 g). Rodent bait that is applied aerially is subject to degradation from rainfall due to exposure to the elements. A heavy rainfall event could substantially reduce the time that bait is available to mice.

To ensure uniformity in the application rate across the islands, steep areas may be flown a second time because steep areas increase the island's surface area; this baiting method may

require a supplemental label. Current label rates specified above would be used for any areas where bait is applied by hand. These areas may include caves, sensitive shorelines, and other areas excluded from aerial bait application.. Bait stations would be initially filled with up to 4.2 oz (120 g) of bait and kept topped up at this level for the duration of their deployment. In areas where bait stations would be deployed, such as in or near housing or gull roosts, they would be positioned at a minimum spacing of two to four meters. The exact number of applications (maximum of three), application rates and application methods would be determined in the development of an operational plan and supplemental bait label application process.

Approximately 1,490 lb (670 kg) of bait pellets would be delivered during each application. It is possible that this amount of bait could be applied in one full day of aerial broadcasting. However, if bait spreading buckets were loaded on the adjacent mainland, each application may require more than one day. During each application of Diphacinone-50 Conservation, there would be approximately 3 helicopter trips and approximately 2 hours of flight time broadcasting bait over the islands.

The specific bait product used for this alternative is registered with the EPA. However, the proposed application regimen would require consultation with USDA/APHIS and EPA to determine if a supplemental label would be necessary to provide the greatest chance of successfully removing mice.

2.12.3 **Bait Application Timing and Schedule**

The optimal time for aerial broadcast operations would be in the late fall based on several factors including weather, seabird and pinniped breeding, mouse abundance, and others. The timing of the bait broadcast operation would occur on three separate days, between October and December. Both aerial and hand bait application and the filling of bait stations would begin as early as possible during the day to ensure the operation can be completed and any gaps in bait application addressed within one day.

The bait application strategy for Alternative C would involve broadcasting a proportion of the total amount of bait required during three applications, each separated by a time interval of approximately seven days. More closely spaced applications are planned for Alternative C than Alternative B as the use of Diphacinone-50 Conservation requires a consistently available source of bait.

Pre-placement of unarmed bait stations would occur six weeks prior to aerial operations to ensure bait stations were in place prior to the eradication taking place and to minimize any risk of neophobia. Pre-placement of bait stations is recommended as good practice (Broome and Brown 2010). Bait stations would be loaded with rodent bait on approximately the same schedule as bait is applied aerially and stations would be continually checked and replenished for at least one month after the last evidence of consumption by mice is observed (Broome and Brown 2010).

Weather or other factors outside the control of the project may require that operations be altered in order to maximize the likelihood of success. For example, if an unexpected rain event

occurred immediately following bait application, some back-baiting (baiting of areas previously baited) may be required to prevent potential gaps in coverage. Any changes in the schedule of bait application or other project actions would utilize an adaptive management and decision-making approach to determine the most appropriate measures to take. The potential need for a supplemental label for back-baiting would be done in consultation with the USDA/APHIS and EPA during development of an operational plan.

2.12.4 **Alternative C: Summary**

In summary, bait delivery methods for this alternative would primarily consist of aerial broadcast of Diphacinone-50 Conservation rodent bait by helicopter using a bait spreading bucket. Hand baiting and the deployment of bait stations would also be undertaken in designated areas. Bait would be systematically applied to all land areas above the MHWS mark on the South Farallones. For potential deviations from the current label, USDA/APHIS and EPA will be consulted to determine the need for a supplemental label and to apply for a supplemental label.

2.13 Comparative Summary of Actions by Alternative

Table 2.5: Comparison of Important Operational Attributes for each Action Alternative.

Action Attribute	Alternative B (Preferred Alternative	Alternative C
Toxicant type/Product	Brodifacoum-25D Conservation (Bell Labs)	Diphacinone-50 Conservation (Hacco, Inc.)
Primary bait delivery method (~90%)	Aerial Broadcast	Aerial Broadcast
Supplementary bait delivery methods (~10%)	Hand Broadcast, Bait Station	Hand broadcast, Bait Station
Timing: start of application	Fall	Fall
Number of aerial applications	2	3
Time between applications	10-21 days	~7 days
Minimum length of exposure required to ensure eradication	4 days following each application	At least 21 days of continuous exposure
Anticipated bait pellet application rates	24 lb/acre (16 lb/acre + 8 lb/acre) 27 kg/ha (18 kg/ha + 9 kg/ha)	37.5 lb/acre (12.5 lb/acre x 3) 42 kg/ha (14 kg/ha x 3)
Anticipated total amount of rodent bait that would be applied	2,917 lb (1,323 kg)	4,482 lb (2,032 kg)
Concentration of rodenticide within rodent bait	0.0025%	0.005%
Anticipated total amount of rodenticide to be applied	33g	102g

Action Attribute	Alternative B (Preferred Alternative	Alternative C
Anticipated hours of flight time required for aerial bait application actions	About 11 hours (~5.5 hours x 2)	About 16 hours (~5 hours x 3)
Total helicopter time over island for bait application	About 6 hours (~3 hours per application)	About 7 hours (~2 hours per application)
Bait application duration	Up to 21 days (2 drops 10-21 days apart)	At least 21 days (3 drops, each about 7 days apart)
Projected bait availability and palatability to gulls	Up to 5 weeks	Up to 15 weeks
Anticipated hours of flight time required for gull hazing	Up to 70 hours (2 hours daily for 5 weeks)	Up to 210 hours (2 hours daily for 15 weeks)
Actions to minimize risk to non-target species	Timing of operation, gull hazing, raptor capture, salamander capture, carcass removal, use of bait stations	Timing of operation, gull hazing, raptor capture, salamander capture, carcass removal, use of bait stations
Actions to minimize bait drift	Baiting of areas above MHWS only, flying only in wind speeds of less than 30kts, use of deflector and dribble buckets.	Baiting of areas above MHWS only, flying only in wind speeds of less than 30kts, use of deflector and dribble buckets

This page intentionally left blank

3 Affected Environment

3.1 Purpose and Structure of this Chapter

The Farallon Islands National Wildlife Refuge (Refuge) was established in 1909 and expanded to its current size in 1969. It consists of all the islands in the Farallon group, including the North, Middle, and South Farallon Islands, as well as Noonday Rock. Within the Refuge, all of the emergent land except the island of Southeast Farallon is designated Wilderness under the Wilderness Act of 1964. The Service has cooperative agreements with Point Blue Conservation Science (Point Blue) and the U.S. Coast Guard to facilitate protection and management of the Refuge.

The waters around the Farallones below the mean high tide line are part of the Greater Farallones National Marine Sanctuary. This 3,295 square mile Sanctuary is one of three contiguous Marine Sanctuaries, with Cordell Bank National Marine Sanctuary to the north and Monterey Bay National Marine Sanctuary to the south and extend from Cambria to Point Arena and out to sea, well past the continental shelf. Designations by the state of California include the Farallon Islands Area of Special Biological Significance (ASBS), Southeast Farallon Island State Marine Reserve, Southeast Farallon Island State Marine Conservation Area, and the Southeast Farallon Island Special Closure. Despite protection under California law, the State Board has identified pollution threats to the Farallon Islands from a variety of sources including oil spills, urban drainage and harbor waste. These contaminants threaten water quality and can harm fish and wildlife.

The Farallones' isolated nature, varied and extensive habitats, and adjacent productive marine environment makes them an ideal breeding and resting location for wildlife, especially seabirds and pinnipeds. The Refuge comprises the largest continental U.S. breeding seabird colony south of Alaska and supports the world's largest breeding populations of ashy storm-petrel, Brandt's cormorant (*Phalacrocorax penicillatus*), and western gull.

The Farallones have also experienced extensive human activity from the early 19th century including the harvesting of pinnipeds for fur, oil, and food; the gathering of seabird eggs in the mid- to late 19th century; and use the South Farallon Islands as a military outpost during two world wars and as a manned U.S. Lighthouse Service/U.S. Coast Guard light station. The overexploitation of Farallon seabirds and pinnipeds in the 19th century resulted in the complete and near extirpation of some species. Russian, British, and American sealers hunted northern fur seals until they were extirpated from the islands by the 1830s (White 1995, Pyle et al. 2001). Common murre eggs were commercially harvested from the late 1840s until the early 20th century; by then the population had declined dramatically (Ainley and Lewis 1974, Carter et al. 2001). Climate change impacts and over-fishing of Pacific sardines (*Sardinops sagax*) in the mid-20th century may have reduced seabird and marine mammal food supplies (Ainley and Lewis 1974, Deyle et al. 2013). This, along with extensive mortality from heavy oil pollution in the early to mid-20th century (Ainley and Lewis 1974, Carter 2003, Hampton et al. 2003) has exacerbated population declines and recovery. The active light station further impacted island wildlife and habitat until the lighthouse was fully automated in 1972.

Under Refuge stewardship, some extirpated species have re-colonized the islands, and wildlife populations as a whole are recovering. For example, northern elephant seals began recolonizing the South Farallon Islands in the early 1970s (Stewart et al. 1994) and northern fur seals returned as breeders in the mid-1990s (Pyle et al. 2001). However, some refuge species remain at reduced population levels or are even declining, and wildlife remains vulnerable to the impacts of introduced invasive plants and animals, oil spills, other pollution, fisheries interactions, oceanic changes, and global climate change.

The overall impact of invasive species to the Farallon Islands has been profound, yet many important steps have been taken to restore the unique island ecosystem. European rabbits were introduced to Southeast Farallon Island sometime between 1856 and 1874 (Cameron 1966) and were present until 1974 when they were removed by the Service and Point Blue (Ainley and Lewis 1974, DeSante and Ainley 1980). Invasive rabbits competed with the larger species of burrowing alcids (e.g., tufted puffin *Fratercula cirrhata* and rhinoceros auklet *Cerorhinca monocerata*) for nesting burrows and cavities, and their grazing effects were deleterious to the native flora (Ainley and Lewis 1974). Domestic cats, a substantial threat to native and endemic fauna on islands, were successfully removed by the Service and Point Blue in 1972 (Ainley and Lewis 1974, Campbell et al. 2011). In addition, the Service continues to remove and control invasive plants on the islands, which reduce nesting habitat of burrowing seabirds such as the Cassin's auklet and rhinoceros auklet and outcompete native plants. The last remaining invasive vertebrate on the Farallon Islands is the house mouse. House mice are negatively impacting breeding seabird populations, notably ashy and Leach's storm-petrels, native invertebrates such as the endemic camel cricket, arboreal salamanders, and native flora.

3.2 General Description of the South Farallon Islands

3.2.1 Geographical Setting

The South Farallon Islands are situated just inshore of the continental shelf edge, about 30 miles west of the Golden Gate Bridge and the City of San Francisco, California, at 37°42'N latitude and 123°00'W longitude (Figure 3.1). The South Farallones consist of two main islands that are separated by a narrow channel: Southeast Farallon Island and West End (or, Maintop Island) Island. Several offshore islets immediately surround the main islands, including Saddle (or, "Seal") Rock, Sugarloaf, Arch Rock, Aulon Islet, Sea Lion Rock, and Chocolate Chip.

The Farallon Island group and the Farallon Islands National Wildlife Refuge include a number of islets that extend several miles to the northwest including the Middle Farallon Island, North Farallon Islands, and Noonday Rock, the latter of which is completely submerged at times. These islets to the northwest are isolated, relatively small, barren, extremely difficult to access, and are not known to harbor house mice or any other invasive mammals. Thus, they would not be included in the mouse eradication action alternatives described and analyzed in this document.

3.2.2 Size and Topography

The South Farallones have a planar land area of approximately 120 acres (49 ha). The highest peak, at the top of Lighthouse Hill, is approximately 357 ft (109 m) above sea level. The topography is generally rocky and uneven, with comparatively flat terraces at the lower elevations of Southeast Farallon. The coastline is generally steep, rocky, wave-washed, and difficult to access. The south side of Southeast Farallon has an extensive marine terrace that terminates into a large intertidal zone. West End is dominated by the steep-sided, dome-shaped peak called Maintop (223 ft or 68 m), and several other smaller peaks and ridges. An extensive north-south valley, called Shell Beach, is situated on the western side.

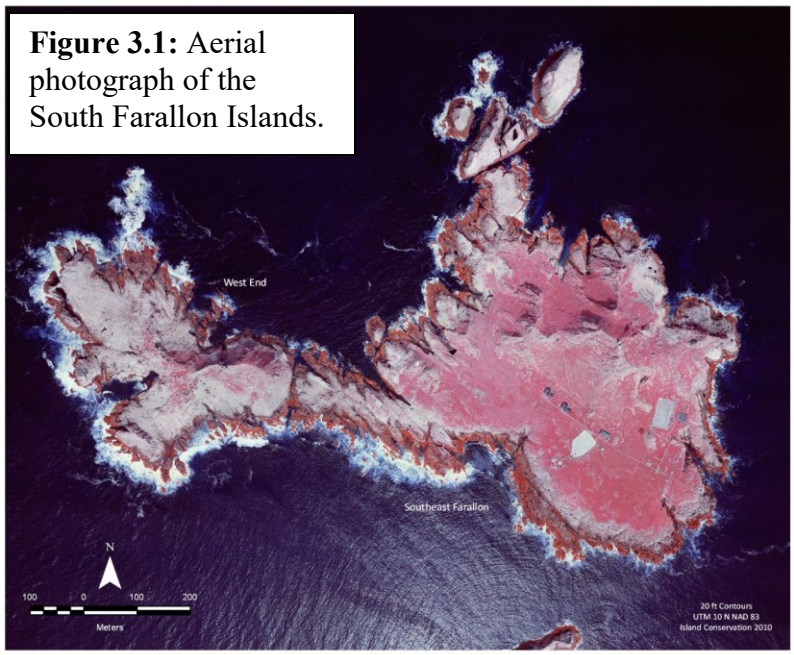


Figure 3.1: Aerial photograph of the South Farallon Islands.

3.2.3 **Climate**

The climate of the Farallones is characterized by moderate temperatures, wet winters, and dry summers. The average temperature is 56.5° F (13.6° C) with little seasonal variation. October is the warmest month (average temperature 61.0° F (16.1° C)), and January the coldest (average temperature 52.5° F (11.4° C)) (Figure 3.2; Point Blue, unpubl. data). The region's hottest days are typically during the fall when high pressure builds into the Pacific Northwest and the Great Basin, and dry offshore winds replace the Pacific sea breeze. The three hottest days on record in recent history in the City of San Francisco occurred in September and October (Null 1995). The lowest and highest temperatures recorded for Southeast Farallon Island from 1971 through 2010 were 34° F (1.1° C) in December 1990, and 90° F (27.2° C) in September 2000, respectively (Point Blue, unpubl. data).

Summertime is characterized by cool marine air with persistent coastal stratus and fog. Rainfall from May through October is relatively rare (Figure 3.2). Considerable moisture, although rarely measurable as precipitation, is due to drizzle when the marine layer deepens sufficiently. Spring and fall are transition periods. Spring and early summer are characterized by strong northwesterly winds. The occurrence of rainfall during the early spring and early fall is infrequent. While most storms during these periods produce light precipitation, there are occasional heavy rainfall events. In winter, the islands experience periods of storminess and moderate to strong winds often from the south (maximum exceeding 50 knots), as well as periods of stagnation with very light winds (Figure 3.3). Annual rainfall averages 20 inches (with a standard deviation of 7.25 in). The November through April period accounts for about 89 percent of the average annual rainfall (Figure 3.2).

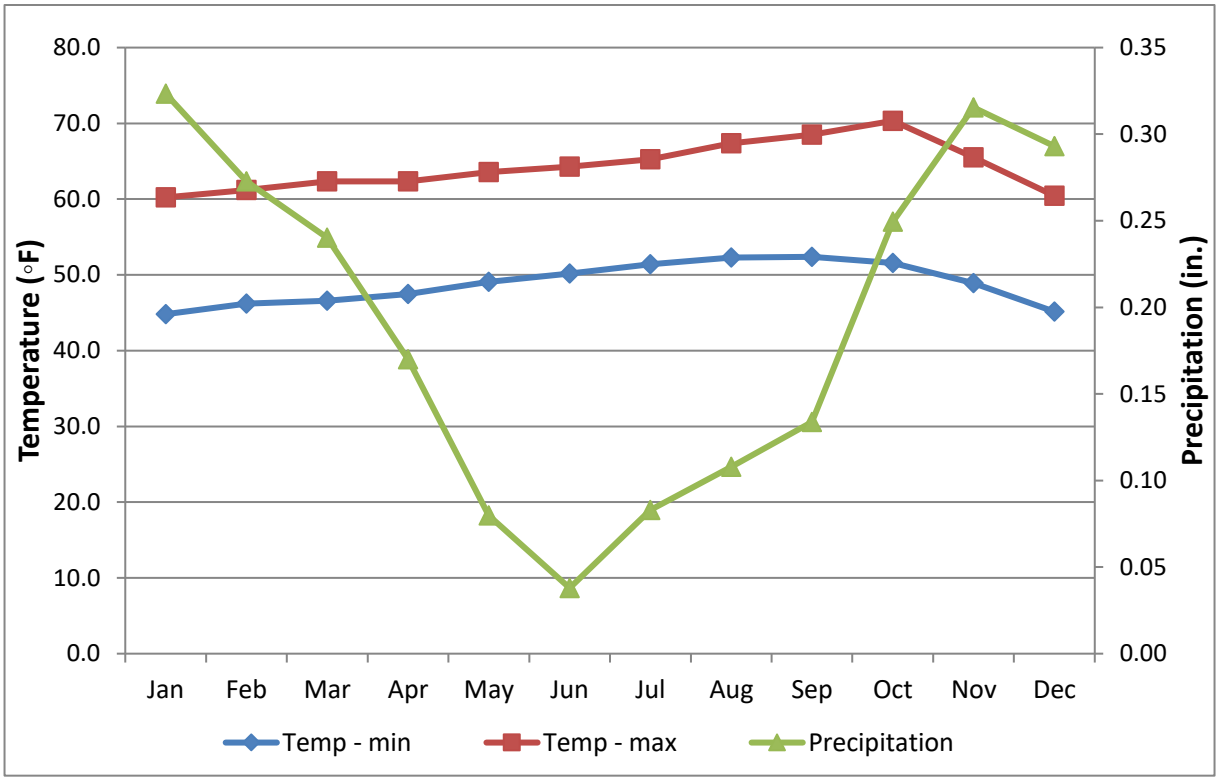


Figure 3.2: Mean air temperature and precipitation on Southeast Farallon Island, 1971–2010 (Point Blue, unpubl. data).

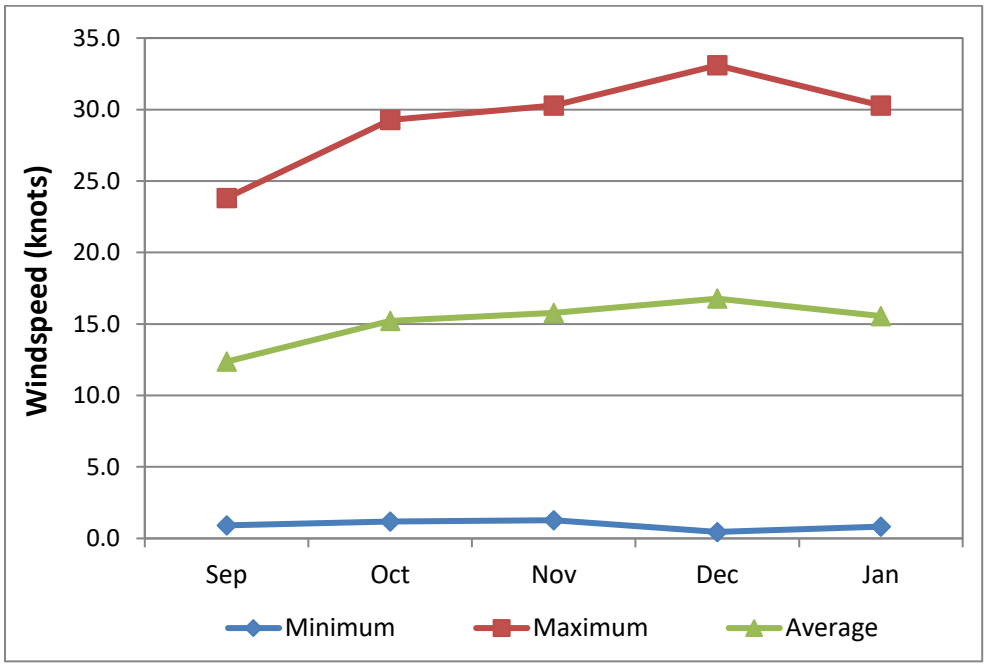


Figure 3.3: Wind speeds on Southeast Farallon Island, 2000–2010 (Point Blue, unpubl. data).

3.3 Physical Resources

3.3.1 Water Resources

Since 1998 a rainwater collection, filtration, and distribution system has supplied most of the field station's water needs. Water samples are tested quarterly for coliforms and nitrates.

In the mid-1970s, waters surrounding the South Farallones were designated by the State of California as an Area of Special Biological Significance (ASBS). This includes the waters within one nautical mile of the South Farallon Islands, Middle Farallon, the North Farallones, and Noonday Rock (State Water Resources Control Board 2003). California regulations prohibit any waste discharge into ASBSs. As a result, a septic system was installed in 2005 on Southeast Farallon to treat all wastewater generated by the field station and disperse it into a leach field located a sufficient distance away from the ocean to avoid pollution of the surrounding waters, as well as to ensure compliance with California marine water quality regulations.

Marine water quality within the surrounding Greater Farallones (formerly Gulf of the Farallones) National Marine Sanctuary (GFNMS) is considered generally good, largely due to the rugged nature of the coastline and the strong currents of the open ocean (Figure 3.4) (NOAA 2008). However, due to the close proximity of the eight million people living in the San Francisco Bay Area and associated threats from urban drainage and harbor waste, the GFNMS is periodically impacted depending on coastal currents (California Coastkeeper Alliance 2011). The Sanctuary is threatened by nonpoint source pollution, which results from multiple sources including runoff, agriculture wastes from the Central Valley, residual sediments and metals from historical mining, aging and undersized septic systems, marinas, boating activities, and more. The City of San Francisco discharges treated wastewater into the bay, which may potentially transport pollution including sewage outfalls, sewage overflows, and emerging pollutants (e.g., endocrine disrupters) (NOAA 2008).

The GFNMS is continually at risk from oil spills due to its proximity to heavy shipping traffic. An estimated 3,000 to 4,000 large vessels transit the Gulf annually, using three separate navigation/traffic lanes maintained by the U.S. Coast Guard (USFWS 2009). The most recent large-scale spill occurred in November of 2007, when the container ship *Cosco Busan* struck into the Bay Bridge and spilled approximately 54,000 gallons of bunker fuel and oil into the bay; the spill killed thousands of birds and left forty miles of beaches and shore contaminated (Swanson 2008). In the event of an oil spill further offshore, the impact to the open coast and the Farallones would mainly be determined by winds, currents, and sea conditions, which could easily overcome protection efforts. Discharges from sunken vessels and illegal discharges from oil tankers and cargo vessels, such as the S.S. *Jacob Luckenbach*, have been a periodic source of negative impacts to marine organisms within the sanctuary. Also, persistent organic pollutants such as DDT and PCBs were widely used nationwide before the mid-1970s; residuals of these chemicals still remain in sediments and organisms within the Sanctuary. Elevated levels of pollutants have been reported for fish, seabirds, and marine mammals found within the Sanctuary (NOAA 2008) and in Farallon Islands' seabirds and marine mammals (Jarman et al. 1996).

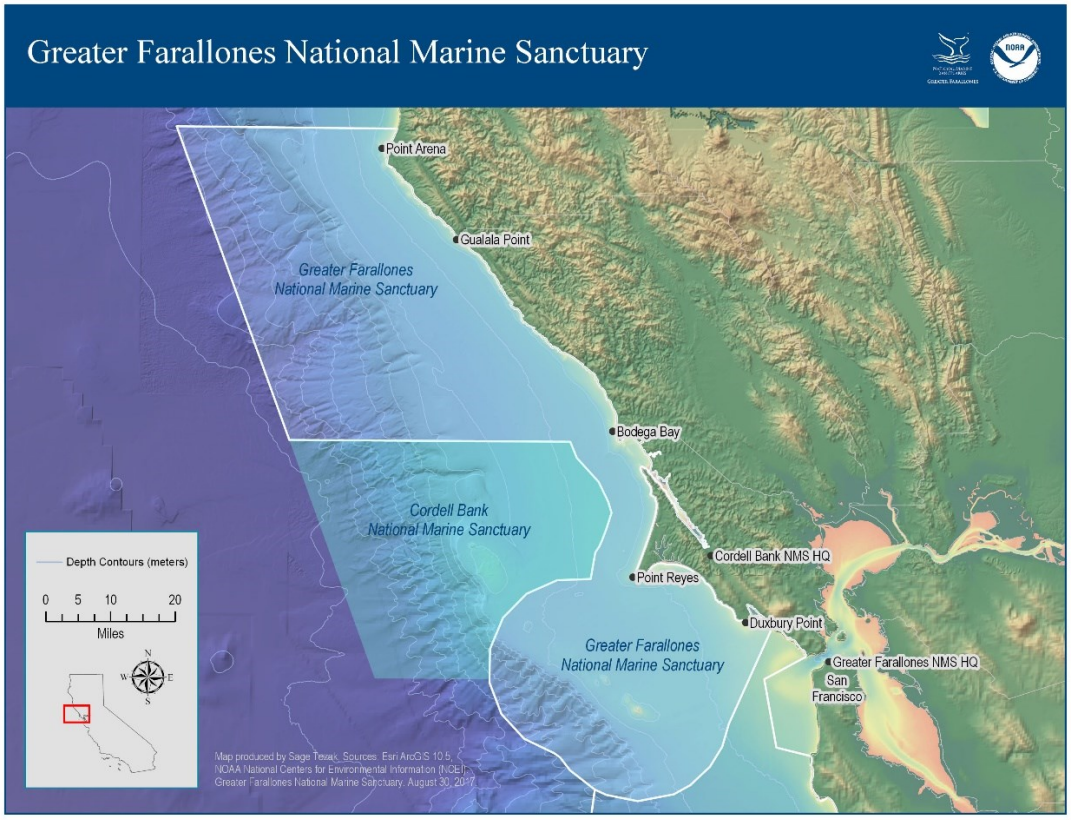


Figure 3.4: Map of the Greater Farallones National Marine Sanctuary.

The GFNMS is also at risk from potential radioactive waste contamination that was dumped into and around the gulf for nearly 25 years. Between 1946 and 1970, nearly 50,000 drums of hazardous and radioactive waste were dumped over a 350 square nautical mile area overlapping the boundaries of the GFNMS (Karl 2001). This area of the sea floor is commonly referred to as the Farallon Islands Radioactive Waste Dump (FIRWD). Unfortunately, the precise locations of these drums are unknown, and only 15 percent of the potentially contaminated area has been mapped (Jones et al. 2001a).

Some studies have investigated radioactive contamination in the FIRWD area. In 1991 and 1992 NOAA conducted two research expeditions to sample sablefish tissues within and outside of the radioactive waste dumpsite. NOAA did not find elevated radioactivity levels in any of the fish tissues within the radioactive waste dumpsite (Lindsay 1992). In 1998, the U.S. Geological Survey (USGS) and the British Geological Survey (BGS) conducted a radioactivity survey of parts of the FIRWD. Analysis from seabed sediment samples and gamma-ray spectrometry both indicate slight leakage of the drums causing very low levels of localized increase in artificial radionuclides. These data do not suggest any significant elevation in regional radionuclide levels. However, only 10 percent of the FIRWD was sampled, and the deeper sections that are believed to contain the highest densities of drums are virtually unstudied (Jones et al. 2001b).

Suchanek et al. (1996) analyzed radionuclide concentrations in deep-sea bottom feeding fishes (Dover sole *Microstomus pacificus*, sablefish *Anoplopoma fimbria*, and thornyheads

Sebastolobus spp.) and intertidal mussels (*Mytilus californianus*) collected around the FIRWD and another reference site in California. No significant differences were found between locations for the various radionuclide concentrations analyzed. However, findings from both sites reported concentrations of some radionuclides notably higher than those reported at other sites worldwide, including potentially contaminated sites (Suchanek et al. 1996).

In 2002, USGS reported measurements of radioactivity of the seafloor and sediments within the radioactivity waste dumpsite and near barrel mounds showed only very low levels of artificial radionuclides (such as Cesium-137). Thus, leakage from the barrels containing radioactive waste does appear to have occurred but this has only caused localized increase in radionuclides on the seafloor (Jones et al. 2001a).

3.3.2 **Geology and Soils**

The Farallon Islands are remnants from ancient marine terraces composed primarily of granitic rock. During the last ice age, the coastline of California extended beyond the Farallones, and the islands were part of a coastal range of hills that is now almost entirely submerged. The Refuge is primarily made up of rocky surfaces with little soil coverage. However, much of the marine terrace and certain other portions of Southeast Farallon Island are covered with dark brown soil up to eight inches thick (Vennum et al. 1994). Upon examination the soil on the Farallones indicates that its composition is largely made up of decomposing guano (i.e., urine and excrement) and granitic sand with lesser amounts of feathers, bone fragments, vegetation, possible fish teeth, and human-made detritus (Vennum et al. 1994).

Seabirds play a vital role in nutrient depositing on island ecosystems and directly impact soil composition. Guano deposition by colony nesting seabirds predominantly determines the nutrient profile of island soils (Bancroft et al. 2005). As birds forage on marine resources and transport these resources to land, soil fertility is frequently enhanced (Polis and Hurd 1996, Mulder and Keall 2001). Anderson and Polis (1999) found that seabird guano directly increases nitrogen and phosphorous concentrations up to 6-fold in soils on islands in the Gulf of California, and these nutrients directly enrich plants. Seabirds produce large amounts of guano due to their high rates of consumption and metabolic activity. For example, in colonies of less than 240,000 seabirds, a minimum of 777 metric tons of guano was produced each year (Ainley 1980). Based on these estimates, the approximate 200,000 to 300,000 seabirds nesting on the Farallones would deposit at least 777 metric tons of guano annually.

3.3.3 **Wilderness Character**

Within the Farallon Islands NWR, all emergent land areas except for the island of Southeast Farallon is designated as Wilderness under the Wilderness Act of 1964 (PL 88-577). Under the Wilderness Act, an area's Wilderness Character is defined by the following qualities:

- Untrammeled by human impacts;
- Undeveloped, without permanent structures or habitations;
- Influenced primarily by natural forces; and
- Have outstanding opportunities for solitude or a primitive and unconfined type of recreation.

The overall goal of wilderness management under the Wilderness Act is to keep lands as wild and natural as possible, including restoring the wilderness character where it has been severely damaged by human use or influence. A major component of wilderness character is that it be untrammeled by human activities and that all necessary wilderness management work be conducted with the "minimum tool" required for the job. The "minimum tool" has the least discernible impact on the land and is the least manipulative or restrictive in achieving a management objective. Under this principle, the use of vehicles, motorized tools, and other mechanized devices are generally prohibited, but in some instances the use of mechanized tools or equipment are necessary to effectively manage designated wilderness areas (PL 88-577, section 4(c)). The Wilderness Act and other related agency-specific guidance provides a general framework for determining the minimum tool necessary to complete a restoration action in a wilderness area.

3.4 Biological Resources

3.4.1 Introduction

The islands of the Farallon Islands National Wildlife Refuge host the largest seabird breeding colony in the contiguous United States. About 25% of California's breeding marine birds, with about 350,000 individuals of 13 species, can be found there. About 50% of the world's population of the rare ashy storm-petrel (listed as a Bird of Conservation Concern by the Service and Endangered by the International Union for Conservation of Nature) breeds on the Refuge. Furthermore, the islands are an important haul-out and breeding site for five species of pinnipeds (seals and sea lions), as well as provide a unique feeding location for white sharks (*Carcharodon carcharias*). The islands host unique populations of other plants and animals, in addition to providing a stopover site for hundreds of species of migrant birds, bats, and insects.

All of the alternatives described and analyzed in this document including the No Action alternative, have the potential to affect the biological resources of the South Farallones. The No Action alternative would allow the continuation of the direct and indirect impacts that invasive house mice are currently having on the native species of the South Farallones (See Section 4.5.3 for a summary of impacts from the No Action Alternative). The proposed action alternatives would have three basic types of impacts to biological resources: impacts from the use of a rodenticide; impacts from the disturbance caused by activities, personnel, and equipment necessary for the application of bait and minimization of non-target species risk; and the anticipated beneficial responses to species and the islands' ecosystem as a consequence of the removal of house mice (See Section 4.5 for a summary of impacts from the three alternatives). This section describes the status, trend, and biology of the animals and plants on and around the South Farallon Islands in an effort to better understand and analyze the potential for each alternative to affect the biological resources.

3.4.2 Birds on the South Farallon Islands

Point Blue has conducted standardized daily monitoring of migrant birds on Southeast Farallon Island since 1968. Over 421 avian species have been recorded on the island, which arrive while

migrating or traveling through the area (DeSante and Ainley 1980; Pyle and Henderson 1991; Richardson et al. 2003; Point Blue unpubl. data). The South Farallon Islands support the largest seabird breeding colony in the continental U.S. south of Alaska, with about 350,000 nesting marine birds of 13 species including: ashy storm-petrel, Leach's storm-petrel, double-crested cormorant (*Phalacrocorax auritus*), Brandt's cormorant, pelagic cormorant (*P. pelagicus*), western gull, California gull, common murre, pigeon guillemot (*Cepphus columba*), tufted puffin (*Fratercula cirrhata*), rhinoceros auklet, and Cassin's auklet. Only one species of shorebird breeds on the islands, the black oystercatcher (Ainley and Boekelheide 1990; McChesney et al. 2013; Warzybok et al. 2016, 2018). In addition, in the early 2010s three new or previously extirpated species began breeding on the islands including common raven (*Corvus corax*), peregrine falcon, and Canada goose (*Branta canadensis*) (Warzybok and Bradley 2011). As of 2018, several pairs of Canada geese have continued breeding, but ravens and falcons no longer breed (Point Blue, unpubl. data).

Substantial numbers of migrant birds visit the Farallon Islands annually. An annual average of ten species and 500 total individuals of seabirds, shorebirds, and waterbirds are recorded at any one time on or just offshore of the islands. The most common species include sooty shearwater (*Puffinus griseus*), brown pelican (*Pelecanus occidentalis*), red phalarope (*Phalaropus fulicarius*), red-necked phalarope (*P. lobatus*), Pacific loon (*Gavia pacifica*), Buller's shearwater (*Puffinus bulleri*), Bonaparte's gull (*Chroicocephalus philadelphia*), black-legged kittiwake (*Rissa tridactyla*), Heermann's gull (*Larus heermanni*), and glaucous-winged gull (*L. glaucescens*). Additionally, an average of nine species and 125 individual landbirds are recorded daily with the most common species including: European starling (*Sturnus vulgaris*), white-crowned sparrow (*Zonotrichia leucophrys*), golden-crowned sparrow (*Z. atricapilla*), yellow-rumped warbler (*Setophaga coronata*), savannah sparrow (*Passerculus sandwichensis*), dark-eyed junco (*Junco hyemalis*), ruby-crowned kinglet (*Regulus calendula*), Wilson's warbler (*Cardellina pusilla*), and American pipit (*Anthus rubescens*) (Richardson et al. 2003).

Appendix H contains a full list of the bird species that have been observed on the Farallon Islands, while Appendix I illustrates the common western gull roosting areas.

3.4.2.1 ***Seabirds***

Breeding seabirds and waterfowl

Breeding population estimates for all 13 species of marine birds (12 seabird species and one species of shorebird) on the South Farallon Islands are provided in Table 3.1. Most habitat types on the Farallones are occupied almost continually by breeding seabirds between late March and mid-August. In certain years, a few species continue raising young through September, while the last ashy storm-petrel chicks do not fledge until November. Cormorants and common murres inhabit rocky slopes and cliffs. Western gulls nest in all habitat types but are most common on the flatter or more gently sloped portions of the islands. Below the surface, rock crevices and burrows house nesting storm-petrels, auklets, guillemots, and puffins.

The South Farallon Islands are the breeding site for about half of the world's population of the ashy storm-petrel, which only breed along the coast of California and northern Baja California,

Mexico. The Refuge also hosts the world's largest colonies of Brandt's cormorant and western gull, as well as one of the southernmost colonies of rhinoceros auklet and tufted puffin. Common murres nest in extremely dense colonies and are the most abundant breeding species on the Farallones; the Farallon colony is the largest in the eastern Pacific south of Alaska (Ainley et al. 2002). California gulls recently colonized SEFI in 2008, but only fledged their first chicks in 2013. By 2017, few were nesting with no young produced (Warzybok et al. 2018)

Many of the seabird species that nest on the Farallones are extremely sensitive to disturbance. They frighten and take flight readily, and in the process may knock their eggs from their precarious perches or leave them exposed to depredation by avian predators. For example, western gulls prey upon unattended gull and murre eggs and chicks, especially when human activities are close to breeding colonies and flush adults off the nest (Ainley and Boekelheide, 1990, USFWS 2009). Some seabirds abandon their nest sites for the season if they are disturbed. Disturbance is a comparatively smaller concern during the non-breeding season but still can disrupt needed resting periods and pre-breeding attendance of nesting areas by breeding populations.

All of the seabirds on the South Farallones can generally be characterized as long-lived and slow-reproducing. All but one species (Cassin's auklet) raise only one brood annually and most of the alcid species lay only a single egg in each clutch. Because they often cannot reproduce rapidly enough to quickly counteract negative impacts to their populations, seabirds are especially vulnerable to factors that reduce the survival of breeding adult birds. Small decreases in adult survival can result in population level declines and hamper population recovery. As a result, factors that increase mortality in adults can seriously jeopardize seabird populations, especially if population levels are already low (USFWS 2005b).

Many factors affect each of the seabird species that are present on and around the South Farallones both at the island and elsewhere in their ranges. The Service's 2005 Seabird Conservation Plan for the Pacific Region (USFWS 2005b) describes current threats, management goals and detailed information for seabirds. The most serious human-caused threats to seabirds in the region include: 1) invasive species; 2) interactions with fisheries (both direct and indirect); 3) oil and other pollution; 4) habitat loss and degradation; 5) disturbance; and 6) global climate change. In addition, all of the species that forage in the waters surrounding the South Farallones are affected by changes in the productivity of the marine ecosystem, which occurs over different spatial and temporal scales. There is a strong link between local marine productivity and breeding success of the seabird populations nesting on the Farallon Islands (Ainley and Boekelheide 1990).

The foraging ecology of the various Farallon breeding seabird species varies considerably. Pelagic cormorants and pigeon guillemots mainly forage on small benthic fish and invertebrates in waters near the islands. Brandt's cormorants and common murres prey mainly on small schooling fish such as juvenile rockfish and anchovies, squid or krill obtained from waters of the continental shelf and slope. Western gulls are opportunistic, feeding on small fish, squid, krill, intertidal invertebrates, eggs, young and adult birds (including Cassin's auklets, and ashy storm-petrels), fishing discards and other human refuse. Rhinoceros auklets and tufted puffins mainly forage over continental slope waters offshore of the islands, where they feed on a variety of

small fish and squid. Cassin's auklets mainly feed over waters of the outer continental shelf and continental slope, feeding mainly on krill and occasionally on small fish (Ainley et al. 1990a, Warzybok and Bradley 2012).

Canada geese began breeding on the island in 2010 and have nested in small numbers (less than 10 breeding pairs) each year since then.

Table 3.1: Marine bird breeding population estimates (numbers of breeding birds) on the South Farallon Islands. Estimates are 2007-2016 averages from Warzybok et al. (2018) except where otherwise noted. X indicates present in low numbers but no recent estimate.

Species	No. Breeding Birds	Species	No. Breeding Birds
Leach's Storm-Petrel	X	Western Gull	16,426
Ashy Storm-Petrel	5,768[1]	Common Murre	286,000[2]
Double-crested Cormorant	275	Pigeon Guillemot	3,243
Brandt's Cormorant	6,492	Cassin's Auklet	19,729[3]
Pelagic Cormorant	276	Rhinoceros Auklet	3,924[4]
Black Oystercatcher	39	Tufted Puffin	238
California Gull	294		

[1] Estimate based on 2010-2012 capture-recapture analyses, with 95 percent confidence interval of 3,790 to 8,778 breeding birds (Nur et al. 2013a, Appendix M).
[2] P. Capitolo (U.C. Santa Cruz) and G. McChesney (USFWS), unpubl. data.
[3] Does not include West End Island, where 2,243 breeding birds were estimated in 2009.
[4] Estimate based on 2006-2015 average (Warzybok et al. 2016). Does not include West End Island.

Non-breeding seabirds and waterfowl

The productive waters surrounding the Farallones provide foraging grounds for a number of additional seabird species such as loons, grebes, shearwaters, pelicans, scoters, phalaropes, and several species of gulls. Most remain in the water or in flight offshore of the islands; however, several species of non-breeding gulls and brown pelicans use the island for roosting. Numerous species of seabirds visit the Farallon Islands during the course of a year, primarily during the spring and fall migratory seasons. Seabird species that averaged at least 10 recorded arrivals per year during the 1968-1999 monitoring period included: Pacific loon, common loon (*G. immer*), eared grebe (*Podiceps nigricollis*), western grebe (*Aechmophorus occidentalis*), western/Clark's grebe (*A. occidentalis/clarkia*), northern fulmar (*Fulmarus glacialis*), pink-footed shearwater (*Puffinus creatopus*), Buller's shearwater, sooty shearwater, short-tailed shearwater (*P. tenuirostris*), black-vented shearwater (*P. opisthomelas*), fork-tailed storm-petrel (*Oceanodroma furcate*), brown pelican, brant (*Branata bernicla*), northern pintail (*Anas acuta*), green-winged teal (*A. crecca*), surf scoter (*Melanitta perspicillata*), white-winged scoter (*M. fusca*), and red-breasted merganser (*Mergus serrator*) (Richardson et al. 2003). Many more seabird and waterfowl species including other loons, grebes, albatrosses, gulls, shearwaters, petrels, ducks, and geese visit the islands or adjacent waters, and some occasionally overwinter. The community makeup of this group of species varies substantially, both seasonally and inter-annually.

3.4.2.2 *Shorebirds*

The South Farallon Islands support a number of shorebird species such as plovers, turnstones, whimbrels (*Numenius phaeopus*), and willets (*Tringa semipalmata*). Black oystercatcher (year-round) and black turnstone (*Arenaria melanocephala*) are the most common shorebirds along the rocky shoreline. Black turnstones are most abundant during fall and winter and small numbers of willet, ruddy turnstone (*Arenaria interpres*), surfbird (*Aphriza virgata*), and wandering tattler (*Tringa incana*) or other species may also be present during winter (Richardson et al. 2003). Most of the island's shorebirds occur along the shoreline where they forage in the intertidal zone on intertidal invertebrates. However, some species forage on the marine terrace, presumably on terrestrial invertebrates.

The only shorebird species that breeds on the Farallon Islands is the resident black oystercatcher. However, numerous non-breeding shorebirds visit the islands, and species that average at least 10 recorded arrivals per year during the 1968-1999 monitoring period include: black-bellied plover (*Pluvialis squatarola*), killdeer (*Charadrius vociferous*), willet, wandering tattler, whimbrel, marbled godwit (*Limosa fedoa*), ruddy turnstone, black turnstone, western sandpiper (*Calidris mauri*), least sandpiper (*C. minutilla*), pectoral sandpiper (*C. melanotos*), short-billed dowitcher (*Limnodromus griseus*), long-billed dowitcher (*L. scolopaceus*), red-necked phalarope, and red phalarope (Richardson et al. 2003). Researchers on Southeast Farallon have recorded a daily average of around 60 shorebird individuals on the islands between mid-November and mid-December (Point Blue unpubl. data)

3.4.2.3 *Raptors*

Researchers have observed an average of four to six individual peregrines on the islands during the winter from 1990-1999 and numerous other migrants (DeSante and Ainley 1980, Pyle and Henderson 1991, Earnheart-Gold and Pyle 2001), a number that increased during the 2000s (Tietz 2013a). A high count of ten individuals was observed on one day in November 2011 (Tietz 2013a). Peregrines feed on a variety of bird species at the Farallones including seabirds, shorebirds and landbirds that are captured either over the island or offshore (USFWS 2009). Several other non-breeding raptors visit the islands during the migratory season including various species of hawks, kites, eagles, falcons, and owls. Of the visiting migrants only a few species averaged at least 10 recorded arrivals per year in 1968-1999 including: burrowing owls, sharp-shinned hawk (*Accipiter striatus*) and American kestrel (*Falco sparverius*) (Richardson et al. 2003).

3.4.2.4 *Other Landbirds*

The South Farallon Islands are well known for the number and diversity of passerines and other landbirds that arrive on the islands during spring and fall migrations (DeSante and Ainley 1980, DeSante 1983, Pyle and Henderson 1991). For example, on average several hundred white-crowned sparrows, golden-crowned sparrows, and savannah sparrows visit the island annually (Pyle and Henderson 1991). More than 421 species of migrating birds have been recorded on the Farallon Islands (Richardson et al. 2003, Point Blue unpubl. data). DeSante and Ainley (1980) concluded that the vast majority of these arrivals are birds that are in the process of returning to

the mainland after veering off their migratory course along California's coast. During the spring and fall, large numbers of migrant landbirds may be present on the island, often concentrated in and around the small trees that were planted near the residences on Southeast Farallon. Nearly all migrating landbirds spend little time on the islands before departing, but up to 30 species may remain throughout the winter. Small numbers of Canada geese began breeding on the island in 2010. Additionally, there are occasional historical nesting records for a few other species, mainly rock wrens (*Salpinctes obsoletus*) (DeSante and Ainley 1980).

3.4.2.5 *Avian Seasonal patterns of the South Farallon Islands*

Seabirds:

3.4.2.5.1 Breeding Seabirds and Waterfowl

Seabirds that breed on the Farallones also visit the islands during other parts of the year. Western gulls are nearly year-round residents and reach peak numbers prior to the start of the breeding season in March. Many adults leave the island at the end of the breeding season in late July or August and most juveniles also leave by mid-September (Pierotti and Annett 1995). However, birds begin returning to the Farallones by early fall to sporadically reoccupy territories with increasing numbers arriving each day until they peak again in March (Penniman et al. 1990). Common murres begin breeding by early May and chicks fledge at only about 3-4 weeks old in July and August; chicks depart with their fathers who continue to raise them at sea (Ainley et al. 2002). It is suspected that most of the breeding population likely remains within a one to two-day flight of the islands during the non-breeding season, and murres begin to return for periodic non-breeding season visits in late October or early November (Boekelheide et al. 1990b). Pigeon guillemots begin arriving to the Farallones by March, breeding begins in May, individuals depart from the island soon after chicks fledge, and colonies are vacated by early September (Ainley et al. 1990c, Ewins 1993).

Cassin's auklet is another common seabird present on the Farallones. Individuals visit their burrows on the island year-round. Depending on the timing of egg laying, Cassin's auklets generally visit their burrows daily between January and June at minimum. Visitation decreases substantially in July as chicks fledge but chick rearing can continue into September or rarely October in some years. Attendance continues to decline through December but birds still visit the island on many nights in varying numbers (Ainley et al. 1990b). The rhinoceros auklet and tufted puffin begin arriving to the island for breeding in March or April and depart by late September (Ainley et al. 1990e).

Leach's storm-petrels begin arriving at the Farallones by the end of February for breeding and depart at the end of September or mid-October. Ashy storm-petrels may be present in any month but generally begin returning to the islands in late December. Peak numbers occur in February to August. Egg laying begins in April. Numbers decline in September and October as chicks fledge, and most birds depart by mid-November (Ainley et al. 1990d).

The most abundant cormorant species found on the Farallones is the Brandt's cormorant; in most years, the Farallones host the largest breeding colony of this species in the world. Breeding birds

begin to arrive in mid- to late March, the population peaks in late May, and the majority of the colony departs by late August (Boekelheide et al. 1990b). In addition, low numbers of roosting individuals do occur on the islands throughout the year. Other cormorant species nesting on the Farallones include relatively small numbers of pelagic and double-crested cormorants. Pelagic cormorants arrive at their breeding territories from December to April, depending on the year, but numbers during the winter remain very low. The population generally peaks in May and June, and most birds depart the island by September (Boekelheide et al. 1990a). Double-crested cormorants generally arrive by April and depart the island by September.

Canada geese formerly occurred only as occasional migrants until 2010, when small numbers began nesting. Nesting birds usually arrive and begin egg-laying in March and have departed by the end of July.

3.4.2.5.2 Non-breeding Seabirds

The greatest density and diversity of visiting seabird species occurs during the fall. Pelagic seabirds that live out in the open sea occur offshore of the Farallones and primarily reach their maximum diversity during September with the exception of two species. Maximum numbers of sooty shearwater typically occur during the summer, and phalaropes are usually most abundant in August. With the exception of pelicans and gulls, none of these seabirds land on the islands but rather stay on or above the surrounding waters.

The migrant brown pelican is usually present in maximum numbers in October, often roosting on the islands (DeSante and Ainley 1980). For other species, early spring dispersers may first appear in late February but usually arrive in March. Spring migration is generally quite sporadic and unpredictable, especially during March and April. Most species are rare during that time, although large numbers of Bonaparte's gulls can be seen occasionally.

3.4.2.6 ***Shorebirds***

Shorebirds begin arriving in July and gradually increase to maximum visitation rates during fall migration in September, when the usually rare estuarine and freshwater species also occur. Small numbers of shorebirds overwinter, with most departing by early May. Black oystercatchers are the only breeding shorebird on the Farallones and are present year-round (DeSante and Ainley 1980). Breeding generally occurs from May to August when pairs are territorial. In the fall and winter, birds often occur in flocks with other shorebirds. Researchers on Southeast Farallon have recorded a daily average of around 60 shorebird individuals on the islands between mid-November and mid-December (Point Blue unpubl. data).

3.4.2.7 ***Raptors***

A limited number of raptors visit the islands during spring migration and those that do generally begin arriving in March and April. The majority of raptors visit the islands in September and October during the fall migration period. For example, mean arrival dates for migrant peregrine falcons are mid-October and range from late July to late December, varying according to

subspecies, age, and sex (Earnheart-Gold and Pyle 2001). Only a few raptor species regularly winter on the islands, including the peregrine falcon and burrowing owl.

Burrowing owls are typically the most numerous raptor species present from fall through early spring. They are not resident, but each year dispersing or migrating burrowing owls land on the South Farallones, mainly on their southbound fall migration (DeSante and Ainley 1980). Most burrowing owls arrive in September to November. Each year, up to several individuals remain to to overwinter, supported by a diet of house mice in the fall and storm-petrels in the winter and spring (Nur et al. 2013a, Chandler et al. 2016, Mills 2016). All birds generally depart the islands by early May (Point Blue, unpubl. data).

3.4.2.8 *Other Landbirds*

Migratory passerines that primarily breed in western North America typically winter either in tropical or temperate regions. Spring migration on the Refuge consists of one or occasionally two major waves of visiting passerines that usually arrive in early or late May, with smaller numbers of birds visiting at other times. Different populations are probably involved in each of these waves, but most are of species that breed in western North America and winter in the tropics. Very few western-breeding landbirds visit the Farallones after late May or very early June. Spring vagrant landbirds may first appear in mid-May but reach maximum diversity during the first half of June; these include predominantly eastern North American bird species (DeSante and Ainley 1980).

During fall migration, landbirds generally arrive at the Farallones in early August and reach maximum visitation rates in September or early October when the major arrival of landbirds wintering in coastal California occurs. The maximum diversity of landbirds usually occurs from mid-September to early October. Landbird visitants decline during late October and dwindle to very low numbers by late November.

Only a few passerine species winter on the island. The most commonly occurring include the white-crowned sparrow, golden-crowned sparrow, fox sparrow (*Passerella iliaca*), yellow-rumped warbler, western meadowlark (*Sturnella neglecta*), and black phoebe (*Sayornis nigricans*) (DeSante and Ainley 1980). Most overwintering landbirds arrive during the fall migration period, primarily October and November, and depart in March and April. Researchers on Southeast Farallon have recorded a daily average of around 30 landbird individuals on the islands between November and December (Point Blue, unpubl. data), which is within the target window for implementation of either action alternative.

3.4.2.9 *Special status bird species*

All the native birds that visit or reside on the South Farallones are protected from take by the Migratory Bird Treaty Act (MBTA). No bird species found on the South Farallones are currently listed as either threatened or endangered under the federal Endangered Species Act (ESA). Species that regularly occur at the islands that are listed by the State of California as endangered or threatened include the willow flycatcher (CDFW 2017). The ashy storm-petrel is listed as endangered by the IUCN but this provides no special legal protection (Birdlife International

2012). The American peregrine falcon (*P.f. anatum*) and California brown pelican (*Pelecanus occidentalis californicus*) formerly were both federally and state listed but have been delisted (CDFW 2017).

Several bird species that breed on or regularly visit the Farallon islands are listed as Birds of Conservation Concern by the Service, including ashy storm-petrel, peregrine falcon (*Falco peregrinus*), black oystercatcher (*Haemotopus bachman*i), short-billed dowitcher (*Limnodromus griseus*), whimbrel (*Numenius phaeopus*), burrowing owl, calliope hummingbird (*Selasporus calliope*), Allen's hummingbird (*Selasphorus sasin*), olive-sided flycatcher (*Contopus cooperi*), willow flycatcher (*Empidonax traillii*), loggerhead shrike (*Lanius ludovicianus*), sage thrasher (*Oreoscoptes montanus*), yellow warbler (*Setophaga petechia brewsteri* and *S.p. sonorana*), and Brewer's sparrow (*Spizella breweri*) (USFWS 2008). The same or others are listed as California Bird Species of Special Concern, including: ashy storm-petrel, tufted puffin, Cassin's auklet, and brant (Shuford and Gardali 2008).

Bald (*Haliaeetus leucocphalus*) and golden eagles are protected under the Bald and Golden Eagle Protection Act, and bald eagles are a Service Bird of Conservation Concern. Both species are very rare migrants at the islands. Between 1968 and 1999, only seven bald eagles were recorded; five occurred between the dates of 1 October and 22 November, while two others occurred in winter (Richardson et al. 2003). More recently, single bald eagles were observed on 12 December 2011, and 17 March and 2 September 2016 (Point Blue, unpublished data). The only golden eagle record for the islands was a single bird on 28 October 1971 (Richardson et al. 2003; Point Blue, unpublished data). Prior to implementation of an action alternative, consultation with the Service's Migratory Bird Permit Office would be done to determine if a Bald and Golden Eagle Protection Act permit is needed.

3.4.3 **Other Terrestrial Wildlife of the South Farallon Islands**

3.4.3.1 ***Salamanders***

The Farallon arboreal salamander is classified as an endemic subspecies due to the distinct spot pattern and coloration as compared with mainland forms (Van Denburgh 1905). While recent genetic analysis has established strong similarities to nearby mainland populations, it has been recommended the South Farallon Islands population should be conserved as a distinct management unit due to their isolated nature and their monophyly in the mtDNA tree (Reilly et al. 2015) . This species belongs to the *Plethodontidae* family of lungless salamanders that respire through their skin. They have relatively large teeth and powerful jaws, enlarged toe tips, and a prehensile tail adapted for climbing (Figure 3.5) (Petranka 1998, Lee 2010). They are largely subterranean, inhabiting crevices and burrows, or, during the wet season, under rocks, logs, or other cover. While they are most active when the surrounding environment is moist, they are not dependent on water for any part of their lifecycle and are more tolerant of dry conditions than most salamander species (Cohen 1952).

Figure 3.5: Farallon Arboreal Salamander

Arboreal salamanders are primarily nocturnal and forage on the ground, tree trunks or other vertical structures for small invertebrates such as spiders, beetles, isopods, larval lepidoptera, ants, sow bugs, caterpillars, and centipedes (Stebbins 1951, Holland and Goodman 1998). They are a predator of the endemic camel cricket (Steiner 1989). Many arboreal salamanders are territorial with very small home ranges (Petranka 1998, Lee et al. 2012) and aggressively defend items that provide high-quality refuge (Smith and Pough 1994).

Like most lungless salamanders, *A. lugubris* is relatively long-lived, slow to mature, and has lower fecundity (the capacity to reproduce) than most frogs and toads (Petranka 1998). The average age of maturity for the Farallon arboreal salamander is approximately three years with a relatively high rate of adult survival, which is estimated to range from 8-11 years (Lee 2010, Lee et al. 2012). They breed and lay eggs during the summer (Boekelheide 1975) with young appearing in the fall (Lee 2008). Plethodontids have no aquatic larval stage and eggs are laid in terrestrial nests; hatchlings resemble miniature adults (Wake and Hanken 1996). Arboreal salamanders on the Farallones exhibit indeterminate growth, meaning individuals continue to grow beyond the size at which they reach reproductive maturity (Lee 2010).

Until recently, only a few studies have examined the arboreal salamander on the Farallon Islands. Several short-term studies conducted on Southeast Farallon Island during the 1950s, 1960s, and 1970s estimated salamander populations from as little as 100-200 per acre (Anderson 1960) to as much as 300 per acre (120/ha) in the most habitat-rich portions of the island (Boekelheide 1975). More recent surveys on Southeast Farallon Island indicate population size appears stable and salamanders are largely sedentary (Point Blue, unpubl. data). However, the presence of significant numbers of transients animals (animals seen only once at a specific location) suggests that emigration is also an important part of salamander ecology (Lee 2010).

Studies begun in 2006 represent the first capture- recapture examination of this species on the Farallones (Lee 2010, Lee et al. 2012). Data collected in 2006-2010 modeled growth and age at maturity for the island population using snout-vent-length (SVL) growth intervals. Annual survival was found to increase from 0.363 in age zero to 0.783 in ages greater than four years, which indicates similar life-history parameters to other terrestrial salamanders from low-elevation Mediterranean climates (Lee et al. 2012). The use of stable isotope analysis is proposed to assess diet of both house mice and salamanders on Southeast Farallon Island (SEFI) to expand an understanding of the predatory and competitive impacts of mice on SEFI and help predict the response of the salamander population if mice are removed.

The fungal pathogens *Batrachochytrium dendrobatidis* (*Bd*) and *Batrachochytrium salamandrivorans* (Bsal) cause the disease chytridiomycosis. This disease has been linked to mass mortality events and population collapse in many species of frogs and salamanders globally (e.g., Lips et al. 2006, Vredenburg et al. 2010, Cheng et al. 2011), and represent the worst case of disease-caused population collapse ever recorded in vertebrates (Skerrat et al. 2007). Fortunately, recent work on the Farallon population in 2016 determined that chytrid fungus has not been found in past or recent samples from Farallon salamanders (Yap et al. 2015; Moyer and V. Vredenburg, San Francisco State University, unpubl. data)

Utilizing cover boards established in 2006 and a new more island wide cover board study instituted in 2012, Berger et al. (2017) examined environmental and physical factors affecting salamander spatial distribution and abundance on the Farallones. They used a combination of GIS and existing salamander data to characterize potential physical drivers (slope, aspect, elevation, moisture) and biological predictors (prey availability and vegetation cover) to describe the spatial distribution and abundance of salamanders across Southeast Farallon Island. Overall the model and predictor variables did significantly well at explaining the distribution and abundance of the Farallon arboreal salamander. Patchy distribution was predicted with greatest abundance occurring within micro-climates associated with low solar exposure, high moisture, high slope, and a mixture of bare soil/anthropogenic features and vegetative cover. These patterns are consistent with the physiological constraints of Plethodontid salamanders. Our results support findings of an earlier capture- recapture study and demonstrate the management application of monitoring long-term patterns of distribution and abundance.

3.4.3.2 ***Bats***

There are no breeding or resident bats on the South Farallones; however, a number of migrant bat species are known to visit and roost on the islands. The majority of visitors are hoary bats (*Lasiurus cinereus*), but others include western red bat (*L. blossevillii*), Mexican free-tailed bat (*Tadarida brasiliensis*), little brown bat (*Myotis lucifugus*), and Eurasian pipistrellus (*Pipistrellus* sp.) (Cryan and Brown 2007, USFWS 2009, Point Blue unpubl. data).

Fall surveys of hoary bats have been conducted in recent years to monitor migrant bats on Southeast Farallon with the goal of determining roosting locations, assessing numbers of bats, assessing interaction between male and female bats, and assessing the effects of weather conditions on bat arrival and departure from the island (USFWS 2009). Hoary bats were most often observed roosting in the trees and mallow plants; however, on a few occasions individual bats used additional roosts such as rock outcrops, buildings, and small caves. There is no evidence to suggest that these roosts were used on a regular basis (Cryan and Brown 2007).

Point Blue biologists have recorded the presence of hoary bats on the island since late1968, and bats have been observed on the islands almost every year that records have been kept. Migratory hoary bats occur on the Farallones generally during the fall migration period from late August through October and are most frequently found in September (USFWS 2009). Hoary bat presence on the Farallones is typically observed on about eight days per fall season, with an average of five bats observed per day when bats were present. In addition to fall records, hoary

bats were observed using the islands on seven days during late April and early May of 1990 (Cryan and Brown 2007).

Cryan and Brown (2007) found that relatively low wind speeds, low moon illumination, and relatively high degrees of cloud cover were important predictors of bat arrivals and departures, and that low barometric pressure was an additional variable that helped predict arrivals. Slight differences in the conditions under which bats arrived and departed from the island suggest that hoary bats may be more likely to arrive on the island with passing storm fronts (Cryan and Brown 2007).

3.4.3.3 *Terrestrial Invertebrates*

Many of the insects on the South Farallones are detritivores (species that primarily consume dead plants or animals) and are most commonly associated with the consumption of seabird carcasses (Schmieder 1992). This is not surprising given the inevitably high number of carcasses found within seabird colonies. Globally, insects play a major role in processing detritus. The role of invertebrates in the decomposition of carcasses on the Farallones is particularly critical given the scarcity of larger detritivores on the islands relative to ecosystems on the mainland.

Few studies of the resident terrestrial invertebrates were conducted on the Farallones in the 20th century. A unique island form of the flightless intertidal beetle (*Endeodes collaris)* was described by Giuliani (1982). From 2013-2014, and insect survey of Southeast Farallon Island was conducted in order to catalog current insect and spider species on the island and to gather information that will be used to examine prey dynamics to aid in the conservation of the endemic salamander *Aneides lugubris*. Results are summarized in Honda et al. (2017), and document 11 insect orders representing 60 families, 107 genera and 112 insect species on Southeast Farallon Island. Holometabolous orders were the most represented on the island with Coleoptera (beetles) and Diptera (flies) being the most abundant, followed by Lepidoptera (moths and butterflies) and Hymenoptera (sawflies, wasps, bees, and ants). One spider order was identified, representing six genera and six species.

The most well-described invertebrate on the island is the endemic Farallon camel cricket, which is found largely in caves around the island (Steiner 1989). Standardized surveys for camel crickets were initiated in 2012 to obtain baseline data before any potential mouse eradication. Quarterly comprehensive surveys of major cave sites have revealed that crickets reach their annual peak in the fall, where there are high numbers of juveniles, and decline throughout the winter and spring to reach their lowest abundance mid-summer (Point Blue, unpublished data). One large cave on Shubrick Point, called Cricket Cave, has been determined at peak fall abundance to have ~10x the abundance of the next most numerous site, and likely supports a major component of the population of this species (Point Blue, unpublished data). It is expected that the removal of house mice would result in increases in invertebrate populations.
Possibly the most abundant terrestrial invertebrate on the Farallones is the cormorant fly (*Fucellia thinobia*). Corm flies are active during the day and are primarily detritivores, including feeding on animal carcasses and bird guano. They form large roosts on vertical structures such as cliffs and cement walls, usually along the shoreline. They provide forage for a variety of migrant, insectivorous bird species.

Island invertebrates play an important ecological role as prey items for the native arboreal salamander (Stebbins 1951, Holland and Goodman 1998) and migrant bat species on the Farallon Islands (Anthony and Kunz 1977, Rolseth et al. 1994, Whitaker et al. 1996, Valdez and Cryan 2009). Additionally, many migratory landbird species consume invertebrates throughout the migratory season and rely on their high protein content to refuel at migratory stopover sites such as the Farallon Islands. Chandler et al. (2016) conducted diet studies on Farallon Burrowing Owls and determined that while insects represented the most numerous prey item for birds on the Farallones, the biomass that insect prey contributed to Burrowing Owl diet was only ~1.5%.

3.4.3.4 *Introduced birds and mammals*

When the Service incorporated the South Farallon Islands into the Refuge in 1969, there were invasive rabbits, feral cats, and house mice present on the islands (Ainley and Lewis 1974, Ainley and Boekelheide 1990). Rabbits were introduced sometime between 1856 and 1874 (Cameron 1966). Although it is not clear exactly when mice were first introduced to the South Farallones, anecdotal evidence suggests that they arrived early in the sequence of human activities, which began in the early 19th century. American and Russian sealers, egg collectors, the U.S. Lighthouse Service, the U.S. Navy, and the U.S. Coast Guard all inhabited Southeast Farallon before the Service assumed management. Any of these previous occupants could have accidently introduced house mice to the islands. The introduction of house mice could also have been a result of one of several shipwrecks that have occurred off the islands. Shortly after the Service assumed management of the South Farallones, a program was implemented to remove rabbits and cats, which concluded successfully in 1975, leaving house mice as the only resident invasive vertebrate remaining on the Farallones.

House mice are small rodents, around 0.5-0.7 oz (15-20 g) in mass. They are prolific breeders, with females commonly producing six to eight litters a year, each with four to seven young, which mature within three weeks and are reproductively active soon after (Witmer and Jojola 2006). Mice typically reside in burrows or crevices and individuals rarely travel outside of a 49-66 ft^2 area (15-20 m^2) surrounding their burrow, although occasional forays of longer distances do occur (Triggs 1991, Ruscoe 2001). House mice are omnivorous opportunistic feeders, and mice on the Farallones eat both vegetation and invertebrates year-round and have been found with eggshell fragments and seabird feathers in their stomachs during the seabird breeding season (Jones and Golightly 2006). The population of invasive house mice on the South Farallones is highly cyclical, growing steadily and rapidly throughout the summer with a peak in October, reaching some of the highest densities ever recorded, followed by a crash throughout the winter as food resources decline to an annual low in April (Irwin 2006, Jones and Golightly 2006).

While mice are the only remaining invasive mammalian residents on the South Farallones, birds that have been introduced to North America such as the European starling, house sparrow (*Passer domesticus*), Eurasian collared-dove (*Streptopelia decaocto*), and rock pigeon (*Columba livia*) may be present during migration and winter. Starling and house sparrow have also bred on the South Farallones in the past (DeSante and Ainley 1980) but have not been recorded breeding in the past decade (Point Blue, unpubl. data). Eurasian collared-doves, which are a recent

invader, first bred on Southeast Farallon in 2017 (Point Blue, unpubl. data). Because of their infrequent attendance and relatively low numbers on the Farallones, these introduced birds are not currently considered to be a major threat to the ecosystem of the Farallon Islands.

3.4.4 Intertidal and Nearshore Ecosystems

3.4.4.1 *Intertidal Invertebrates and algae*

The first survey of the intertidal algae and invertebrates of the Farallon Islands was by Blankinship and Keeler (1892), and the next survey was 87 years later, conducted by the California State Water Resources Control Board as a reconnaissance survey for the area as an Area of Special Biological Significance (California State Water Resources Control Board 1979). The results from both investigations were general in describing the island's geology and biota. Other investigations on the islands focused on the distribution of Foraminifera (Grivetti 1962) and systematics of Porifera (Klontz 1989). More extensive surveys and monitoring of the South Farallones intertidal community have been conducted since 1993 as part of the Sanctuary Ecosystem Assessment Surveys (SEAS), a Greater Farallones National Marine Sanctuary (GFNMS) program to monitor rocky intertidal algal (seaweed) and invertebrate species abundances at the South Farallon Islands. Quantitative non-destructive sampling methods are used to track the species abundances in six study areas on wave-exposed rocky shores that typify the area. These are Blowhole Peninsula, Mussel Flat, Low Arch, Raven's Cliff, Drunk Uncle's Islet, and Dead Sea Lion Flat. Results of monitoring up until 2011 have been summarized in Tenera Environmental and GFNMS (2012) and Roletto et al. (2014) and are considered to provide a reliable baseline of species abundance and trends upon which potential impacts of action alternatives can be measured against. The following summarizes information contained in those reports.

Over 190 algal species/taxa, at least one seagrass, over 230 invertebrate, and 10 intertidal fish species/taxa on the islands have been documented in the program. The list is from the sampling, shore walk observations, and collections since 1993. The top 10 species/taxa averaged across all six of the study areas comprised more than 90 percent of the total upright algal cover, but abundances were variable for most species across the study areas (Appendix J). The articulated coralline algal species *Corallina vancouveriensis* was an exception and was abundant (more than 20 percent mean cover) in all six study areas. The *Mazzaella* flaccida-complex, a foliose red algal assemblage, was abundant overall but was sparse at study sites at Mussel Flats. This complex consists of several species of *Mazzaella* with *M. flaccida* being the most abundant. The green sea lettuce alga *Ulva* spp., the branched turf alga *Gelidium* spp., and red bladed *Mastocarpus papillatus*, were common but variable in abundance across the six study areas (generally less than 20 percent mean cover in each area).

A major change over time has been an overall decline in total upright (non-crustose) species abundance from 1993 through 2011. For example, total upright algal abundance at Low Arch has declined from nearly 240 percent mean cover (combined layering coverage of all upright species) down to approximately 140 percent mean cover. This decline has been partially offset by increases in crustose algal cover, which was greatest at Dead Sea Lion Flat where the combined coverage of crustose species increased from less than 10 percent mean cover to over

50 percent mean cover from 1993 to 2011. This decline in total upright algal cover has been apparent with a corresponding increase in uncolonized substrate cover in all areas (primarily bare rock, but also sand).

Mussels (primarily *Mytilus californianus*) have also declined in overall abundance. For example, at Blowhole Peninsula mussel cover has declined from approximately 75 percent cover down to approximately 45 percent cover, and at Low Arch mussel cover has declined to near absence. Even with the declines in species abundances, abundances have still remained relatively high but less than the levels in 1993 and species richness (number of species) has remained relatively unchanged across study areas.

The cause for the long-term decline in algal and mussel abundance and increased uncolonized substrate cover remains unknown, as numerous factors can account for such shifts. Variations in water temperature and biological factors, such as spore and larval supplies, grazing, predation, and competition for space can all affect the composition, abundance, and distribution of species over various spatial and temporal scales. The changes have also been coincident with increasing numbers of pinnipeds hauling out onto the shore. As such, the changes may be the result of elevated trampling effects from pinnipeds. Declines also coincide with recent increases in total seabird numbers on the islands. Accordingly, the declines could also be attributed to increased nutrient and uric acid loading from seabird (and pinniped) wastes. Compounding effects from changes in sea surface temperature, upwelling, and changes in ocean conditions are also possible. Further assessments and analyses are needed to investigate these possible associations.

Black abalone (*Haliotis cracherodii*), an intertidal gastropod, was listed as endangered in 2009 (74 FR 1937). Critical habitat, which includes the intertidal and subtidal habitats of the South Farallon Islands, was designated in 2011 (NMFS 2011). Results of SEAS surveys indicated very few black abalones occurred around the South Farallones. To further investigate the status of black abalone around the South Farallones, an intensive survey was conducted by a team familiar with the species and its preferred habitats (Roletto et al. 2015). No black abalone were found. The only abalone found was a single red abalone (*Haliotis rufescens*). A review of prior black abalone records for the islands found few, with the last records of two individuals found in separate areas in 2012. These individuals were searched for but not found in 2015. Reasons for the lack of black abalone are unclear, but may be associated with food availability, competition for space with other invertebrates, habitat disturbance by pinnipeds, and insufficient recruitment of abalone larvae. Although the species has declined dramatically throughout much of its range, the main cause of the decline (withering syndrome) appears unlikely to be the reason for such low numbers of black abalone around the Farallones (NMFS 2011, Roletto et al. 2015).

3.4.4.2 *Nearshore Fish and Invertebrates*

Fish species found around the Farallones include several species of nearshore rockfish (genus *Sebastes*), pink seaperch (*Zalembius rosaceus*), kelp and painted greenlings (*Hexagrammos decagrammus* and *Oxylebius pictus*), lingcod, spotted ratfish (*Hydrolagus colliei*), wolf eel (*Anarrhichthys ocellatus*), California halibut, big skate (*Raja binoculata*), Pacific sanddab (*Citharichthys sordidus*), cabezon and other sculpins (*Cottida*e), red brotula (*Brosmophycis marginata)*, gunnels (*Pholidae* spp.), Chinook salmon, northern anchovy

(*Engraulis mordax*), Pacific sardine (*Sardinops sagax*), white shark, and several other species (Ainley and Boekelheide 1990, Marine Applied Research and Exploration and Pacific States Marine Fisheries Commission 2012, Lindholm et al. 2014). Some of these are preyed upon by Farallon seabirds and marine mammals. Below are summaries of some of the more common species found in the waters immediately surrounding the South Farallon Islands.

Several species of rockfish from the genus *Sebastes* are found in the waters surrounding the Farallon Islands and these are important prey items for many upper trophic level predators. At least 16 species of rockfish are found around the Farallones with a range from the intertidal zone to almost 9,800 ft (3,000 m) deep. Adults of these species usually live in the benthic zone on various substrates, often around rock outcrops, where they feed on a variety of plankton, krill, copepods, shrimp, squid, and small fish such as juvenile rockfish, anchovies, crabs and the like. Most spawning occurs in winter. Larval and young juvenile stage rockfish are pelagic, mainly occurring at relatively shallow depths (less than 80 m or 264 ft) where they are opportunistic feeders, preying on copepods, invertebrate eggs, krill and other invertebrates. Juveniles usually settle to the bottom when they are 3-9 cm (1.2-3.6 in) in length and 3-6 months old. In California, most juvenile settlement occurs in May-July. Some rockfish species are very long lived, amongst the longest living fish on earth, with several species known to surpass 100 years of age (Love et al. 2002, Fishbase. 2013).

The pink seaperch can be found between 30 and 700 feet deep in the water column. They range from the California border to Guerrero Negro along the Pacific side of Baja California and, with the exception of the extreme northern portion, in the northern half of the Sea of Cortez. They reach a maximum length of 18 inches. Pink seaperch reside in schools or lose aggregates feeding primarily on invertebrates (Love et al. 2002, Fishbase. 2013).

The kelp greenling occurs in rocky inshore areas of the northern Pacific and is common on kelp beds and on sand bottoms. They feed on crustaceans, polychaete worms, brittle stars, mollusks, and small fishes. The young are food for large predators such as lingcod and halibut (Fishbase. 2013). The painted greenling is native to the Eastern Pacific Ocean from Kodiak Island, Alaska to central Baja California. It can reach a total size of 10 in (25 cm). It inhabits rocky areas usually shallower than 164 ft (50 m). It feeds on crustaceans, polychaetes, small molluscs and bryozoans (Fishbase. 2013).

Lingcod are unique to the west coast of North America, with the highest abundance off the coast of British Columbia. They are found on the bottom of the ocean, with most individuals occupying rocky areas at depths of 32 to 328 ft (10 to 100 m). Tagging studies have shown lingcod are a largely nonmigratory species, with colonization and recruitment occurring in localized areas only. Starting in October, lingcod migrate to nearshore spawning grounds. Spawning takes place between December and March. The larvae are pelagic until late May or early June, when they settle to the bottom as juveniles. Initially they inhabit eel grass beds, and then move to flat sandy areas that are not the typical habitat of older lingcod. They eventually settle in habitats of similar relief and substrate as older lingcod, but remain at shallower depths for several years (Fishbase. 2013).

The spotted ratfish can be found in the Northeastern Pacific Ocean. The range of depths in which this fish is found extends from zero to 3,000 feet (0 to 910 m). Ratfish tend to move closer to shallow water during the spring and autumn, then to deeper water in summer and winter. Spotted ratfish can most commonly be found living near the bottom of sand, mud or rocky reefs of the ocean floor. Spotted ratfish are particularly drawn to crustaceans and mollusks like crabs and clams. In addition, the spotted ratfish also feeds on shrimp, worms, small fish, small crustaceans, and sea stars (Fishbase. 2013).

The wolf eel feeds on crustaceans, sea urchins, mussels, clams and some fishes. It can grow to be 80 in (203 cm), 41 lb (18.6 kg), and is found in the northern Pacific Ocean, ranging from the Sea of Japan and the Aleutian Islands to northern California. The wolf eel makes its home on rocky reefs or stony bottom shelves from shallow to moderate depths, picking a territory in a crevice, den, or lair in the rocks (Fishbase. 2013).

The California halibut, or California flounder, is a large-tooth flounder native to the waters of the Pacific Coast of North America from the Quillayute River in Washington to Magdalena Bay in Baja California. They feed near shore and are free swimming. California halibut feed almost exclusively upon anchovies and similar small fishes. They typically weigh 6 to 50 pounds (3 to 23 kg) (Fishbase. 2013).

Big skates are usually seen buried in sediment with only their eyes showing. They feed on polychaete worms, mollusks, crustaceans, and small benthic fishes. Polychaetes and mollusks comprise a slightly greater percentage of the diet of younger individuals (Fishbase. 2013).

The Pacific sanddab is a medium sized flatfish, a light brown color mottled brown or black, occasionally with white or orange spots. The Pacific sanddab is endemic to the northern Pacific Ocean, from the Sea of Japan to the coast of California. They are most commonly found at a depth of 160 to 490 ft (50 to 150 m), though the young inhabit shallower waters, occasionally moving into tide pools. It is an opportunistic predator, feeding on a variety of crustaceans, as well as smaller fish, squid, and octopuses (Fishbase 2013).

The cabezon is a sculpin native to the Pacific coast of North America that can reach weights of up to 25 lb (11 kg). As the Spanish-origin name implies, the fish has a very large head relative to its body. Cabezon feed on crustaceans, mollusks, fish and fish eggs. Cabezon are found from northern British Columbia to southern California (Fishbase 2013).

Red brotula is a species of viviparous (bearing live young) brotula found along the North American Pacific coast from Alaska to Baja California. This species grows to a length of 18 in (46 cm). They are found in tropical and subtropical waters throughout the world and live in surface waters or around reefs. Brotulas thrive on a diet of crustaceans (Fishbase. 2013).

The gunnels are a family of marine fishes in the order Perciformes. They are elongated, somewhat eel-like fishes that range from the intertidal zone to depths of 660 ft (200 m), though the majority are found in shallow waters. Most are restricted to the North Pacific, ranging as far south as Baja California and East China. They typically reach a maximum length of 7.9–12 in (20–30 cm). They eat small crustaceans and mollusks (Fishbase 2013).

White sharks are common in nearshore waters surrounding the South Farallon Islands during the fall months, where they prey mainly on young elephant seals and sea lions (Brown et al. 2010). The central California white shark population is one of the best studied in the world (Klimley and Ainley 1998), though population numbers are low – estimated recently at 219 – and of major conservation concern (Chapple et al. 2011). Shark feeding events, tagging, and photo-identification studies have shown that sharks are generally present around the Farallones between August and December, but most feeding events occur between late September and early December. Many of the same individuals return year after year. By January, white sharks depart central California for waters between Baja California, Mexico, and Hawaii (Weng et al. 2007, Jorgensen et al. 2009).

The main source of information regarding the nearshore, subtidal invertebrate community immediately surrounding the islands is from surveys conducted in 2009 (Marine Applied Research and Exploration and Pacific States Marine Fisheries Commission 2012). They reported a total of 27 species or species groups (i.e., Cancer crabs Complex) around the South and Middle Farallon Islands. Species with higher densities included the California sea cucumber (*Parastichopus californicus*), fish eating urticina (*Urticina piscivora*), red sea star (*Mediaster aequalis*) and white plumed anemone (*Metridium giganteum*). Lindholm et al. (2014) conducted more extensive surveys off the Farallon Islands but in deeper (20 to 116 m, or 66 to 381 ft) waters.

In addition to that reported above, three subtidal invertebrates have or have had important commercial fisheries near the Farallon Islands: Dungeness crab (*Cancer magister*; current fishery); red abalone (former fishery); and red sea urchin (*Strongylocentrotus franciscanus*; former fishery). Dungeness crabs are highly mobile, benthic crustaceans residing mainly on sandy to sand-mud substrates of bays, estuaries and the open ocean, usually at depths less than 750 feet (230 meters). Adult crabs are opportunistic feeders, but prefer clams, fish, isopods and amphipods. Cannibalism is common. Several species of predators feed on Dungeness crabs, especially the pelagic larvae and small juveniles, including octopuses, larger crabs and predatory fish such as salmon, flatfishes, lingcod, cabezon and various rockfishes (Hankin and Warner 2001). They are numerous in offshore areas of the Gulf of the Farallones, and support one of the most productive fisheries in California. The Dungeness crab fisheries along the coastal western states are considered sustainable due in part to the combination of crab life history and a simple but effective fishery management scheme (CDFW 2013). Dungeness crab reach sexual maturity in a relatively short period of time and only the larger older males are removed from the population. The consensus among fishery managers based on research from northern California is that while the fishery removes most of the legal males each year (~80-90%), enough sublegal males remain that virtually every female is fertilized (CDFW 2013). The wide fluctuations in catch appear to be directly related to crab abundance which in turn seems to be a function of ocean conditions (CDFW 2013). The local commercial season typically begins on the second Tuesday of November and ends June 30. Fishing is not permitted within the Southeast Farallon Marine Reserve that surrounds the South Farallones and the Southeast Farallon Island Marine Conservation Area that extends to the 3-mile state boundary to the south and west of the South Farallones (https://www.wildlife.ca.gov/Conservation/Marine/MPAs). Crab fishing is widespread in waters between the islands and the mainland, and active crab pots are often seen

by island personnel during commercial crab season as close as a mile or so from Southeast Farallon. However, as reported in Lindholm et al. (2014) and by long-time commercial and recreational diver R. Elliott (personal communication, 12/11/2017), Dungeness crabs appear to be rare in the waters immediately surrounding the islands, probably because of the mostly rocky substrate.

Red abalone occur in the coastal waters of California from the intertidal zone to depths of about 200 ft. A former fishery in central California, including waters surrounding the South Farallones, has been closed since 1997 due to major population decline (CDFG 2005). During years of regular commercial abalone diving efforts off the Farallon Islands in the 1980s and early 1990s, high subtidal red abalone abundance was reported; however, surveys in 2000 showed very low densities (CDFG 2003, 2005). In more recent years, anecdotal observations by long-time commercial and recreational diver R. Elliott (pers. comm.; 12/11/2017) have suggested some increase in subtidal red abalone numbers. Abalone feed mostly on brown algae, often in the form of drifting kelp (CDFG 2005).

Sea urchins are subtidal, benthic echinoderms that feed primarily on kelp and other brown algae. Formerly abundant throughout much of California, populations declined in the 1990s (Kalvass and Rogers-Bennett 2001). Fisheries for sea urchins still occur in much of the state but fishing ceased off the Farallon Islands about a decade ago because of market forces (R. Elliott, personal communication, 12/11/2017).

3.4.5 **Marine Mammals**

3.4.5.1 *California sea lion*

California sea lions are the most abundant pinniped occurring on the South Farallones. There are roughly between 1,000 and 3,300 animals present on the island and in immediate surrounding waters year-round, with peak numbers from May through August (Ainley and Allen 1992, Point Blue, unpubl. data); however peaks of more than 10,000 animals have been observed in recent years during warm water events (Point Blue, unpubl. data). California sea lions breed from May through July with the majority of pups being born in June (Wilson and Ruff 1999). The South Farallones are not considered a major breeding site for California sea lions, however the numbers of pups born each year have increased to over 500 in recent years (Point Blue, unpubl. data). Most California sea lions that are found on the Farallones breed either on California's Channel Islands or on islands off the coast of Mexico (Sydeman and Allen 1997). California sea lion abundance has increased substantially at the South Farallones over the last 40 years. Based on pup counts, southern California populations on average had an estimated 5.2 percent annual growth rate between 1975 and 1994 (NOAA 1997). West coast population estimates of California sea lions in 1994 ranged from 161,066 and 181,355 individuals (Barlow et al. 1995). See Appendix K for maps of pinniped haul out sites on the South Farallon Islands.

3.4.5.2 *Northern elephant seal*

Northern elephant seals have been recovering from near extinction in the 19th and early 20th centuries, primarily the result of overharvesting for their blubber. Following extirpation in the

19th century, the current elephant seal colony at the Farallones began with the arrival of one individual in 1959 and grew to 100 individuals by 1971. The colony grew rapidly during the 1970s, and in 1983 a record 475 pups were born on the South Farallones (Stewart et al. 1994). Since then, the size of the South Farallones colony has declined, stabilizing in the early 2000s and then declining further (Berger 2012a). In 2012, a total of 90 cows were counted on the South Farallones, and 60 pups were weaned (Berger 2012a). Monthly counts from 2000-2009 ranged from 20 individuals in July to nearly 500 individuals in November (Point Blue, unpubl. data).

Northern elephant seals are present on the islands and in the waters immediately surrounding the South Farallones year-round for either breeding or molting; however, they are more abundant during breeding and peak molting seasons (Le Boeuf and Laws 1994, Sydeman and Allen 1997). They live and feed in deep, offshore waters the remainder of the year. In mid-December, adult males begin arriving on the South Farallones, closely followed by pregnant females on the verge of giving birth. Females give birth to a single pup, generally in late December or January (Le Boeuf and Laws 1994) and nurse their pups for approximately four weeks (Reiter et al. 1978). Upon pup weaning, females mate with an adult male and then depart the islands. The last adult breeders depart the islands in mid-March. The spring peak of elephant seals on the rookery occurs in April, when females and immatures (one to four years old) arrive at the colony to molt (a one-month process). The year's new pups remain on the island throughout both of these peaks, generally leaving by the end of April. The lowest numbers of elephant seals present on the rookery occurs during June, July, and August, when subadult and adult males molt. Another peak of immatures return to the islands for a haulout period in October, and at that time some individuals undergo partial molt (Le Boeuf and Laws 1994).

3.4.5.3 *Pacific harbor seal*

Pacific harbor seals are one of the most common pinnipeds in California and are present on or around the South Farallones year-round (NOAA 1997). Their populations have increased significantly since the Marine Mammal Protection Act (MMPA) was established in 1972 (NOAA 1997). In the mid-1990s their population was estimated at 30,000 in California alone (Wilson and Ruff 1999). Harbor seal abundance at the Farallones appears to fluctuate largely based on food availability in waters closer to shore; harbor seals are generally most abundant directly off the mainland coast, but they venture out to the Farallones when food near the coast is scarce (Sydeman and Allen 1997). Female harbor seals give birth to one pup per year, which occurs between April and May in California (Wilson and Ruff 1999). Less than ten pups are born on the South Farallones each year (Point Blue, unpubl. data). Pups are weaned at three to six weeks and breeding generally takes place two weeks later (Wilson and Ruff 1999). Harbor seal abundance has increased at the South Farallones since the early 1970s, annual population increases average 15.9 percent from 1973 to 1985 and nine percent from 1985 to 1997 (Sydeman and Allen 1999). The increase in abundance is thought to be largely the result of immigration from coastal waters (Sydeman and Allen 1997). Average monthly counts of harbor seals on the Farallones ranged from 39 in September to 91 individuals in July from 2000 to 2009 (Point Blue, unpubl. data).

3.4.5.4 *Northern fur seal*

Northern fur seals are present year-round in the waters near the South Farallones. They are most common in late summer and although the monthly average counts of northern fur seals is generally less than 50, their population is increasing annually (Tietz 2013b). During 2000-2009, average fur seal numbers ranged from very few in January through May and peaking to 45 individuals in August (Point Blue, unpubl. data). Although the Farallones were a major northern fur seal breeding area before the arrival of hunters in the early 19th century, the species was essentially extirpated from the region by the second half of that century (Wilson and Ruff 1999). Northern fur seals did not recolonize the Farallones until 1996 (Pyle et al. 2001), and each year since then they have bred in increasing numbers on West End during the summer; 521 animals were observed in 2012 (Tietz 2013b). Aerial photographic surveys of the rookery in recorded an increase in pup numbers from 401 to 1,126 pups between 2013 and 2016 (Berger et al. 2014; Point Blue and USFWS, unpubl. data). Male fur seals generally come ashore in late May or June to prepare for the breeding season. Females come ashore in late June or July and give birth to one pup per year (Wilson and Ruff 1999).

3.4.5.5 *Steller sea lion*

Steller sea lions are primarily a species of the North Pacific, and their colony on the South Farallones is near the southern end of their breeding range. Steller sea lions currently breed at Año Nuevo Island and previously bred at the California Channel Islands. Historically, the Farallon Islands were a significant breeding colony for Steller sea lions, with average counts of 600 to 790 animals from 1927 to 1947 (Bonnot et al. 1938, Bonnot and Ripley 1948). Steller sea lions are present on and around the South Farallones year-round, but their numbers are considerably greater during the summer breeding season and again in late fall (Hastings and Sydeman 2002). Monthly averages of Steller sea lion counts range from a few individuals to nearly 350 (Berger 2012b). Breeding on the South Farallones primarily occurs on West End Island, although breeding sites have shifted over the years. The South Farallones breeding colony had become less productive since the 1970s; generally only between five and ten pups are born annually compared with 20 to 30 pups annually during the 1970s (Sydeman and Allen 1997). However, numbers may be increasing again as just over 40 pups were counted in 2017 and 2018 (Point Blue, unpubl. data). In general, the Steller sea lion population using the South Farallones for breeding and resting has undergone a major decline since the 1970s. The reasons for this decline are unclear; it is possible that some adult animals have merely shifted their geographic range northwards (Hastings and Sydeman 2002).Other potential causes include competition with increasing numbers of, California sea lions, disease, and changing oceanic conditions may be contributing factors (NMFS 2008).

The eastern Distinct Population Segment (DPS) of Steller sea lions, which includes individuals occurring in California (including the South Farallones), Oregon, Washington, Canada and southeast Alaska, was listed as Threatened under the Endangered Species Act (ESA) in 1990. However, this population was delisted in 2013 because of increases in the greater part of the range (NOAA 2013).

3.4.5.6 *Other marine mammals in the Gulf of the Farallones*

In addition to the marine mammals discussed above, Guadalupe fur seals (*Arctocephalus townsendi*) and southern sea otters (*Enhydra lutris nereis*) have on rare occasions been spotted on the islands or in the waters surrounding the Farallones (Brown and Elias 2008; Point Blue, unpubl. data). The rarity with which these species occur precludes them from detailed analysis in this document.

There are also a number of cetacean species that regularly inhabit the Gulf of the Farallones including gray (*Eschrichtius robustus*), blue (*Balaenoptera musculus*), and humpback (*Megaptera novaeangliae*) whales, as well as several species of dolphins and porpoises (Pyle and Gilbert 1996). These individuals are highly unlikely to be affected by any of the actions described and are not analyzed in this document because project activities are restricted to the islands themselves and will not be undertaken in the surrounding marine environment.

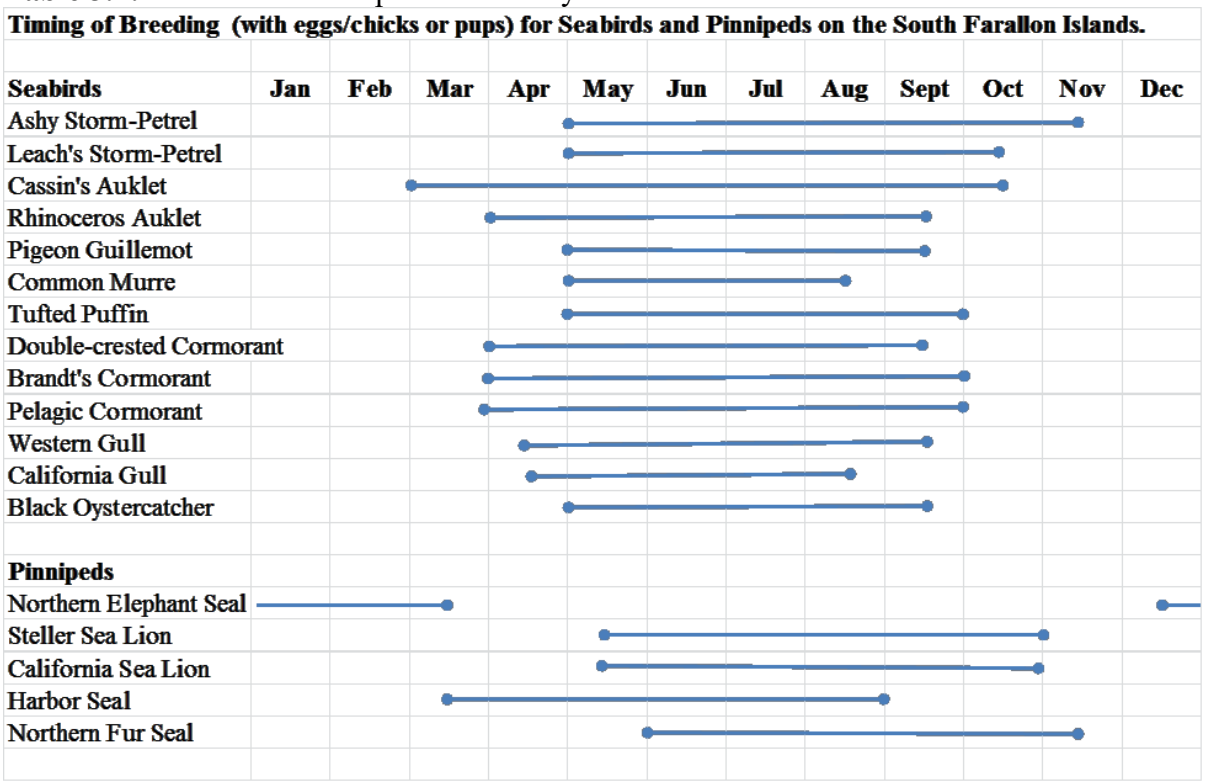
3.4.5.7 *Special legal protection for marine mammals*

All of the marine mammals at the South Farallones are protected from harm under the Marine Mammal Protection Act (MMPA).

3.4.6 **Breeding Seabird and Pinniped Seasonality**

Seasonality of breeding on the Farallon Islands varies among species of seabirds and pinnipeds. Most species breed in spring and summer, while Northern elephant seals breed in winter (Table 3.2).

Table 3.2: Seabird and Pinniped Seasonality



3.4.7 **Terrestrial Vegetation**

The diversity of vegetation on the Farallon Islands is low compared to the nearby mainland due to the harsh marine environment and limited habitat types (Coulter 1971, 1978; see Appendix L for a full species list). Sparse soil coverage, guano, and continuous trampling by seabirds and pinnipeds also contribute to the limited diversity and extent of vegetation on the Farallones. The islands' flora now includes at least 44 species, 26 of which are non-native (Coulter and Irwin 2005). Maritime goldfields cover much of Southeast Farallon Island. Maritime goldfields are specialized for life on offshore seabird colonies, occurring on islands, sea stacks and coastal cliffs along the Pacific coast of North America from San Luis Obispo County, California to Vancouver Island, British Columbia. They are tolerant of the caustic soil conditions that are characteristic of guano-covered seabird habitat (Crawford et al. 1985, Vasey 1985). The majority of the native vegetation on the Farallones senesces or dies during the summer and rebounds in the late fall and winter when seasonal rainfall begins.

The non-native plant community includes two invasive grass species, which currently dominate Southeast Farallon's southeast end (great brome *Bromus diandrus* and hare barley *Hordeum murinum leporinum*), New Zealand spinach (*Tetragonia tetragonioides*), cheeseweed mallow (*Malva parviflora*), and narrowleaf plantain (*Plantago coronopus*). Most invasive plants are found on the marine terrace in the south and southeast portions of Southeast Farallon and up the south-facing slopes of Lighthouse Hill and Little Lighthouse Hill. The spread of some of these invasive plants to the northern side of the island could pose additional threats to native species and habitats (Coulter and Irwin 2005, Hawk 2015, Holzman et al. 2017).

New Zealand spinach has been identified as a particularly serious threat to the Farallones ecosystem because it forms impenetrable mats of growth, degrading seabird burrowing and nesting habitats (USFWS 2005b, 2009). Several species of invasive grasses including great brome, foxtail barley (*Hordeum leporinum*), upright veldt grass (*Ehrharta erecta*), *Avena fatua, Cynodon dactylon, Festuca* sp., *Hordeum murinum* and narrowleaf plantain, are also plants of concern because they have the potential to displace native plants and degrade seabird nesting habitats (USFWS 2009). They actively grow or cover habitat during the nesting season (when native plants are usually dormant) and tend to alter the habitat character from one of a nearly barren nesting substrate to a habitat less suitable for nesting seabirds. Annual weed management efforts by the Service, conducted mainly in late spring to mid-summer, include herbicide treatment, hand-pulling, and occasionally other techniques to control the spread and density of spinach, mallow, and to a lesser extent, other species.

Several trees were planted on Southeast Farallon Island before the island was added to the Refuge, nearly all of which no longer exist (White 1995). There are two Monterey cypress (*Hesperocyparis macrocarpa)* individuals that were planted in 1982 (Pyle and Henderson 1991) near the houses. A lone, low-growing Monterey pine (*Pinus radiata*) is on the east side of the island. There are also three managed patches of non-native bush mallow (*Malva arborea*), near the housing units and near the east end of the Marine Terrace (Pyle and Henderson 1991). These plants have not shown to be invasive and are kept for their value to migrant landbirds. New studies have recently begun to monitor the island's plant communities over time.

3.5 Social and Cultural Resources

3.5.1 Ownership/Management/Major Stakeholders

The South Farallon Islands are managed as part of the Farallon Islands National Wildlife Refuge, a subset of the national system of Federal lands managed by the Service for the primary benefit of wildlife and their habitats. However, the U.S. Coast Guard holds continued access rights to Southeast Farallon Island to maintain the navigational light. Coast Guard personnel visit the island about once or twice a year to maintain the automated, solar-powered light at the top of Lighthouse Hill.

The surrounding waters are managed primarily by the National Oceanic and Atmospheric Administration (NOAA) as the Greater Farallones National Marine Sanctuary (GFNMS), while commercial and recreational take of marine resources are managed by the California Department of Fish and Wildlife. On May 1, 2010, the California Fish and Wildlife Commission designated a 5.34 square mile area surrounding the South Farallon Islands as the Southeast Farallon Island State Marine Reserve (SMR; Figure 3.6). The take of all living marine resources is prohibited within this area. Additionally, the Southeast Farallon Island Special Closure was established to prohibit access to all waters within 300 feet of the islands except at Fisherman's Bay and East Landing, with the additional exception of a seasonal closure from December 1st to September 14th off Saddle Rock and between East Landing and Shubrick Point (California Dept. of Fish and Game 2010). Additionally, the Southeast Farallon Island State Marine Conservation Area (SMCA) was established, a 12.95 sq. mi. area adjacent to and offshore of the SMR (see Fig. 3.6). The take of all living marine resources is prohibited in this area except the recreational take of salmon by trolling and the commercial take of salmon by troll fishing gear (California Dept. of Fish and Game 2011).

In 1971, the State of California designated the Southeast [South] Farallon Islands, including Maintop (West End) Island, Middle Farallon, the North Farallones, Noonday Rock, and the waters surrounding each island within one nautical mile from the shoreline as a state game refuge (Fish and Game Code Section. 10843.). The State of California designated approximately 20 areas within the state as game refuges in order to prohibit hunting under state law and provide a protected area for certain species (CDFG Report to the Legislature, January 1, 2011 (https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=82677&inline). Most game refuges in the state are located on federally-owned or private land. The game refuge designation has no practical effect in the case of the Farallon Islands National Wildlife Refuge because the islands are owned by the United States and managed by the Service as a federal wildlife refuge. The Service prohibits hunting and other public use on the refuge.

Due to the sensitive nature of the wildlife and the difficulty of landing on the islands, access to the South Farallones is strictly monitored and currently limited to Service and Point Blue staff, their approved contractors and collaborators, special use permit holders, and the U.S. Coast Guard. Vessels use the waters just off the East Landing and less often Fisherman's Bay in the North Landing, as calm-weather anchorages.

The South Farallones are within San Francisco City and County limits, but the islands do not provide any employment opportunities for the general public. The waters near the islands are used by commercial fishing operators. Wildlife-viewing and sport-fishing charter boats, none of them operated by the Service, also generate income for the region. While fishing is prohibited within the SMR immediately surrounding the islands, certain fishing is permitted outside of the SMR (see current regulations).

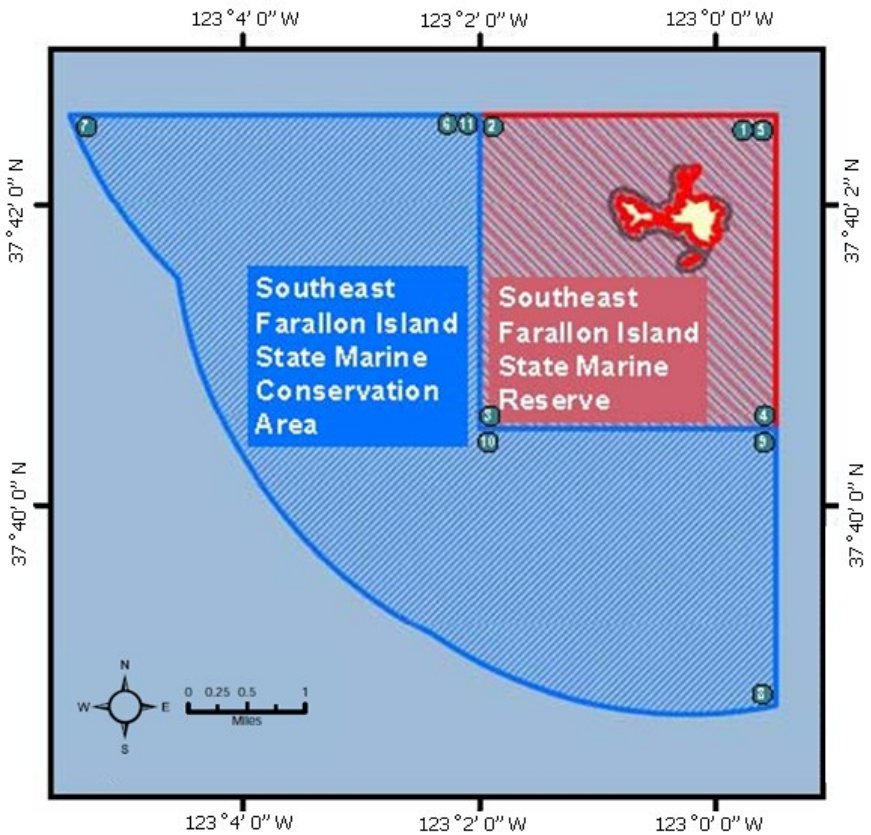


Figure 3.6: Southeast Farallon Island State Marine Reserve and Southeast Farallon Island State Marine Conservation Area (adapted from California Department of Fish and Game 2010).

3.5.2 <u>Recreational and Aesthetic Uses</u>

The Refuge is closed to the public. Thus, there are currently no on island recreational opportunities available to the public. However, the immediate surrounding waters provide an estimated 3,500 "wildlife viewing visitor days" annually (USFWS 2005a). Several wildlife-viewing boats conduct natural history tours throughout the year or seasonally (weather permitting) to the waters surrounding the islands. These tours focus on whales, seabirds, pinnipeds, and sharks. The wildlife-viewing opportunities associated with the Farallones extend to the nearby mainland coast, as well as to some of the seabird species that breed on the Farallones and forage near the mainland.

For several major species – notably nearshore rockfishes, surfperches, greenlings, lingcod, flatfishes, salmonids, and sculpins – north-central California accounts for a majority of the statewide recreational catch.

In addition to guided tours and recreational fishing, there are other private pleasure boats that use the waters surrounding the South Farallones. However, due to the often-unsettled nature of the weather and seas, general recreational boating is much less common near the islands than within or just offshore of the more protected waters of the San Francisco Bay.

To assist the assessment of economic impacts of the proposed mouse eradication project, Table 3.3 summarizes the numbers of sightseeing and shark tourism boats, recorded by personnel stationed on Southeast Farallon Island, visiting waters immediately surrounding the South Farallones in October through December 2014-2016, the same period as the proposed operational window for the Farallones mouse eradication project (although operations likely would not occur in October). All sightseeing and shark cage diving boats that are observed by island personnel are recorded and then reported in monthly reports prepared by Point Blue staff. While this may not represent all sightseeing and shark tour boats that visited the islands, it does represent the majority of boats.

Table 3.3. Monthly totals of sightseeing (e.g. whale watching, bird watching) and shark cage diving tour boats recorded at the South Farallon Islands, October to December 2014-2016.

Table 3.3: Sightseeing and Shark Tourism Boats off the South Farallon Islands*									
Year	Type	October		November		December		Total	
		# Operators	# Boat Days	# Operators	# Boat Days	# Operators	# Boat Days	# Operators	#Boat Days
2014	Sightseeing	4	25	4	24	3	8	11	57
	Shark	1	13	1	13	0	0	2	26
2015	Sightseeing	8	39	7	48	1	1	16	8
	Shark	2	25	2	16	0	0	4	18
2016	Sightseeing	8	26	3	8	3	6	14	40
	Shark	2	7	2	4	0	0	4	11
Average for All		8.3	45	6.3	37.7	2.3	5	8.5	26.7
Average for Sightseeing		6.7	30	4.6	26.7	2.3	5	13.6	35
Average for Shark		1.7	15	1.7	11	0	0	3.3	18.3

* Source: Farallon Islands NWR Monthly Reports for October – December 2014-2016

** Number of operators and boat days for sightseeing and shark tourism were calculated and averaged per month. These values were used to determine the impact to tourism operations from the proposed mouse eradication (See Section 4.6)

3.5.3 Commercial Fisheries

Within the Southeast Farallon Island SMR, take of all living marine resources is prohibited. Within the Southeast Farallon Island SMCA, the take of all living marine resources is prohibited except the recreational take of salmon by trolling and the commercial take of salmon by troll fishing gear (California Dept. of Fish and Game 2011b).

The waters near the South Farallon Islands are currently productive grounds for commercial fishing. Scholz and Steinback (2006) conducted an in-depth examination of the use of the adjoining National Marine Sanctuaries that span the coast of central California as fishing resources. Currently, the most important fisheries in the study area (the Cordell Bank and Gulf of the Farallones and adjacent port communities from Bodega Bay to Pillar Point, Half Moon Bay) are Dungeness crab (*Metacarcinus magister*), groundfish (including several nearshore species), herring, salmon, squid, tuna, and urchins. Between 1981 and 2003, these seven fisheries yielded an average of nearly 35 million pounds of landings worth over $31 million per year (in constant 2003 dollars).

In general, the fisheries in this area are more valuable than in the state as a whole. Over the period 1981-2003, the proportion of revenues derived from commercial fisheries' landings in study-area ports increased, from five percent of the state total in 1981 to several times that number in the recent years (Scholz and Steinback 2006).

3.5.3.1 *Essential Fish Habitat Assessment*

Prior to implementation of the proposed action, the Service will complete an Essential Fish Habitat Assessment in conformance with the 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act (see Federal Register 62, 244, December 19, 2017). The 1996 amendments to the Magnuson-Stevens Act set forth a number of new mandates for the National Marine Fisheries Service (NOAA Fisheries), eight regional fishery management councils (Councils), and other federal agencies to identify and protect important marine and anadromous fish habitat. The Councils, with assistance from NOAA Fisheries, are required to delineate EFH for all managed species. Federal action agencies which fund, permit, or carry out activities that may adversely impact EFH are required to consult with NOAA Fisheries regarding the potential effects of their actions on EFH and respond in writing to the NOAA Fisheries' recommendations.

The proposed project is located within an area designated as EFH for Finfish, Market Squid, Krill (*Thysanoessa spinifera*), Krill (*Euphausia pacifica*), Other Krill Species, Pacific Coastal Pelagic Species, Pacific Highly Migratory Species, West Coast Salmon, and Groundfish under the jurisdiction of the Pacific Fishery Management Council. The proposed project is located in the vicinity of the Farallon Island-Fanny Shoal EFH Conservation Area. No Habitat Areas of Particular Concern are anticipated to be impacted by project activities.

Pacific coastal pelagic species in the area include jack mackerel (*Trachurus japonicus*), Pacific (chub) mackerel (*Scomber japonicus*), Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*) (central subpopulation), and northern anchovy (northern subpopulation). Pacific highly migratory species in the area include bigeye thresher shark (*Alopias superciliosus*), bluefin tuna (*Thunnus thynnus*), dolphinfish (dorado; *Coryphaena hippurus*), Pacific thresher shark (*Alopias vulpinus*), and swordfish (*Xiphias gladius*). All species and stocks of West Coast salmon (*Salmonidae* species) also occur in the region.

3.5.4 Cultural Resources

The South Farallones have had extensive human history beginning as a pinniped hunting ground, a coveted egg gathering site, a military outpost, and a manned Lighthouse Service and U.S. Coast Guard light station. These past activities left behind many remnants some of which possess historic significance. Thus, the entire Southeast Farallon Island was listed on the National Register of Historic Places in 1977. Since that time, a number of elements have been evaluated to determine whether they contribute to the historic setting. Specific structures that have been determined to be culturally significant include the two residences, the rail cart system, the Carpenter's Shop, and the Lighthouse Hill trail and rock walls (Table 3.4).

Table 3.4: Status of Historical or Potential Historical Elements on Southeast Farallon Island.

Element #	***Description***	***Construct Year***	***Facility Type***	***Status***
1	Loading Boom	1988	Other structures/ facilities	Not evaluated
2	Residence Building	1879	Residences	Evaluated in 1998, contributing historical element
3	Office/ Laboratory	1883	Office buildings	Evaluated in 1998, contributing historical element
4	Powerhouse	1940	Other buildings	Evaluated in 1998, not eligible
5	Lighthouse Hill Trail	1880	Service trails	Evaluated in 2007, contributing historical element
6	North Landing Storage Building	1915	Storage buildings	Not evaluated
7	Water Distribution Line	1960	Water distribution lines	Not evaluated
8	Water Catchment System	1900	Water treatment facilities	Evaluated in 1998, not eligible
9	Rail Cart System	1900	Other structures/ facilities	Evaluated in 1998, contributing historical element

Element #	***Description***	***Construct Year***	***Facility Type***	***Status***
10	Old Structures (debris)	1940	Other structures/ facilities	Not evaluated
11	Carpenter/ Pipe Shop Building	1940	Shop/ service buildings	Contributing historical element
12	North Landing Trail	1945	Service trails	Not evaluated
13	North Landing	1945	Piers	Evaluated in 2000, not eligible
14	Concrete Landing Pad	1955	Other structures/ facilities	Evaluated in 1998, not eligible
15	Pump House	1960	Other buildings	Not evaluated
16	Abandoned Water Pipe	1960	Water lines	Not evaluated

The oldest structural remain on the South Farallones is thought to be the Russian House foundation used by seal hunters in the 19th century. The area surrounding the Russian House foundation has the highest concentration of historic marine mammal bones yet to be uncovered on the island.

The infamous Farallon Egg Wars were fought here in 1863 (White 1995, Wake and Graesch 1999). Other areas with significant egging history are the stone enclosures and wall south of North Landing. These structures were used by eggers for cleansing and storage of eggs (Wake and Graesch 1999). Russian era shelters and eggers barracks also contain a high frequency of surface artifacts and mid-19th century bottle glass. Sewer Gulch and Garbage Gulch served as dump sites in the latter part of the 19th century. Many archaeological deposits are still present in these areas and help to provide insight into early human occupation on the island.

Figure 3.7: Houses on Southeast Farallon Island.

The two existing residences (Figure 3.7) built to accommodate lighthouse crews originally were limited to men and eventually families. The architect is unknown, but the houses are good examples of late 19th century institutional architecture. These residences were extensively altered around 1959, but renovations in 1999 returned them closer to their original appearance. The two residences are considered culturally significant and are included in the National Register of Historic Places. Moreover, the function of these houses as residences or quarters still continues for Point Blue biologists, Refuge staff, and other visiting researchers and contractors. Rock features in front of one of the houses could have provided an area used for butchering and preparation of marine mammals and other prey (Wake and Graesch 1999).

During habitation by the lighthouse crews, the rail cart system on the Southeast Island was an important vehicle for transporting goods from ships to the main structures. The rail cart system is estimated to have been built in about 1878 to connect the North Landing with the residences and coal storage. The line was later extended to the East Landing. The system carried coal and other freight from the landing to the quarters by mule power and was never motorized. The last mule was used in 1913 and since then, carts have been powered by residents. The portion of the rail system that remains running from East Landing to the housing units is considered culturally significant because it represents a certain function during a historic period (1878-1939). The foghorn remnants have not been evaluated but may retain some historical significance as the island's first attempt at providing a navigational warning.

The building known as the Carpenter's Shop was constructed by the U.S. Navy in 1905 as barracks and was occupied until about 1945. The structure was evaluated in 2005 and is considered a significant cultural element because it is the only standing building that represents the Navy period. While the water catchment area is not considered culturally significant, the area surrounding it may contain high potential sub-surface artifacts and features that should be carefully traversed to prevent potential damage (Valentine 2000).

A limited number of aboriginal artifacts are present on the Southeast Farallon Island. Some artifacts are ascribed to Aleut or Northwest Coast origin, while others are associated with California Native Americans. Those items that were manufactured by Native Americans were thought to be associated with the Russian fur traders and their various Native American servants. Other cultural pieces such as bones from elk, deer, and pigs, indicates that occupants relied on meat from the mainland.

4 Environmental Consequences

4.1 Purpose and Structure of this Chapter

Chapter 4 analyzes the environmental consequences of the alternatives as presented in Chapter 2. For comparative purposes, Chapter 4 also includes a similar analysis of the consequences of taking No Action to address the problem of invasive house mice on the resources of the South Farallones. The purpose of the impacts analysis in this chapter is to determine whether or not any of the environmental consequences identified may be significant.

The concept of significance, according to CEQ regulations (40 CFR 1508.27), is composed of both the *context* in which an action would occur and the *intensity* of that action on the aspect of the environment being analyzed. "Context" is the setting within which an impact is analyzed, such as a particular locality, the affected region, or society as a whole. "Intensity" is a measure of the severity of an impact. Determining the intensity of an impact requires consideration of the appropriate context of that impact as well as a number of other considerations, including the following:

- Impacts may be both *beneficial* and *adverse*. A significant effect may exist even if on balance the effect would be beneficial.
- The degree to which an action affects *public health or safety*.
- *Unique characteristics of the geographic area* (e.g., historical or cultural significance, specially protected lands, ecologically critical areas).
- The degree to which the impacts of an action are likely to be *controversial*. DOI's NEPA regulations define controversial as referring to circumstances where a substantial dispute exists as to the environmental consequences of a proposed action and does not refer to the existence of opposition to a proposed action, the effect of which is relatively undisputed (43 CFR 46.30).
- The degree to which the possible impacts of an action are *highly uncertain or involve unique or unknown risks*.
- The degree to which an action may i) *establish a precedent* for future actions with significant effects; and/or ii) *represents a decision in principle* about a future consideration.
- Whether an action is related to other actions with individually insignificant but *cumulatively significant impacts*. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment.
- The degree to which an action may adversely impact properties listed in or eligible for listing in the National Register of Historic Places, or may cause *loss or destruction of significant scientific, cultural, or historical resources*.
- The degree to which an action may *adversely impact an endangered or threatened species or critical habitat as listed under the ESA*.
- Whether the action *threatens a violation of Federal, State, or local law* or requirements imposed for the protection of the environment.

4.2 Environmental Issues (Impact Topics) Addressed

4.2.1 Scoping for Environmental Issues (Impact Topics)

The Service compiled a list of major environmental issues, or impact topics that warranted specific consideration in this analysis. The compilation of this list of issues was informed by a scoping process that included informal discussions with representatives from numerous government agencies, private groups and individuals with relevant expertise or a stake in the Farallon Islands, and solicitation of public comments (see Section 1.4 and Section 5.3-4).

In the analysis below, the potential significance of effects of each action alternative and the No Action alternative would be discussed on a case-by-case basis for each environmental issue considered.

4.2.2 Impact Topics

- The impact topics analyzed in this document include:
- Impacts to physical resources
    - Impacts to water resources
    - Impacts to geology and soil
    - Impacts to wilderness
- Impacts to biological resources
    - Impacts to Birds
    - Impacts to Mammals
    - Impacts to Amphibians
    - Impacts to Fish
    - Impacts to Invertebrates
    - Impacts to Vegetation
- Impacts to the social and cultural resources
    - Impacts to personnel safety
    - Impacts to refuge visitors and recreation
    - Impacts to fishing resources
    - Impacts to economic and cultural resources
- Unavoidable adverse impacts
- Cumulative impacts
- Irreversible or irretrievable commitment of resources
- Relationship of short-term uses to long-term productivity

Brief descriptions of many of these topics can be found in Section 1.8.

4.2.3 Significance Thresholds for the Farallon Islands

- ❖ Significance thresholds reflect the severity or long-term impact to a resource from the implementation of any alternative proposed for eradicating invasive house mice on the Farallon Islands National Wildlife Refuge.

- Long-term is considered to be five or more years, unless otherwise indicated.
- Significance determinations reflect the expected impact from the alternative being assessed.
- Impacts may be beneficial or adverse.
- Significance levels will be classified as negligible, not significant, or significant:
  - **Negligible** – no measurable impacts are anticipated.
  - **Not Significant** – short-term impacts are anticipated, but no long-term impacts are anticipated.
  - **Significant** – long-term impacts are anticipated.

4.2.3.1 *Significance Thresholds by Impact topic*

- **Physical Resources**
  - Soil – contamination that results in long-term persistence in the soil making it biologically available.
  - Water – contamination that results in long-term persistence in water and that is not authorized by regulatory agencies.
  - Wilderness – long-term impacts to wilderness character that materially alters wilderness qualities.

- **Biological Resources**
  - Plants and Animal Species – long-term negative or positive impact in the abundance or distribution of a species at the population level.

- **Social and Cultural Resources**
  - Personnel Safety – severe injury or death of any personnel.
  - Refuge Visitors and Recreation – long-term impacts to the tourist industry or other recreational activities that materially alters use patterns.
  - Fisheries Resources – long-term impacts to a fishery resulting in material reductions in recreational or commercial take such that fishing patterns change.
  - Social and Historical Resources – a resource is irreparably damaged, destroyed or lost.

4.3 Aspects of the Environment Excluded from Detailed Analysis (with Rationale)

4.3.1 Air quality

Impacts of the action alternatives on air quality at the South Farallones were not analyzed in detail because there are no activities proposed that would represent a measurable change from the background levels of air pollution caused by human activities on the mainland and islands or nearby watercraft and aircraft. The brief, localized helicopter operations that would occur as part of each action alternative would have no more than a negligible contribution to local or regional changes in air quality.

4.3.2 Cetaceans (e.g., whales and dolphins) and Sharks

Potential impacts of mouse eradication activities to cetaceans (whales, dolphins, and their close relatives) and sharks in the waters surrounding the South Farallones are not analyzed in this FEIS. The likelihood of cetacean or shark exposure to brodifacoum or diphacinone would be negligible, and they would have to consume extremely large quantities of bait or other individuals that consumed bait to experience any lethal or sublethal affects. Most cetaceans and sharks occur offshore of the Farallones, outside of the implementation zone and where limited quantities of bait could drift into the nearshore environment. In addition, the bait pellets would breakdown relatively quickly and would settle on the ocean floor within hours or days. The potential effects of the limited boat and aircraft traffic during operations are also expected to be negligible.

4.3.3 Environmental Justice

The impacts of the action alternatives on environmental justice (the agency mandate set in Executive Order 12898 of 1994 to identify and address the potential for disproportionate placement of adverse environmental, economic, social, or health impacts on minority and low-income populations) would not be analyzed in detail because there are no minority or low-income populations that would be affected by any of the alternatives.

4.4 Consequences: Physical Resources

4.4.1 Water Resources

4.4.1.1 *Analysis framework for water resources*

The potential for significant water quality impacts was analyzed for the identified action alternatives with respect to potentially adverse physical and biological impacts.

House mice on the South Farallones are frequently found on and around the shoreline. For this reason, it is essential that the action alternatives involve the application of the rodenticide all the way down to the mean high-water spring (MHWS) mark to ensure that all mice on the island are exposed. Even though substantial effort would be taken to minimize bait drift into the marine environment, permitting for aerial pesticide use around the littoral zone would be sought in compliance with EPA's Clean Water Act (CWA) National Pollution Discharge Elimination System (NPDES) guidelines for aerial pesticide applications over waters of the United States, in addition to any other required state or federal permits.

4.4.1.2 *Alternative A: No action*

House mice are known to carry pathogens that pose a risk to humans and wildlife and there is potential for some of these to be transmitted via water (de Bruyn et al. 2008). However, there is no recent or past information to suggest that house mice on the South Farallones are affecting the quality or quantity of island drinking water or marine water resources, nor would the Service

expect any future impacts. Under the No Action Alternative, water resources would remain unchanged.

4.4.1.3 *Alternative B: Aerial Broadcast of Brodifacoum*

Bait pellets applied near the shoreline or on steep slopes may drift into nearshore marine waters during bait application operations. However, the proposed bait application techniques include mitigation measures that would minimize such bait drift (Section 2.10.7.7). In addition, the Service would acquire and comply with all necessary permits or authorizations from the GFNMS, California EPA, and the Regional Water Quality Control Board for any unintended discharge into the water surrounding the islands.

Even if bait does drift into the water bodies on or around the South Farallones at the full application rate, it would be very unlikely to contribute to detectable levels of brodifacoum in the water column. Physical and chemical properties of the bait formulation, low water solubility of rodenticide and strong chemical affinity of brodifacoum to the grain matrix, significantly reduce the chance of rodenticide contaminating aquatic or marine environments. An example of the low contamination risk posed to water by brodifacoum was provided in 2001 when a truck crashed into the sea at Kaikoura, New Zealand, spilling 18 tons of Pestoff 20R (20 ppm brodifacoum) cereal pellets into the water. Measurable concentrations of brodifacoum were detected in water samples from the immediate location of the spill within 36 hours; however, after nine days concentrations were below the level of detection (0.02 µg/L or parts per billion) (Primus et al. 2005). Similar to Kaikoura, the Farallones are characterized by their steep rocky coastline, high wave action, and strong currents which would break down any bait pellets relatively quickly if they were to accidently drift into the marine environment. In a more recent study, Pitt et al. (2015) documented that no sea water samples out of 27 collected were positive for brodifacoum following rodenticide bait application on Palmyra Atoll; only one of seven freshwater samples collected from the same study were positive for brodifacoum.

Environmental testing during rodent eradications and eradication trials in the California Current marine system and elsewhere have failed to detect more than trace amounts of brodifacoum in any water samples taken after bait application (Buckelew et al. 2005, Buckelew et al. 2008, Howald et al. 2010, Pitt et al. 2015). Other studies have suggested similar findings, where minimal to no nearshore contamination of ocean biota, suggestive of water contamination, was detected following analysis of post-application samples at Anacapa Island and Ulva Island (Buckelew et al. 2005, Howald et al. 2010, and Masuda et al. 2015).

Water supplies used by personnel on the South Farallones would be isolated from exposure during bait application to prevent the entry of toxicant into water catchment areas. Based on the information presented above, the significance determination for this alternative is expected to be negligible.

4.4.1.4 *Alternative C: Aerial Broadcast of Diphacinone*

Bait pellets applied near the shoreline or on steep slopes may drift into nearshore marine waters during bait application operations. As with Alternative B, the bait application techniques

described would include mitigation measures to minimize bait drift into water bodies at a level well under the target bait application rate (Section 2.10.7.7). In addition, the Service would acquire and comply with all necessary permits or authorizations from the GFNMS, Regional Water Quality Control Board, and California EPA for any unintended discharge into the water surrounding the islands.

Even if bait does accidently drift into the water bodies on or around the South Farallones at the full application rate, it would be unlikely to contribute to detectable levels of diphacinone in the water column. The low water solubility and strong chemical affinity of diphacinone to the grain matrix of the bait pellets largely reduces the probability of rodenticide entering aquatic/marine environments via run-off. Additionally, the Farallones are characterized by their steep rocky coastline, high wave action and strong currents, which would likely break down any bait pellets relatively quickly if they were to accidently drift into the marine environment.

Environmental testing after two rodent eradications in Hawaii (Mokapu and Lehua Islands) examined the impact that diphacinone had on the marine environment including the impacts the toxicant had on marine invertebrates. For Mokapu Island, seawater samples were below the limit of detection (90 parts per trillion), with the same findings occurring in limpets and fish fillets (Gale et al. 2008). For Lehua Island, seawater (limit of detection of 0.4 parts per billion), fillet of fish, limpet, whole-body crab, and soil samples were analyzed following application of bait and revealed no detectable concentrations of diphacinone in any of the samples (Orazio et al. 2009). The bait application protocol used on Lehua Island in 2009, which required a 30-m buffer from the coast to reduce bait drift into the ocean, may have contributed to undetectable contamination of the marine environment.

As with Alternative B, water supplies for personnel on the South Farallones would be protected during bait application activities to prevent the entry of pellets into water catchment areas. Based on the information presented above, the significance determination for this alternative is expected to be negligible.

4.4.2 Geology and Soils

4.4.2.1 *Analysis framework for geology and soils*

The major issues of concern for the geology and soil resources of the Farallones are 1) permanent damage to granitic rock formations, 2) increases in soil erosion, and 3) contamination of soils.

4.4.2.2 *Alternative A: No action*

Under the No Action alternative, the continued presence of house mice would not measurably impact rock formations or contaminate soils. However, if house mice continue to remain on the Farallon Islands, there is a possibility, based on past projects, that the reduced number of seabirds on the islands could decrease the amount of nutrients deposited by the birds on the island and therefore incorporated into the soil (Maron et al. 2006). Under the No Action alternative, geologic resources on the islands would remain unchanged. The possibility of

additional reductions in nutrient availability for soils could result in negligible adverse impacts to soils over the long-term.

4.4.2.3 *Alternative B: Aerial Broadcast of Brodifacoum*

The activities in Alternative B would not have a significant impact on soil erosion and rock formations. The installation and maintenance of bait stations in limited circumstances may cause physical disturbance to soil and rock but these impacts would not be significant. The relatively small amount of brodifacoum in bait pellets coupled with the low solubility of brodifacoum is not likely to lead to long-term soil contamination (World Health Organization 1995, Ogilvie et al. 1997; Pitt et al. 2015).

Monitoring data from projects that have used brodifacoum indicate either no soil contamination or insignificant levels of contamination. Brodifacoum binds strongly to soil particles and has a published half-life of 157 days under laboratory conditions in sandy clay loam soil (USEPA 1998). Radio-labeled brodifacoum was found to be effectively immobile (i.e. not leached) in four soil types (World Health Organization 1995). Craddock (2003) reported that where soil residues were found below disintegrating Pestoff® 20R pellets at Tawharanui Regional Park, Auckland, they were low (near the limit of detection of 0.02mg/kg) and after 110 days no residues could be detected. Results from soil monitoring for brodifacoum residues six to nine months after bait application on Red Mercury Island, Coppermine Island (Morgan and Wright 1996) and Lady Alice Island (Ogilvie et al. 1997) were all negative. Similarly, on Anacapa Island trace levels were detected in just one of 48 samples collected approximately six months post bait application in 2003 (Howald et al. 2010). The one positive sample contained 1.2 µg/g of brodifacoum. After 153 days the highest residue concentration measured from soil extracted from underneath Pestoff 20R baits used on Hauturu Island in 2004 was 0.07 µg/g (Weldon et al. 2011). Soil samples taken 28 days following aerial application of 10mm Pestoff 20R baits containing 20ppm brodifacoum to the Ipipiri Islands in the Bay of Islands, New Zealand in June 2009 contained an average brodifacoum concentration of 0.0016 µg/g (Walker 2010).

Soil samples were collected from the Bay of Islands 58 days post baiting and contained brodifacoum residues of approximately 0.002 µg/g. These samples were taken 8 inches below each sampled bait pellet on the pasture (Weldon et al. 2011). In simulated rainfall trials, Booth et al. (1999) did not detect brodifacoum in the soil underneath any bait. Alifano et al. (2012) found trace amounts of brodifacoum (greater than 1 µg/g) in topsoil analysis on Palmyra Atoll during monitoring efforts conducted 50 days after bait application. In a separate study on Palmyra Atoll, soil samples collected approximately two months following rodenticide bait application (three applications at an average rate of 75.5 kg/ha) contained brodifacoum concentrations ranging from 0.03 µg/g (the method limit of detection) to 0.056 µg/g (Pitt et al. 2015).

Monitoring of marine sediments following the aforementioned spill of 18 tons of brodifacoum bait at Kaikoura, New Zealand found only one of seven sediment samples taken at the immediate location of the spill the following day to contain measurable concentrations of brodifacoum (0.060 µg/g). Furthermore, samples taken nine days after the spill were below the level of detection (0.02 µg/gm) (Primus et al. 2005).

Based on available evidence, the significance determination for this alternative is expected to be not significant for geology and soils.

4.4.2.4 *Alternative C: Aerial Broadcast of Diphacinone*

The activities in Alternative C would not have a significant impact on soil erosion, rock formations, or soil contamination. The installation and maintenance of bait stations in limited circumstances may cause physical disturbance to soil and rock but these impacts would not be significant. The relatively small amount of diphacinone in bait pellets would not lead to long-term soil contamination (World Health Organization 1995). Similar to brodifacoum above, diphacinone residues tightly bind to soil particles and are highly immobile. Therefore, any diphacinone from rodent bait is not expected to infiltrate beyond the soil surface. Diphacinone undergoes relatively rapid degradation into diphenylglycolic acid as the primary breakdown product. Leaching adsorption and desorption studies have shown that more than 75 percent of the applied material stays in the top 2.5 inches (6 cm) of soil (USEPA 1998). In aquatic/marine environments, diphacinone is expected to be partitioned in suspended and bottom sediments rather than in the water column.

Diphacinone was undetectable during post application monitoring for residue in soil on Lehua Island within one week of bait application (Orazio et al. 2009). Monitoring after a bait trial in 2010 on Palmyra Atoll found less than 2 µg/g of diphacinone in the soil after 28, 36, and 50 day samples (Alifano et al. 2012). When tested in the laboratory, the half-life of diphacinone in sandy loam soils under aerobic conditions was about 30 days (USEPA 1998). A leaching study conducted on radio-labelled 'Ramik' baits showed that after three weeks and 13 mm of simulated rainfall, 60 percent of the diphacinone remained in the bait, 12 percent could be detected in the soil and five percent was detected in the leachate (Nomura 1977). In a ^{14}C-diphacinone aquatic sediments laboratory study, diphacinone residues in soil decreased from measured concentrations of 0.34 ppm to 0.22 ppm, a 35 percent decrease over 80 days. Approximately eight percent of the ^{14}C-diphacinone applied to the soil leached into the water (Ells 1976).

For these reasons, the significance determination for this alternative is expected to be not significant for geology and soils.

4.4.3 <u>Wilderness</u>

4.4.3.1 *Analysis framework for wilderness character*

In 1974, Congress designated the South Farallones, with the exception of Southeast Farallon Island, as wilderness in recognition of the importance of the refuge as a nesting area for seabirds and the presence of many native plant species and haul out sites for pinnipeds. The importance of the Farallon Islands as a preserve and breeding site for birds and other native species is a feature of value for the Farallon Wilderness. The Farallon Wilderness comprises about 141 acres, of which about 50 acres or 35% are infested with house mice.

This analysis addresses the effects of the alternatives on wilderness character and the Farallon wilderness's special features of value. Under the Wilderness Act of 1964 (16 U.S.C. 1131-1136), an area's wilderness character is defined by the following qualities:

- Untrammeled by human impacts;
- Undeveloped, without permanent structures or habitations;
- Influenced primarily by natural forces; and
- Outstanding opportunities for solitude or a primitive and unconfined type of recreation.

The Service has prepared a Minimum Requirements Analysis (MRA) in compliance with the Wilderness Act to determine the minimum necessary actions in the wilderness regarding management for house mice, using a Minimum Requirements Decision Guide (Appendix G). The MRA compares the positive and negative effects of seven alternatives to each of the four characters of wilderness quality. The MRA helped to identify action alternatives for consideration in the EIS, including the Preferred Alternative for the FEIS.

4.4.3.2 *Alternative A: No action*

The presence of invasive house mice has degraded the natural wilderness character. Mice also adversely impact the value of refuge wilderness as a breeding ground for birds and the islands' native plant communities. Taking No Action with regard to non-native mice on the South Farallones would sustain the same levels of degradation that currently exist. The significance determination for this alternative is expected to be significant since without the complete removal of mice their negative impacts would continue in perpetuity.

4.4.3.3 *Alternative B: Aerial Broadcast of Brodifacoum-25D Conservation*

Alternative B would temporarily affect the untrammeled and undeveloped qualities of wilderness through the aerial application of bait, ground-based bating activities, the transport and presence of personnel and equipment, helicopter use, motor boat use, and gull hazing techniques. These impacts would cease when project-related activities terminate.

Low-flying helicopters over the wilderness and the use of biosonics, pyrotechnics, and propane cannons within wilderness would adversely affect solitude, even though the wilderness is closed to the public. These impacts would be intermittent and would cease once project-related activities terminate.

This alternative would result in beneficial and adverse impacts to the natural quality of wilderness. The use of Brodifacoum would negatively impact the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. Short-term adverse impacts (including mortality) to non-target species such as gulls would also occur. Mitigation measures such as gull hazing and the capture and holding of raptors and salamanders would minimize non-target impacts. No adverse population level impacts would occur to any species.

Operations associated with bait application, gull hazing and personnel activity in wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea

lions). This disturbance will be intermittent and would only last for the duration of project activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

The eradication of mice would result in significant, long-term beneficial impacts to the natural quality of wilderness by eliminating the adverse impacts of mice on the populations of native ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, other terrestrial invertebrates, and maritime goldfields. For these reasons, mouse eradication would also benefit the Farallon wilderness's special features of value as an important breeding ground for birds and other native species.

In summary, impacts to the untrammeled, undeveloped and solitude qualities of the Farallon Wilderness would be short-term and not significant. Mouse eradication would result in several significant benefits to the natural quality of the Farallon Wilderness, including benefits to populations of several native species (e.g., ashy storm-petrel, Leach's storm-petrel, Farallon arboreal salamander, Farallon camel cricket, and the maritime goldfield). These long-term benefits offset the temporary adverse impacts to other aspects of wilderness character resulting in an overall beneficial impact on wilderness character.

4.4.3.4 *Alternative C: Aerial Broadcast of Diphacinone-50 Conservation*

Alternative C is similar to Alternative B in terms of its impacts to the untrammeled and undeveloped qualities of wilderness through the aerial application of bait, ground-based bating activities, the transport and presence of personnel and equipment, helicopter use, motor boat use, and gull hazing techniques. Because Alternative C has a slightly longer operational period, these impacts would last somewhat longer than under Alternative B but would cease when project-related activity terminates.

Alternative C is also similar to Alternative B with regard to impacts on opportunities for solitude.

Like Alternative B, Alternative C would result in beneficial and adverse impacts to the natural quality of wilderness. The use of Diphacinone would negatively impact the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. Diphacinone is less potent than Brodifacoum and poses a somewhat reduced risk to certain non-target species. Nevertheless, short-term adverse impacts (including mortality) to non-target species such as gulls likely would still occur. Mitigation measures such as gull hazing and the capture and holding of raptors and salamanders would minimize non-target impacts. No adverse population level impacts would occur to any species.

Operations associated with bait application, gull hazing and personnel activity in wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds. This disturbance will be intermittent and would only last for the duration of project activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

If Diphacinone was successful in eradicating mice, the long-term benefits to the natural quality of wilderness and the wilderness's value as a breeding ground for birds and other species would be similar to those under Alternative B.

In summary, impacts to the untrammeled, undeveloped and solitude qualities of the Farallon Wilderness would be short-term and not significant. If mice were successfully eradicated, the resulting beneficial impacts on native species (e.g, ashy storm-petrel, Leach's storm-petrel, Farallon arboreal salamander, Farallon camel cricket, and the maritime goldfield) would significantly enhance the natural quality of the Farallon Wilderness. These long-term benefits would offset the temporary adverse impacts to other aspects of wilderness character resulting in an overall beneficial impact on wilderness character.

4.5 Consequences: Biological Resources

4.5.1 Introduction

In order for the project to be considered a restoration success, the long-term benefits of house mouse eradication must outweigh impacts to non-target resources. The eradication of mice is expected to have benefits for a number of animals and plants that are currently being negatively affected by mouse presence. However, exposure to rodent bait pellets and disturbance from project operations have the potential to result in adverse biological impacts including potential mortality, injury or disturbance to sensitive wildlife species. The analysis below also addresses whether any native species would potentially be negatively or positively impacted by mouse removal. This document's analysis of impacts to biological resources identifies both the benefits (positive effects) and the costs (negative effects) of house mouse eradication.

The impacts of each alternative to the biological resources of the South Farallon Islands were examined as they relate to individual animals, but the primary focus was to analyze whether impacts to a particular resource (species or taxonomic group) could be considered significant according to the general significance criteria described in Sections 4.2.3 and 4.5.2. The concept of significance is defined separately for each impact topic analyzed below.

Species listed under the Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), or the Marine Mammal Protection Act (MMPA) would be treated with extra precaution during operations in an effort to minimize short-term impacts to species that have been assigned specific legal protection. However, significance determinations for listed species will follow the same criteria as non-listed species since the primary purpose of assessing significance is to determine the long-term effect to a specific species at the population level from a given alternative rather than the short-term effects to an individual (601 FW 1; 601 FW 3).

4.5.1.1 *Lessons Learned from Other Rodent Eradication Projects*

The Service has identified several key lessons from previous eradication projects that were incorporated into this FEIS in an effort to minimize potential impacts to the islands resources (see Section 1.5). The primary lessons include the need to identify the most at risk habitats and species from project implementation and develop mitigation and monitoring protocols designed

to minimize expected impacts. Additionally, it is pertinent that the Service employ sufficient staff to fully implement all of the essential tasks of the project without the concern that staff will be taken off of key tasks aimed at minimizing impacts to the islands resources for tasks aimed at maximizing project success. The Service has been and would continue to work with permitting agencies to identify project limitations and develop measures to mitigate the concern, while maximizing the likelihood of successfully eradicating the target species.

In order to maximize potential success of a mouse eradication and minimize non-target impacts, the Service has incorporated as many of the lessons learned from prior rodent eradications as possible into planning for the South Farallon Islands mouse eradication project. In this section, we have provided a summary of the lessons learned we considered most critical to developing and analyzing the expected impacts from the action alternatives. However, this list is not considered to be exhaustive. While most of these lessons learned stem from a review of many rodent eradication projects and literature describing eradication methods, many of these lessons learned were taken specifically from an evaluation of the Rat Island, Alaska rat eradication project (reference). Other major sources of information came from the best practices for mouse eradications in New Zealand (Broome et al. 2017), an evaluation of rodent eradications on tropical islands (Ornithological Council 201.), and more recent eradications at Palmyra Atoll (Pitt et al. 2015), Desecheo Island (Shiels et al. 2017), and Pinzon Island (Galapagos Islands; Rueda et al. 2016, in press). It is essential to have a broad understanding of the non-target species that are likely to be present in the region during the eradication operation and exposure windows. If sufficient data are unavailable to accurately determine a species' presence and behavior, planners should use worst case scenario planning and developing detailed contingency plans that can provide a framework for decision-making during operations, as well as reduce the likelihood of making ill-informed or unevaluated mistakes (Section 2.6.5).

Based on typical operational planning, lessons learned and best management practices developed from past eradication projects, the following measures are planned as part of the South Farallon Islands house mouse eradication project:

a) The Service has evaluated and determined the likely density and expected behavior of the target species prior to developing the bait broadcast plan. It is imperative to use sufficient bait to ensure that every target individual receives a lethal dose of the toxicant, while limiting the amount of bait used in total to minimize impacts to non-target species.
b) The Service intends to monitor bait uptake during the operation and continually assess rodent activity to ensure that there is sufficient bait to provide a lethal dose to every individual, as well as ensure that non-target individuals are not impacted in a manner inconsistent with NEPA and other permits.
c) Detailed mitigation measures, including feasible carcass and bait removal, with contingency plans have been developed to provide a framework for adaptive management, outline mitigation protocols, and determine the appropriate command structure, if an unexpected incident were to occur.
d) Reasonable efforts have been made to assess both primary and secondary impacts to non-target species prior to the development of a detailed operational plan. A broad range of alternatives, including a range of toxicant and non-toxicant approaches, were considered

and evaluated by the Service. The Service's approach included a detailed Alternatives Assessment Process (Section 2.6), a justification for dismissed alternatives (Section 2.7), and evaluation of both agency and public comments (Appendix P) from the RDEIS prior to choosing a preferred alternative.

e) Clear lines of communication and standard terminology are essential to any complex eradication project. A project command structure would be developed in the operational plan. The operational plan should provide as much detail as possible to minimize the likelihood of conflict between personnel, as well as reduce the potential to fail to eradicate the target species or have a greater than expected level of impact to non-target species.

f) The Service has committed to employing a sufficient number of staff and resources for the project with sufficient funding to continue mitigation and monitoring efforts to continue mitigation and monitoring efforts until the risk to island resources has been reduced to a negligible level. This will be determined by assessing the risks to island resources and clearly defining significance thresholds based on the best available data (Section 4.5.6).

4.5.2 Assessing Significance of Impacts to Biological Resources

As described in Section 4.2.3, the concept of significance is shaped by the context of an action, the duration of the impact, and the intensity of its effects. Many of the species that utilize the South Farallones have large ranges and interact at a population level with other individuals spread out over an area much larger than the South Farallones. Consequently, the most appropriate context within which to consider impacts to the biological resources found on the South Farallones is at the population level, whether it be just to the local population (i.e., Farallon Islands region) or range-wide population. The intensity of each effect is dependent on numerous variables specific to.

In general, impacts to the individual, however major, are not considered significant (unless impacts to individuals also impact the population). Individuals can experience grave impacts from operations in the short-term without having a long-term effect on the population. Since the Service is charged with managing refuges with a focus on populations rather than individuals (601 FW1; 601 FW 3), with the exception of ESA and MMPA-listed species (see Section 4.5.2.1) it was determined that significance would be considered in the context of population-level impacts to species utilizing the South Farallones. As an example, species that have large populations and/or a wide range, and thus are capable of rapidly recovering from losses, are unlikely to suffer long-term, population level effects from factors that impact one or a small number of individuals including death of the individual(s). Results of risk analyses for individual animals contributed to the overall significance determination for each biological taxon evaluated, but effects to individuals are not considered interchangeable with the significance determination for each biological resource.

While the impacts of each alternative can be analyzed with considerable confidence over the short-term, it is more difficult to accurately predict specific long-term responses to the alternatives due to the many external variables that impact long-term population levels, the

imprecise knowledge of impacts of mice to resources, and the lack of long-term studies following eradication projects. Short-term impacts include sublethal impacts from primary and secondary toxicant exposure, individual mortality events, disturbance from eradication operations and mitigation efforts like hazing, and other negative impacts that are only expected to impact island species for a short period of time without having long-term negative impacts to island populations. Long-term significant impacts are impacts that have exceeded the Significance Threshold for that species' population with the likelihood of impacting the population for an extended period of time (e.g. dramatic decreases in island population, reproductive failures that will cause population level decline, etc.).

In the analysis below, data from other island rodent eradications were reviewed and, where appropriate, combined with known information of South Farallon Islands' biological resources to project long-term effects to species. For this analysis, the significance threshold for each species was defined to be a long-term negative or positive impact in the abundance or distribution of a species at the population level.

For all biological resources analyzed, the significance determination was made by asking the following two questions for each alternative:

1) Is there a high likelihood that the species' population would incur change that would be measurable at the local/regional level, including at the South Farallon Islands, Gulf of the Farallones or central California region; and
2) Is there a high likelihood that the species' population would incur change that would be measurable throughout the species' range?

Thus, if it was determined that significant impacts were likely to occur, we determined whether the impact would be to the local population only or to the range-wide population.

4.5.2.1 *Special considerations for ESA-listed species*

The Endangered Species Act (ESA) of 1973 requires Federal agencies to ensure that the actions they take are not likely to "jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat" (ESA Section 7(a)2). If a Federal action is likely to adversely impact an ESA-listed species or its designated critical habitat, the action agency must initiate a formal process of consultation (Section 7) with either the National Marine Fisheries Service (NMFS) or the Service (depending on the species) to determine whether or not the action would put the potentially affected species in jeopardy of continued survival. Additionally, if individual animals that are listed under the ESA are likely to be "taken" by the agency's action, the Service must apply for an Incidental Take Permit.

One ESA listed species occurs at the South Farallon Islands, the black abalone, listed as Endangered (74 FR 1937). Additionally, the South Farallones are designated Critical Habitat for black abalone (NMFS 2011). Listing under the ESA provides a context for impacts analysis that differs from that of non-listed species. As a result, the FEIS uses different significance thresholds for ESA listed species and critical habitat. In this case, the potential for both short-term and long-term impacts are assessed for the species and its critical habitat. In the short-term, take of any individual black abalone would result in a significant impact. Long-term impacts would be the

same as for other species (Section 4.5.2). For critical habitat, any impacts to habitat that would affect short- or long-term black abalone survivorship, reproduction, or recruitment were considered. To minimize the risk of negative impacts, additional mitigation measures may be necessary and will be determined through Section 7 consultation with NMFS.

4.5.2.2 *Special considerations for MMPA-listed species*

Protection under the Marine Mammal Protection Act (MMPA) of 1972 provides a context for impacts analysis that differs from that of other species. As a result, this FEIS uses different significance thresholds for MMPA species. The MMPA regulations generally prohibit the killing, injury, or disturbance of marine mammals, but permits can be granted allowing exceptions to this prohibition for actions that may impact a marine mammal if the impact is incidental to, rather than the intention of, the action. Permits for intentional harassment associated with marine mammal research also can be issued. The analysis in this FEIS uses different thresholds for MMPA species.

An MMPA permit would require the Service to take additional precautions to minimize the impacts to listed species. For this reason, both short-term and long-term impacts are assessed for the five marine mammal species that occur on the islands: Steller sea lion, California sea lion, harbor seal, northern elephant seal, and northern fur seal. For this FEIS, the significance threshold for short-term impacts to MMPA species would be Level A Harassment, defined as "any act which injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild" (MMPA 515.18(A)). Long-term impacts are assessed as for other species (see Section 4.5.2).

4.5.3 **Impacts of Alternative A (No Action) on Biological Resources**

4.5.3.1 *Introduction*

If No Action is taken regarding invasive house mice on the South Farallones, the impacts that mice are currently having to the islands' biological resources would continue. The Service and other island staff would continue to control mice in the inhabited dwellings that are on the island, but no other efforts to control mice on the islands would be made. This section summarizes those impacts both known and anticipated. Species on the islands that are unaffected by mice are not addressed. This section also describes the potential for new impacts emerging in the future, as has occurred on certain other islands where mice were introduced (Angel et al. 2009).

4.5.3.2 *Impacts on Birds*

Most of the over 400 species of birds that have been recorded on the South Farallon Islands are not known to be impacted, or negatively or positively, by the presence of house mice. However, several species are impacted by the presence of mice. The following are impacts assessments for those bird species that are affected by mice on the islands and thus could be impacted by Alternative A. Species chosen for assessments are those that occur at relatively high enough frequencies and numbers, and over relatively long periods of time (i.e., season or year-long) as

opposed to those species that occur very infrequently, in low numbers or for only brief migratory stop-overs. For species scientific names not included in the text, see Appendix H.

4.5.3.2.1 Raptors:

- **Long-eared Owl**

Long-eared owls occasionally visit the Farallones, with some individuals (1-2) sometimes remaining for periods of weeks to months in fall and winter. Generally, long-eared owls consume small mammals and small birds (Marks et al. 1994). Like Farallon burrowing owls, it is possible that many of the long-eared owls that remain for periods of time on the islands do so because of the availability of house mice. Although these individual owls may benefit from the presence of house mice, because of the very small numbers of long-eared owls that occur on the islands the significance determination for this species is not significant.

- **Barn Owl**

Because of their secretive and nocturnal habits, barn owls can be difficult to locate on the islands. However, one to two barn owls are frequently present in the fall-spring period. Generally, barn owls consume primarily small mammals, and to a lesser extent small birds, reptiles, and arthropods (Marti et al. 2005). On the Farallones, barn owls are known to prey on Cassin's auklets and house mice (Mills et al. 2016; Point Blue, unpubl. data). Like the better studied burrowing owl, it is possible that at least some barn owls remain on the islands for periods of time because of the availability of house mice. Although these individual owls may benefit from the presence of house mice, because of the very small numbers of barn owls that occur on the islands the significance determination for this species is not significant.

- **Burrowing Owl**

Burrowing owls are fairly common on the Farallones during the fall and winter periods. Because of their secretive and nocturnal habits, burrowing owls can be difficult to locate. Based on available data, the estimated number of individuals likely to occur on the islands through fall-winter is between two and 12 birds but actual numbers are likely greater. Generally, burrowing owls are opportunistic feeders and consume small mammals, small birds, and arthropods (Haug et al. 1993). On the Farallones, they feed primarily on house mice, ashy storm-petrels, invertebrates, and other small birds (Chandler et al. 2016, Mills 2016). As described in Section 1.2.2.1, some fall migrant burrowing owls are attracted to remain on the islands for the fall-winter period because of the availability of house mouse. Although these individual owls may benefit from the presence of house mice, because of the small numbers of burrowing owls that occur on the islands relative to the regional and world populations, the significance determination for this species is not significant.

4.5.3.2.2 Seabirds:

- **Ashy Storm-Petrel and Leach's Storm-Petrel**

These storm-petrels both breeding species on the South Farallones. As described in Section 1.2.2.1, invasive house mice are negatively affecting populations of these small seabirds on the islands. The ashy storm-petrel is a Service Bird of Conservation Concern (USFWS 2008), a California Species of Special Concern (Carter et al. 2008), and are listed as endangered on the IUCN's Red List (Birdlife International 2012). On the South Farallones, house mice indirectly contribute to reduced population size of the ashy storm-petrel, and likely also to the Leach's storm-petrel, by supporting a winter population of burrowing owls that in turn prey on these species.

If house mice remain on the South Farallon Islands, there will likely continue to be elevated rates of burrowing owl predation on storm-petrels. The elevated rates would be the result of house mice providing a prey base which supports an unnaturally larger and longer-staying winter population of burrowing owls on the islands, such that the owls remain on the islands until ashy storm-petrels arrive to initiate breeding activities in mid-winter (Nur et al. 2013a, in review; Appendix M). In order to evaluate the effects of mouse removal on the islands' burrowing owls and ashy storm-petrels, Nur et al. (2013a, in review) conducted a study using best available data from field surveys of owls, mice, and depredated storm-petrel carcasses conducted during 2000-2012. They found that, on a monthly basis, owl predation on storm-petrels was positively related to burrowing owl abundance and negatively related to house mouse abundance. In other words, in months when more burrowing owls are present on the islands, owl predation on storm-petrels is greater, and in months when mouse abundance is lower, owls consume more storm-petrels. Statistical models demonstrated that owl predation on storm-petrels, an indirect impact of house mice, reduced storm-petrel survival and population size in years of high mouse owl abundance (Nur et al. 2013a, 2018). For more information on this topic, see Section 1.2.2.1.
Based on the demonstrated impact of house mice to the Farallon population, and because the Farallon population represents the over 98% of the regional population (McChesney et al. 2013), the significance determination for ashy storm-petrel is significant for the regional population. Because the similar Leach's storm-petrel is less numerous on the South Farallon Islands but still represents the majority of the regional population (Carter et al. 1992, McChesney et al. 2013), and likely is experiencing similar impacts to ashy storm-petrels from owl predation, the significance determination for Leach's storm-petrel is significant for the regional population.

4.5.3.3 *Impacts on Mammals*

Pinnipeds:

Mice are not currently known to impact any of the pinniped species on the South Farallones. Pinnipeds would not be affected if the No Action alternative is adopted and mice are allowed to remain. Based on current information, MMPA significance triggers would not be reached if the No Action alternative were implemented. The significance determination for all pinnipeds is negligible.

4.5.3.4 *Impacts on Amphibians*

- **Arboreal Salamanders**

Arboreal salamanders forage for small invertebrates such as spiders, beetles, isopods, larval lepidoptera, ants, sow bugs, caterpillars, and centipedes on the ground or on the trunks of trees (Lee 2010). Their prey types overlap with the omnivorous diet of the house mouse (Berry 1968, Jones and Golightly 2006). Although direct evidence is lacking, it is likely that when mice are abundant during the summer and fall they limit the amount of food available to salamanders. It is also possible that mice prey on salamander eggs or juvenile salamanders. Competition for prey and/or predation of eggs or juveniles may suppress salamander population size. If mice remain on the islands, these impacts to the salamander population would continue under the No Action Alternative. For this reason, the significance determination for mouse impacts to salamanders is significant.

4.5.3.5 *Impacts on Fish*

Mice are not known to impact fish found around the South Farallones. Fish would not be affected if the No Action alternative is adopted and mice are allowed to remain. The significance determination is negligible.

4.5.3.6 *Impacts on Invertebrates*

Terrestrial Invertebrates

Terrestrial invertebrates comprise a major portion of the diet of mice on the South Farallones (Jones and Golightly 2006) and on other islands (Smith 2008). Although the extent has not been documented, mice have been anecdotally observed feeding on endemic Farallon camel crickets. Preliminary analyses of Farallon mouse diet through stable isotope studies support of these observations (Point Blue, unpublished data). Comparisons to other islands with introduced house mouse populations (Rowe-Rowe et al. 1989, Crafford 1990, Cole et al. 2000) suggest that mice have a substantial impact to the South Farallones invertebrate community, especially during the annual mouse population boom of the late summer and fall (also see Section 1.2.2.3). In New Zealand, researchers have estimated that one house mouse would need to consume 0.16 oz (4.4 g) of invertebrate prey each day, if no other foods were available to meet its daily energy requirements (Miller 1999 as cited in Ruscoe 2001). One study on Mana Island, New Zealand documented a significant increase in capture rates for the Cook Strait giant weta after mice were eradicated (Newman 1994). Invertebrates perform numerous important ecosystem functions on the South Farallones including pollination and decomposition, and they are a food resource for numerous species including salamanders and migrating birds. These adverse impacts would continue if mice are allowed to remain. Thus, the significance determination for insects, spiders, and other terrestrial invertebrates is significant.

Intertidal and Marine Invertebrates

Following the black rat eradication at Anacapa Island, densities of intertidal invertebrates increased significantly as a result of decreased rat predation (Newton et al. 2016). However possible, intertidal and marine invertebrates are not known to be a major portion of the house mouse diet. While it is unlikely that mice would prey on adult endangered black abalone because of their hard shells, it is possible that mice could prey on recently settled juvenile abalone. Thus,

mice could impact the chances of juvenile black abalone to survive to adulthood. However, given the species status on the islands and the region, impacts from this are likely very low. Thus, no population impacts from mice to these intertidal or marine invertebrates are suspected and the significance determination for all intertidal and marine invertebrates is negligible.

4.5.3.7 *Impacts on Vegetation*

The native plant community of the Farallones existed for thousands of years without grazing pressure from rodents or other mammals, which makes house mice a potential threat to the native plants of the islands. Of particular concern are the impacts that house mice are having on the native maritime goldfield, which are a common food item for mice on the South Farallones (Jones and Golightly 2006). Maritime goldfields is annual plants whereas many of the introduced, invasive plants of the South Farallones are perennial and originally evolved under grazing pressure from small mammals such as rodents on the mainland (Coulter 1971, Coulter and Irwin 2005, Hawk 2015, Holzman et al. 2017). Mouse predation on native plant seeds almost certainly reduces cover of these species, better enabling invasive species to outcompete them. So, mice are likely to have less of a negative impact on native plants. The Service currently recognizes invasive plants as a major threat to the South Farallones ecosystem. The presence of mice on the Farallones increases the likelihood that invasive plants outcompete native plants for space, outcompeting native plant communities. For these reasons, the significance determination for native plants is significant.

4.5.4 Impacts of Action Alternatives on Biological Resources

4.5.4.1 *Analysis framework for impacts from toxicant use*

The risk to wildlife from rodent bait is generally determined by two factors: the extent of exposure and the toxicity of the compound (Erickson and Urban 2004). The compounds in the two action alternatives differ in toxicity and the likelihood of exposure for each of the species present on the Farallones. These are discussed in the following sections.

4.5.4.2 *Toxicant Exposure*

Foraging, feeding and other specific behaviors can increase or decrease an animal's exposure to the toxicant. Exposure to a toxicant is primarily dependent on the following factors:

- The availability of the toxicant in the local environment;
- The diet and behavior of the species in question; and
- The effectiveness of mitigation measures at preventing exposure.

The toxicants used for rodent eradications can only effectively be delivered through a bait that must be ingested. Animals can either ingest the toxicant by consuming bait pellets (known as "primary exposure"), preying or scavenging on other animals that previously consumed bait pellets (known as "secondary exposure"), or by consuming soil or other environmental media contaminated with rodenticide. Brodifacoum and diphacinone adhere strongly to the bait pellet matrix and because of their insolubility and relative immobility in soil, they do not leach significantly into ground and surface water. Once the pellets disintegrate into particles too small

for most foraging vertebrates to consume, the toxicant becomes bound to soil particles and is relatively immobile within the environment. Although environmental fate and transport data are scant for diphacinone and brodifacoum, available information suggests that low residue concentrations of the toxicant remaining from a fully disintegrated pellet would break down into non-toxic compounds including carbon dioxide and water with no toxic intermediate compounds (USNPS 2000).

4.5.4.2.1 Primary exposure

Primary exposure is the direct consumption of rodent bait pellets containing the toxicant. Granivorous and omnivorous species, particularly omnivorous scavengers, are more likely to directly consume bait (primary exposure) than carnivorous, herbivorous, or insectivorous species because the bait matrix is composed primarily of grain. It is unlikely that carnivorous and insectivorous species on the Farallones would consume bait pellets intentionally as food.

4.5.4.2.2 Secondary exposure

Secondary exposure is the consumption of prey items that previously consumed rodent bait pellets or incidental ingestion of contaminated environmental media, such as soil. Mice and other animals that directly consume bait could act as a source of the toxicant which can then be passed on to predators or scavengers. Different organisms show considerable variation in the amount of time that they retain toxicants in their bodies. For vertebrates that are exposed sub-lethally, brodifacoum can be retained in the liver for many months. Fisher (2009) reported brodifacoum half-life estimates for chickens as 5.3 days in muscle, 2.79 days for fat and 3.17 days for ovarian tissue. However, brodifacoum retention times for most bird species have not yet been determined. Brodifacoum concentrations in the liver of rats dosed sub-lethally with the toxicant were reduced by 50 percent after 350 days (Erickson and Urban 2004). For invertebrates, the exact mechanisms of brodifacoum retention are unclear but it is generally understood that most invertebrates retain brodifacoum only briefly in their digestive system and not in body tissues (Booth et al. 2001).

Until recently, results from post-eradication monitoring programs have determined that there is not widespread and high rodenticide contamination of fish and wildlife, suggesting that residues do no persist long-term. However, two recent studies highlight the potential for rodenticide residues to persist long-term in the environment. At Desecheo Island, biological sampling the week prior to the 2016 rat eradication attempt revealed that brodifacoum residues can persist in parts of the food web for up to 4 years (Shiels et al. 2017). Low level brodifacoum contamination (generally < 100 µg/g) was detected in a small number of samples consisting of rat, bird, lizard, or insect tissue. An additional case of elevated brodifacoum body burden was described for lava lizards from Galapagos Islands, where livers from lizards contained detectable brodifacoum concentrations (> 10 ppb) greater than 800 days after bait application (Rueda et al. 2016). These findings suggest that post-eradication monitoring programs, including the one proposed for the South Farallon Islands, should, at a minimum, include multi-year (e.g., ≥ 2 years) monitoring of terrestrial organism rodenticide residues and a hazard assessment of the potential impacts, including sublethal effects, associated with vertebrate exposure to lingering rodenticide residues in the environment. These recent findings also indicate that advanced analytical chemistry

methods, such as liquid chromatography-tandem mass spectrometry, a method that is more sensitive than previous liquid chromatography methods used in earlier island eradication monitoring programs, should be used in future post-eradication monitoring programs.

At the Farallones, several species would be at risk of exposure to rodenticides through a secondary pathway. House mice may be at risk of secondary exposure by consuming invertebrates, such as crickets or other insects, dead birds, and other mice that have previously consumed bait. In addition, a small percentage of house mice diet may include soil (Beyer et al. 1994), which could be contaminated with rodenticide following bait application. Shorebirds, landbirds and salamanders may be at risk of secondary exposure to rodenticide through the consumption of invertebrates that have previously consumed bait and contaminated soil or other environmental media. Gulls and raptors present on the Farallones would also be at risk to secondary exposure by potentially consuming poisoned mice and/or non-target species.

Mice that have consumed bait and die in accessible locations would also pose a hazard for the length of time that the carcass remains palatable. Based on anecdotal evidence, carcasses are expected to fully degrade within a five-week period. Carcass collection would also occur when feasible and safe for operations staff, reducing the exposure risk to wildlife scavenging on mouse carcasses.

4.5.4.3 *Toxicity*

4.5.4.3.1 Toxicity to birds and mammals

The acute toxicity of a particular compound to an individual animal is often expressed in a value known as the "LD_{50}" – the dosage (D) of a toxicant that is lethal (L) to 50 percent of animals in a laboratory test, expressed as parts per million (ppm) or milligrams of active ingredient per kilogram of body weight (mg/kg). The EPA has compiled laboratory LD_{50} values and data for both diphacinone and brodifacoum for a number of species. However, due to the difficulty and expense of obtaining extensive laboratory data, the LD_{50} values for many species, including the majority of the species present on the Farallones, are not available for either toxicant. However, it is reasonable to infer LD_{50} information from tests performed on analogous species (Tables 4.1 and 4.2). For the purposes of this assessment, the hazard to many island species was inferred from the most analogous species.

The EPA has determined the acute toxicity of brodifacoum to birds and most mammals to be high to very high (EPA 1998), with a single 24-hour feeding event often sufficient to be lethal. In contrast, diphacinone is generally considered to have low to moderate toxicity to birds and mammals, typically requiring consumption of the toxicant multiple times over many days to be lethal (Erickson and Urban 2004). The impacts of these toxicants are directly correlated with the type of species in question, its metabolism, its weight, and feeding habits. For example, large animals like pinnipeds would need to consume extremely large quantities of rodent bait in order to cause mortality.

There is considerable variation between species, and sometimes between individuals, in regard to the number of bait pellets an individual animal needs to consume to ingest a lethal dose, and the

lethal dose may not always be predictable. Assuming similar sensitivity to a toxicant, animals with a larger body mass must ingest more of the toxicant to reach a toxic threshold, whether that be death or a sublethal effect; for example a 660 lb (300 kg) animal may need to consume approximately 5,000 pellets, or 5 kg (assuming 1 g per pellet at 25 ppm) of Brodifacoum-25D Conservation bait in order to reach a lethal dose, assuming the animal has a sensitivity similar to the Norway rat (EPA 1998). However, other factors also come into play including age, gender, general health status, history of previous exposure, behavior, and the presence of anticoagulant resistance.

Predators and scavengers can also be exposed through secondary pathways by consuming individuals previously exposed to the toxicant. Numerous studies have identified secondary exposure of and/or toxicity of anticoagulant rodenticides to predatory wildlife, including predatory birds, as well as non-predatory birds. Example species that have exposure, toxicity, or potential impact data associated with them include American kestrel (Rattner et al. 2011), Eastern screech owls (Rattner et al. 2012), little spotted kiwi (Robertson and Colbourne 2001), and other raptor species (Thomas et al. 2011). Because of the challenges associated with estimating how much of a rodenticide-exposed prey item a particular predator or scavenger would need to consume to ingest a lethal dose, and because of the lack of toxicity data for the vast majority of species on the Farallones, the hazard analysis outlined within this FEIS is conservative and estimated based on the risk pathways and potential for exposure rather than toxicity data.

Table 4.1. Acute toxicity of brodifacoum to avian species (modified from Erickson and Urban 2004, Godfrey 1986, Eason et al., 2002, Bowie and Ross 2006).

Species	LD_{50} (mg ai/kg bw)	Reference
Mallard	0.26	EPA, 1998a
Canada goose	<0.75[a]	Godfrey (1986)
Southern black-backed gull	<0.75[a]	
Purple gallinule	0.95	
Pukeko	0.95	Eason et al. (2002)
Blackbird	>3[b]	Godfrey (1986)
Hedge sparrow	>3[b]	Godfrey (1986)
California quail	3.3	
Mallard	4.6	
Black-billed gull	<5a	
House sparrow	>6[b]	
Silvereye	>6[b]	Eason et al. (2002)
Ring-necked pheasant	10	Godfrey (1986)

Species	LD_{50} (mg ai/kg bw)	Reference
Australasian harrier	10	
Paradise shelduck	>20[b]	Eason et al. (2002)

[a] the lowest concentration tested
[b] the highest concentration tested

Table 4.2. Acute toxicity of diphacinone to avian species.

Species	LD_{50} (mg ai/kg bw)	Reference
American kestrel	97	Rattner et al. (2011)
Eastern screech owl	130 (LLD)[a]	Rattner et al. (2012)
Northern bobwhite	2,014	Rattner et al. (2010)
Mallard	3,158	Erickson and Urban (2004)

[a] Lowest lethal dose (LLD); LD_{50} could not be calculated.

4.5.4.3.2 *Toxicity to amphibians*

Except for an acute toxicity study with salamanders completed as part of this FEIS (Witmer 2018; Appendix Q), there are no published or known unpublished studies on the toxicity of brodifacoum or diphacinone to amphibians. In general, however, the primary toxicity of brodifacoum and diphacinone to aquatic organisms ranges from moderate to very high (EPA 1998), which may apply to amphibians where, for many species, part of or their entire life cycle is aquatic. Anti-coagulants like brodifacoum and diphacinone block the vitamin K cycle and impede synthesis of active forms of several blood clotting factors necessary for hemostasis in mammals and birds. Because amphibians are poikilothermic (cold-blooded), their blood chemistry and physiology are different from that of mammals and birds (warm-blooded) (Merton 1987), and blood coagulation mechanisms in amphibians are slower than those of mammals (Frost et al. 1999, Kubalek et al. 2002). Based on recent data from a USDA/APHIS study (Witmer 2018; Appendix Q), salamanders appear less at risk from oral exposure to brodifacoum and diphacinone than other vertebrate species. Data and observations from invasive species eradication and control projects that have used these compounds corroborate these findings, an example being the eradication of rats from Anacapa Island (Croll and Newton 2012, Newton et al. 2016). However, hazard to salamanders dermally exposed to rodenticide bait for up to 14 days appears to be elevated, as evidenced by mortality in two of three test species and skin lesions and other sublethal effects (Witmer 2018; Appendix Q). Although the salamander toxicity study represented a worst-case exposure scenario (i.e. where exposure to a rodenticide is maximized), results from the study indicate that potential hazards to salamanders do exist from consuming or being dermally exposed to rodenticides.

In several cases, native amphibian populations either increased or were not substantially affected by an invasive rodent eradication (Table 4.3) (Towns 1991, Newman 1994, North et al. 1994, Towns and Dougherty 1994, Eason and Spurr 1995, Towns et al. 2001, NMFS 2005, Parrish 2005, Daltry 2006, Newton et al. 2016). Thus, the preponderance of evidence suggests minimal negative impacts can be expected to occur to amphibians from the implementation of either action alternative. However, there is still uncertainty associated with the toxicant effect of brodifacoum and diphacinone to amphibians, including salamanders, since only high exposure scenarios have been tested in a laboratory setting. To mitigate for this uncertainty, about 40 individual Farallon arboreal salamanders would be captured and maintained in captivity until risk of exposure and toxicity is negligible, for reintroduction in case of unexpected population impacts (see Section 2.10.7.5).

Based on the results of the study, while exposure to extremely high concentrations of brodifacoum and diphacinone pose a hazard, risk to Farallon arboreal salamanders in a rodent eradication appears to be very low (See Section 2.8.12). The amount of rodenticide in the environment would be of orders of magnitude less than salamanders were exposed to in the study. Combined with the salamanders' largely underground life, risk of dermal exposure is very low and potential impacts from dermal exposure are negligible. Risk of secondary oral exposure from consuming invertebrates that consumed bait pellets is medium to high, but risk of impacts to salamanders is low based on (Witmer 2018; Appendix Q) study results. Thus, the potential for impacts to the Farallon arboreal salamander population is not significant. This finding is consistent with documented impacts to amphibians (including salamanders) from other rodent eradications that used rodenticides.

Table 4.3: Bait consumption and impacts to amphibian species from anti-coagulants.

Island or Region	Species	Impact/Bait	Results	Reference
Anacapa Island, California, USA	Channel Islands slender salamander (*Batrachoseps pacificus*)	No consumption noted of Brodifacoum 25D bait.	No recorded mortality. Post-eradication monitoring indicated that the population was lower than pre-eradication but still numerous in 2011.	(Croll and Newton 2012, Newton et al. 2016)
Hunua Ranges, New Zealand	Hochstetter's frogs (*Leiopelma hochstetteri*)	No consumption noted of brodifacoum, cholecalciferol, or cyanide bait.	No recorded mortality. Post-eradication monitoring showed that frog abundance was significantly greater in pest control area than outside and there were a greater number of juvenile frogs inside the control area, indicating control efforts have had a positive effect on frogs.	(Baber et al. 2007)

Island or Region	Species	Impact/Bait	Results	Reference
Waitakere Ranges, New Zealand	Hochstetter's frogs (*Leiopelma hochstetteri*)	No consumption noted of brodifacoum bait.	No recorded or observed mortality. Frog capture-recapture study indicated that after 7 years of rat control the abundance of frogs within the control area was equal to that outside of the control area. Juvenile abundance and recruitment was similar inside and outside of control area, as well.	(Najera-Hillman et al. 2009)

4.5.4.3.3 *Toxicity to fish*

There is little data on the toxicity of brodifacoum or diphacinone to marine fish. Exposure data (i.e. tissue residues) are more common and are sometimes associated with a fish kill event. The paucity of residue data is not surprising considering marine vertebrates rarely accumulate anticoagulant residues (e.g., 3.1% of samples tested positive for brodifacoum across ten published studies on eradication projects`; Masuda et al. 2015).

Recently presented, unpublished data suggest that 1) fish exposed to anticoagulant rodenticides under laboratory conditions are less sensitive than other vertebrate species, and 2) the risk of direct toxicity from brodifacoum and diphacinone on non-target fish during rodent eradication efforts should be minimal (Riegerix et al. 2017). However, data from other toxicity tests using several freshwater fish species used in standard laboratory tests resulted in diphacinone being labeled as moderately toxic to fish. The 96-hour LC_{50} for technical diphacinone in channel catfish (*Ictalurus punctatus*) was 2.1 mg/L, 7.6 mg/L in bluegill sunfish (*Lepomis macrochirus*) , and 2.8 mg/L in rainbow trout (*Oncorhynchus mykiss*) (Extoxnet. 1996). The 48-hour LC50 in *Daphnia magna*, a small freshwater crustacean, was 1.8 mg/L (Extoxnet. 1996). Brodifacoum is considered to be highly toxic to fish species tested in laboratory trials in the USA. The LC_{50} for rainbow trout exposed to brodifacoum for 96 hours was 0.015 mg/L. The LC_{50} for bluegill sunfish exposed to brodifacoum for 96 hours was 0.025 mg/L (USEPA 1998). A recent study with black triggerfish (*Melichthys niger*), red-toothed triggerfish (*Odonus niger*), largemouth bass (*Micropterus salmoides*) and fathead minnow (*Pimephales promelas*) demonstrated that these species are among the least sensitive to diphacinone and brodifacoum (Riegerix et al. 2017). Using intraperitoneal injection, LC_{50} values for brodifacoum and diphacinone, respectively, were calculated to be: 75 – 96 µg/g and 248 – 303 µg/g in largemouth bass; 47 – 52 µg/g and 165 – 241 µg/g in fathead minnow; 50 – 75 µg/g and 90 – 122 µg/g in black triggerfish; and 36 – 48 µg/g and 137 – 175 µg/g in red-toothed triggerfish. The average estimated half-life

of brodifacoum or diphacinone in fish liver was less than seven days for all species except for brodifacoum in red-toothed triggerfish (8 days), demonstrating that anticoagulant rodenticides are cleared rapidly from fish liver (Riegerix et al. 2017).

The USDA/APHIS collected 23 samples of two different mullet species found in the lagoons of Palmyra Atoll after Brodifacoum-25W Conservation was broadcast at 84kg/ha and 79kg/ha in two separate applications for rat eradication in 2011. Brodifacoum residues were detected in all fish found dead after bait application. Two species of mullet were found, "kanda" (*Moolgarda engeli*) and "square-tailed mullet" (*Liza vaigiensis*). The average residue in the 23 mullet samples was 0.337 ± 0.014 mg/L and residues declined over time with the highest residues recorded in the earliest recovered samples. In addition, ten samples consisting of 30 individual black-spot sergeant fish (*Abudefduf sordidus*) were collected systematically around the atoll following the bait application period (Pitt et al. 2015). Nine of the 10 sergeant fish samples collected during this period contained detectable brodifacoum residues. The average residue detected was 0.143 ± 0.027 µg/g. The only other fish species recovered from Palmyra Atoll following bait application was a puffer fish and analysis showed brodifacoum residues of 0.44 mg/L (Pitt et al. 2015). It should be noted that bait application rates used on this project were much higher than those proposed for the Farallones.

On Wake Island, Brodifacoum-25W Conservation rodent bait was applied at 18kg/ha and 9kg/ha in two separate applications to eradicate rats. Of 42 fish samples (various *spp.*) collected from the atoll's lagoon after bait application, low levels of brodifacoum (0.002 – 0.005µg/g) were found in four black snappers (*Macolor niger*) and one papio (*Caranx melampygus*) (Island Conservation, unpubl. data).

Marine fish surveys on Kapiti Island, New Zealand were conducted at three sites before and one to two months after the aerial application of brodifacoum in the form of Talon 7-20 bait (containing 0.002% brodifacoum). No change was found in the density of spotty (*Notolabrus celidotus*) during observations, and divers did not find any dead or moribund organisms (Empson and Miskelly 1999). Empson and Miskelly (1999) also conducted an aquarium trial with blue cod (*Parapercis colias*), spotty, and triplefins (*Forsterygion varium*) where individuals were fasted for 24 hours before being exposed to brodifacoum bait for 1 hour and then held for 23-31 days of observation. Six of 24 triplefins exposed to bait died, although none were observed eating bait and no residue was detected in their livers. Six of 30 spotties ate toxic bait and one died of brodifacoum poisoning. Two other spotties died, did not eat bait, but showed clinical signs of poisoning. It is likely in the latter two that the poison was absorbed through gills or skin (Empson & Miskelly 1999). It is important to note the amount of intact baits that fish were exposed to during this trial was extremely high compared to that which would be expected following the proposed South Farallon Islands mouse eradication.

Eighteen tons of brodifacoum bait was accidentally spilled into the ocean at Kaikoura, New Zealand in May 2001 (Primus et al. 2005). No fish were found dead and of the five fish sampled only a Japanese butterfish (*Psenopsis anomala*) tested nine days after the spill had detectable residues of 0.040 mg/L in the liver and 0.020 mg/l in the gut (Primus et al. 2005).

Banded wrasse (*Notolabrus fucicola*; n = 5 fish); girdled wrasse (*Notolabrus cinctus*; n = 1 fish); spotty (*Notolabrus celidotus*; n = 10 fish), trumpeter (*Latris lineata*; n = 5), and blue cod (*Parapercis colias*; n = 30) were collected following the application of brodifacoum bait on Ulva Island in 2011 (Masuda et al. 2015). Brodifacoum was found only in blue cod. Brodifacoum was detected in liver but not muscle tissue in two of six composite samples (5 individuals each) collected 43 days after the first application of bait on the island. Samples collected at 77 days and 176 days following bait application were not positive for brodifacoum residues. There was no observed fish kill following aerial application of rodenticide bait.

4.5.4.3.4 *Toxicity to invertebrates*

Most invertebrates are not susceptible to anti-coagulants because they do not have the same blood clotting systems as vertebrates (Shirer 1992 in Ogilvie et al. 1997). However, there are exceptions, where diphacinone and brodifacoum can be moderately to highly toxic to invertebrates, such as in stagnant, freshwater conditions (EPA 1998). Primary exposure to toxic bait has been reported in several invertebrate taxa (including *Coleoptera, Blattodea, Orthoptera, Scorpiones, and Haplotaxida*); however, consumption of diphacinone or brodifacoum baits did not result in mortality (Morgan and Wright 1996, Ogilvie et al. 1997, Booth et al. 2001, Booth et al. 2003, Gerlach 2005). Toxic residues have been found in the tissues of various invertebrate species. The National Wildlife Residue database reported 38 out of 76 samples (including beetles, cockroaches, weta (*Hemideina* spp.), and others) contained brodifacoum residue; the highest concentration (7.47 µg/g) was found in a 4.3 g weta, the common name for a group of about 70 insect species in the families *Anostostomatidae* and *Rhaphidophoridae* endemic to New Zealand (reported in Booth et al. 2001). A recent literature review identified that brodifacoum residues in marine species have been monitored following 10 aerial applications between 1997 and 2011. Brodifacoum residue was detected in 11 of 196 marine invertebrate samples (5.6%) across all case studies (Masuda et al. 2015). Brodifacoum residue concentrations ranged from 0.0001 to 0.022 µg/g.

Based on past studies and public comments on the RDEIS, exposure of land crabs to and/or potential toxicity from rodenticides has been an issue of potential concern. Certain land crabs are known to consume large amounts of rodenticide bait pellets. Although brodifacoum was not found to be toxic to land crabs (*Gecarcinus lagostoma*) on Ascension Island (Pain et al. (2000), another study found dead land crabs containing brodifacoum residues under similar conditions on Palmyra Atoll (Pitt et al. 2015), although brodifacoum could not be confirmed as the cause of death. On Palmyra Atoll, fiddler crab brodifacoum concentrations peaked (both in concentration and number of positive samples) after two weeks of the first application. Both brodifacoum concentrations and number of detections decreased following the second aerial application. In hermit crabs, brodifacoum concentrations were highest approximately one week after the first application and around the same time as the second aerial application. Brodifacoum residues in hermit crabs did not decrease substantially until approximately two months following first aerial application; the same trend was observed for numbers of hermit crabs with detectable brodifacoum concentrations. There is some uncertainty about potential long-term impacts of brodifacoum to crabs because relatively few of them were collected dead following applications, and no searches were conducted two months after the first application. However, the comparison between Palmyra Atoll and South Farallon Islands is arguably inappropriate, especially

considering the high rodenticide application rate used on Palmyra Atoll (total of 155 kg/hectare for aerial application) and that there are no land crabs or similar species on the South Farallon Islands. Other studies have also demonstrated that land crabs are not negatively affected by anticoagulant rodenticides, though they indicated crabs could be sources of secondary exposure (Buckelew et al. 2005, Island Conservation 2010).

Field studies suggest that some species of terrestrial mollusks are unaffected by brodifacoum (Brooke et al. 2010, Brooke et al. 2011). However, mortality as a consequence of deliberate exposure to brodifacoum has been recorded for three species of land snail, *Achatina fulica, Pachnodus silhouettanus,* and *Pachystyla bicolor* (Gerlach and Florens 2000, Booth et al. 2001, Gerlach 2005). The only gastropods on SEFI are found in the marine environment and the likelihood of their exposure to anticoagulants at the levels that caused mortality in the three species listed above is considered negligible. Nevertheless, precautions will be taken to minimize the risk of bait drift into marine areas and monitoring of impacts to marine gastropods would be incorporated into the proposed monitoring program (Section 2.10.7.7).

In the aforementioned May 2001 brodifacoum bait spill at Kaikoura, New Zealand, concentrations of brodifacoum in mussels peaked at 0.41 µg/g one day after the spill and averaged just above detectable concentrations by Day 29. Mean brodifacoum concentrations in abalone gut and muscle tissues were the highest on Day 29, and at Day 191 there was a mean of 0.003 µg/g brodifacoum for gut and of 0.0015 µg/g for muscle tissue. Residues in mussels and abalone took up to 31 months to decline to concentrations below the limit of detection. This persistence of brodifacoum was thought to be due to a combination of a prolonged half-life in these invertebrates and re-exposure of these invertebrates to particulate brodifacoum in the high dynamic tidal marine environment (Primus et al. 2005).

4.5.4.3.5 Sublethal effects

Aside from anticoagulant rodenticide effects on blood clotting, these compounds can elicit other sublethal effects in multiple organ systems of exposed vertebrates. In humans, clinical effects include anemia (red blood cell deficiency), fatigue, dyspnea (breathlessness), nosebleeds, bleeding gums, hematuria (blood in the urine), melena (darkened feces associated with gastrointestinal bleeding), and extensive ecchymosis (large bruises) (Roberts and Reigart 2013). In dogs, exposure to these compounds can manifest in ocular abnormalities such as subconjunctival hemorrhage (Griggs et al. 2016). In wildlife, anticoagulant rodenticide effects can result in the above-mentioned effects as well as include alteration of liver and kidney function, hemorrhaging in various organ systems, growth reduction, behavioral abnormalities, metabolic alterations, and increased immune system susceptibility. At the cellular and organ response levels, plausible linkages have been made for ischemia (restriction of blood supply to tissues), necrosis (uncontrolled cell death), decreased bone density, blood acidosis, and organ dysfunction (Rattner et al 2014). Some anticoagulant rodenticides, like diphacinone, may also affect cellular energy generation by uncoupling oxidative phosphorylation which has the potential to result in fatigue and restlessness (van den Berg and Nauta 1975). At the individual level, decreased fitness and body condition are possible. Population-level impacts to predatory mammals and birds have been hypothesized, but not yet established (Rattner et al. 2014). Other researchers have suggested that wildlife exposed to anticoagulant rodenticides may become more

susceptible to environmental stressors, such as adverse weather conditions, food shortages, and predation, although there is a paucity of data on these topics.

Among birds, raptors are especially susceptible to secondary poisoning and among the most sensitive group of wildlife. Initial observed signs of secondary exposure toxicity in raptors exposed to first generation anticoagulants, like diphacinone, include fatigue, evidenced by wing-drooping (Radvanyi et al. 1988). Sub-lethal effects can occur despite relatively low doses of diphacinone and low tissue residue concentrations. For example, livers from American kestrels administered diphacinone contained low diphacinone residue concentrations (less than 1 µg/g down to the detection limit of diphacinone), but histological evidence revealed hemorrhages in lung and liver tissues and other histological abnormalities (Rattner et al. 2011). Eastern screech-owls fed diphacinone for 7 days exhibited sublethal responses such as coagulopathy and histopathological lesions in the liver and heart at a small fraction (<5%) of the acute oral dose (Rattner et al. 2012). Subtler, overt signs of toxicity included pale oral cavity and featherless tracts in the study with eastern screech-owls.

Sublethal signs of brodifacoum toxicity in birds are similar to above descriptions, but additional abnormalities have been documented in the literature. For example, Japanese quail exposed to brodifacoum under laboratory conditions showed signs of lethargy, ataxia, and minor bleeding at sites of new feather growth (Webster et al. 2015). Adverse effects to reproduction are possible, too, as evidenced by gross abnormalities observed in quail ovaries and testes. However, data on reproductive effects are generally lacking in most wildlife species.

A range of sublethal effects that have been reported in published literature for birds have a reasonably foreseeable chance of occurring in exposed non-target bird species of the South Farallons Islands. Based on analyses of the existing wildlife of the islands, western gulls, raptors, and intertidal feeding species have the greatest chance of being exposed to anticoagulant rodenticide and experiencing sublethal effects. However, none of the described sublethal effects would rise to the level of significance under either action alternative. The chance of bird exposure and potential adverse effects will be minimized through implementation of a series of mitigation measures, including an extensive hazing program.

4.5.4.4 *Analysis of High-Risk Species*

4.5.4.4.1 Western Gulls

4.5.4.4.1.1 Biology and Status

Western gulls are expected to be present in variable numbers on the Farallones during and after the proposed timing of the eradication operation (Section 2.10.7.1). Gull numbers on the South Farallon Islands vary day to day and between years. Over the years western gull populations for the entire proposed operational window ranged from a low of 1,800 to a high of 14,000, while daily counts of gulls have been as low as 15 individuals (Point Blue, unpub. data). Annual numbers of western gulls typically are lowest in late summer to mid-fall (Penniman et al. 1990), when most birds present are in overnight roosts in shoreline areas. Around early December, attendance begins to increase as breeders begin to sporadically visit the island. If no measures

were taken to reduce gull attendance, the number of western gulls present on the Farallones would likely increase over the period of the eradication operation.

Western gulls are generally opportunistic omnivores that eat nearly anything of interest both at sea and on land. Western gulls at the Farallones primarily feed on marine invertebrates and fish. They also regularly eat eggs and chicks of seabirds (including their own species), scavenge carrion and refuse on land, forage and scavenge at sea, in intertidal areas, along beaches, and at landfills (Ainley et al. 1990a, Pierotti and Annett 1995, Shaffer et al. 2017).

In addition to western gulls, several other gull species that visit the Farallones during the non-breeding season may be present during the proposed operational period. See Sections 4.5.6.1.1.7 and 4.5.6.2.2.7 for estimates of the numbers of gulls and the impact assessment for each species expected to be present during the operational period of each action alternative. Like the western gull, most but not all of these other gull species are omnivorous, opportunistic feeders. The risk to these species from either action alternative is similar to but somewhat lower than that of western gulls because of their lower population numbers and smaller range of habitats used; most occur solely in shoreline roost sites. However, the Service would take the same precautionary measures to mitigate risks to these species as planned for western gulls (Section 2.10.7.1).

4.5.4.4.1.2 Potential Rodenticide Exposure Pathways for Farallon Gulls

Given the diet and behavior of gulls and the environmental fate of brodifacoum and diphacinone following bait application, there are two major routes of exposure to gulls: 1) ingestion of rodenticide pellets (primary uptake); and 2) ingestion of rodenticide-contaminated carcasses (e.g. mice, birds; secondary uptake). Gulls present on the Farallones during and after a mouse eradication operation could potentially be exposed to the rodenticide through these pathways.

The quantitative risk assessment, presented in Appendix F and discussed briefly in Section 4.5.4.4.1.4, evaluates the degree of the toxicological risk to western gulls via primary and secondary exposure pathways. Tertiary and further pathways of exposure are possible as are multiple, repeated exposures via the exposure pathways. However, these were not evaluated in this analysis because of the high likelihood of mortality from a single feeding exposure event. There is uncertainty in calculating the toxicological risk to western gulls due primarily to the lack of species-specific toxicity data for western gulls; however, other model parameters that are variable or have high uncertainty are either treated as distributions or considered in a sensitivity analysis to determine their importance to model predictions.

4.5.4.4.1.3 Gull Population Viability Analysis

Trials undertaken on the Farallon Islands National Wildlife Refuge (Appendix A) identified western gulls as a non-target species at risk from the proposed mouse eradication operation. Although abundant and widespread, the South Farallon Islands supports the largest known colony of this species. Consequently, investigating potential population level-impacts to western gulls was considered critical in evaluating the feasibility of the proposed project. A population viability analysis using long-term Farallon gull data sets to model future trends for this population was undertaken (Nur et al. 2013c) and updated with an Addendum for this FEIS

(Appendix N). Western gulls are the only species considered in the modeling exercise as they typically out number other gulls by at least 100 to one and are likely the only gull species at high risk of population-level impacts without implementing mitigation measures. Additionally, the Service would utilize the same mitigation tools to prevent impacts to other species during the operational window.

Population viability analysis (PVA) is a species-specific method of risk assessment frequently used in conservation biology. PVA has been described as a marriage of ecology and statistics that brings together species characteristics and environmental variability to forecast population health and risk. Each PVA is individually developed for a target population or species, and consequently, each PVA is unique. An important strength of a Population Viability Analysis is that it incorporates the unpredictable variation in demographic parameters (e.g., survival, breeding success, probability of breeding, age at first breeding, etc.) that reflects underlying environmental variability. The basis of the PVA is a matrix whose values or elements are allowed to fluctuate in relation to variation in the future environment. This allows for a quantitative assessment of future populations and evaluation of actions that may reduce or increase risk. This PVA incorporates data based on Point Blue's continuous long-term studies of westerns gulls on the Farallon Islands.

Future scenarios were assessed with and without anticipated gull mortality associated with a mouse eradication operation under varying environmental conditions accounting for strong statistical variability over multiple decades. Three background environmental scenarios were modeled depending on long-term future breeding success (or, productivity; numbers of chicks produced per pair per year): 1)" Optimistic" with high gull productivity; 2) '" Realistic", with long-term average gull productivity; and 3)" Pessimistic", with greater incidence of very low productivity as was observed from 2009 to 2011. Variable reproduction rates were taken into account, based on 30 years of continuous data for this species at this site. The range of scenarios addressed was broad and inclusive of likely outcomes for this population over the next 20 years.

Model predictions were that this western gull population would grow by 10.6 percent under Optimistic conditions, decline by 8.7 percent under Realistic conditions, or decline by 27 percent under Pessimistic conditions after 20 years with no one-time mortality event of gulls as could occur during a mouse eradication project. Using these results, additional models examined the numbers of gulls that could be removed from the population in a one-time mortality event (as could occur during a mouse eradication project) that would produce no detectable change in population trend (or, no population level impacts) for each scenario over 20 years. Estimates were 1100 (Optimistic), 1700 (Realistic), and 1900 (Pessimistic) western gulls. Since the Realistic scenario is the expected scenario, impacts assessments for this project use the value of 1700 western gulls as the significance threshold. There was concern that if very low breeding success observed in 2009-2011 continued, the Realistic scenario may not be appropriate. Additional modelling (Addendum to Appendix N) actually showed that under the Pessimistic scenario, even more gulls could be removed from the population with no population level impact. In addition, gull breeding success since 2011 has reflected the Realistic scenario (Warzybok et al. 2018).

Under Realistic breeding conditions, the loss of up to 1,700 western gulls, given an overall population of 32,200 birds including all individuals of all breeding and non-breeding states (many of which would not be on the island during proposed implementation), would be unlikely to cause long-term impacts for this population. In light of the success of recent avian hazing trials (Section 2.10.7.1), the results of a gull risk assessment (Section 4.5.4.5.1.4), and the planned use of adaptive management in project decision making, it is concluded that gull mortality as a consequence of either action alternative would be unlikely to exceed the threshold of 1,700 individuals.

4.5.4.4.1.4 Gull Risk Assessment

Western gulls are considered the non-target species most at risk of impacts from the application of rodent bait to eradicate mice from the South Farallon Islands. Consequently, the Service determined that an analysis of potential risks to western gulls, to quantify the likely risk and identify key risks to individuals, was warranted.

A probabilistic model known as the Western Gull Risk Model was used to estimate the effects of the two action alternatives to western gulls at the South Farallones (Appendix F). The exposure portion of the western gull risk model includes both the primary and secondary routes of dietary exposure. The model estimated daily intake of rodenticide from ingestion of pellets and mice for each of 90 days following initial application. The whole-body tissue concentration in gulls on any given day is the total daily intake for that day plus the tissue concentration remaining from the previous day. The model runs were for a total of 90 days to account for the possibility of two or three applications depending on the toxicant with an interval of up to several weeks apart. The second and subsequent applications could result in pellets being in the environment for a substantial period of time given that there will be few mice available to consume them. However, by 90 days, weathering and consumption is expected to have removed all or very nearly all rodent bait from the environment. The exposure metric chosen by the model for comparison to the effects metric is the maximum tissue concentration in gulls during the 90-day simulation.

The Western Gull Risk Model determined the fate (i.e., alive or dead) of 11,000 gulls, which is the maximum number of gulls expected to be on South Farallon Islands during the November to March timeframe if under typical conditions. Each simulation of the model determined the fate of a western gull. At the outset of a simulation the characteristics of the gull were randomly chosen (i.e., sex, body weight, life stage). At the same time, the model determined whether the gull would be present to forage on pellets and/or mice. As a mitigation measure, gull hazing would be implemented as part of the eradication operation to reduce the number of gulls on the islands immediately following bait application. Thus, the probability of a gull being present is equal to the user selected value for expected hazing success. Gulls that are not responsive to repeated hazing will be present each day to forage on the islands.

Most of the Farallon western gull population is not expected to be present if initial application occurs in the expected timeframe of early to mid-November. Thus, for each gull, a starting date for its appearance on the island was determined by the model. Once a gull appears on the islands, it was assumed to remain in the area until at least mid-February though only unhazed gulls were assumed to forage on the island.

Availability of rodenticide pellets at any given time step is a function of initial availability (i.e., initial application rate) and the rate at which pellets disappear from the environment (e.g., due to consumption by mice, weathering). Subsequent rodenticide applications increase availability of pellets. The probabilities of an unhazed gull consuming pellets and mice over time were calculated using observational data from South Farallon Islands in 2010. If by random chance pellets and/or mice are consumed at a time step, then the numbers of pellets and/or mice consumed were determined by the model based on the energetic requirements of western gulls and estimated availability of pellets and mice on the island. Primary exposure for each time step is a function of the number of pellets consumed multiplied by rodenticide concentration in each pellet. A similar approach was used for secondary exposure.

The availability of both pellets and dead mice changed over time in the Western Gull Risk Model. Subsequent time steps accounted for the relative availability of pellets and mice by assuming that consumption rates are linearly related to availabilities (i.e. gulls do not increase or decrease their search efforts in response to declining availability of pellets and mice). In the case of pellets, availability declines rapidly after the initial rodenticide application because of consumption by mice, gulls, and weathering if a significant rainfall event occurs shortly after application. For subsequent applications, however, pellet availability remains constant until a significant rainfall event occurs causing the pellets to break down over the next few days. In the case of mice, availability declines rapidly from the time they experience symptoms to their death several days to less than two weeks later. After that, mice are not part of the gull diet, and thus there is no further secondary exposure.

Gulls learn over time, and thus the model assumed conditional probabilities for primary and secondary exposure. That is, if a gull consumes pellets by random chance in the preceding time step, then there is an increased probability of consuming pellets in the subsequent time step. Conversely, if a gull does not consume pellets in the preceding time step, then there is a reduced probability of consuming pellets in the subsequent time step. The same logic was used for gulls consuming mice.

At each daily time step in the model, a tissue concentration is calculated for the gull of interest. The model then searched for the maximum tissue concentration that occurred during the simulation. The maximum tissue concentration is the exposure metric for the gull of interest. The maximum tissue concentration in each western gull was compared with a randomly chosen gavage dose (in units of mg active ingredient/kg body weight to match the units of the exposure metric) from the dose-response curve for a gull or surrogate species. If the exposure dose for the gull exceeded the randomly chosen effects dose, the bird was considered dead. Otherwise, the bird was assumed to have survived the rodenticide applications. The model then proceeded to simulate the next gull. The process repeated for the number of model simulations selected by the user.

The net result over many simulations was that the entire dose-response curve was sampled capturing the expected range of sensitivities in the South Farallones gull population. By sampling the expected range neither the conservative analysis is biased, as would be the case with

selecting a 'no observed effect' level or a low percentile on the dose-response curve (e.g., LD_{50}); nor are potential effects to sensitive birds missed, as would be the case with relying on the LD_{50}.

Model runs were conducted to determine how different application options (e.g., different application dates, differing rates of hazing success, etc.) for the two action alternatives affected predictions regarding mortality of western gulls. A PVA conducted by Nur et al. (2013c; Section 4.5.4.5.1.3) indicated that a one-time mortality event of 1,700 individual gulls would not result in an ecologically distinguishable change in the expected population trend of the western gull on the South Farallones over a 20-year period. Gull risk model predictions were compared to this benchmark.

It is clear from modeling analyses that Alternative B (Preferred Alternative) poses a higher risk to non-target western gulls than does Alternative C. The modeling analyses further indicate that an early application date, high hazing success, and an early rainfall event after the last application significantly reduce predicted gull mortality. Assuming an early initial application date (November 1) and hazing success of 90 percent or higher, neither alternative is likely to exceed the thresholds described in Section 4.5.4.5.1.3. The modeling analyses also demonstrated that the primary route of exposure (direct consumption of pellets) was, by far, the most important route of exposure for western gulls for both rodenticides. Consequently, to minimize gull mortality, both action alternatives would include gull hazing, would start as early as is feasible, and would include other measures such as carcass and bait removal if necessary to reduce gull exposure to bait.

4.5.5 Analysis framework for impacts from disturbance

4.5.5.1 *Helicopter operations*

Low-flying aircraft used for the application of rodent bait or to support a gull hazing program on the South Farallon Islands would result in short-term disturbance to wildlife from sound, the visual appearance of an aircraft, or a combination of both (Efroymson and Suter II 2001). Wildlife would be exposed to noises that exceed background levels. Pinnipeds and seabirds on the Farallones are at a higher risk of disturbance from helicopter operations than other species. This is due to the relatively low altitude at which helicopters would need to fly to apply bait and support gull hazing operations. However, the majority of helicopter noise would be focused in a narrow cone directly underneath the helicopter, reducing the area of disturbance for each helicopter pass (Richardson et al. 1995). Animals on shore would be exposed to higher-decibel noise than animals in the water.

Short-term impacts to seabirds, shorebirds and pinnipeds from helicopter bait broadcast operations will include flushing animals off roosts and haul-outs. Because it would be outside the breeding season for all bird species but ashy storm-petrels which are nocturnal and nest underground, no breeding birds would be affected. Giese and Gale found that adult and chick king penguins (*Aptenodytes patagonicus*) responded to helicopters at a decibel level associated with flying below 900 feet (Giese and Gales 2008). Most birds, except for gulls which will be hazed from the islands, are expected to either land on the water nearby or return to the islands within several minutes of flushing. Sudden pinniped flushing events can result in stampeding,

which can result in injuries to certain animals. To minimize the chances of such occurrences, pinnipeds will first be herded slowly towards the water to clear areas of animals immediately prior to baiting. Most pinnipeds are expected to return to haul-outs within a few hours of flushing. While no pinniped species will be actively breeding at the time of implementation, the two sea lion species and northern fur seals will still be nursing pups born during in the June-July period. Pups of their ages are highly mobile, are left alone for several days at a time, and enter the water regularly.

During each application of rodent bait, all points on the Farallones would most likely be subject to at least two overflights by the helicopter. Over the course of bait application operations, which would entail two to three applications depending on the alternative, there would likely be two to six days during which the helicopter would operate. The responses of animals to aircraft disturbance and the adverse effects of this disturbance vary considerably between species and different seasons. However, given the short duration of operations, impacts of helicopter disturbance to seabirds and pinnipeds are expected to be short-term and would not result in significant harm to individuals or their populations.

A quieter reciprocating engine (piston) helicopter may be used to support a hazing program to reduce the number of gulls on the islands (Section 2.10.7.1, Appendix E). If a helicopter was used for gull hazing it is expected to be used for a period of up to 9 weeks for Alternative B and 17 weeks for Alternative C. Alternative C may require additional operation days due to the additional time for Diphacinone-25 Conservation bait to degrade to a level that would be undetectable or unpalatable to western gulls. The helicopter would require flights over most areas of the South Farallon Islands. Helicopter activity would be concentrated along the shoreline and over areas where gulls are difficult to haze via ground-based hazing techniques (Appendix E). Flights would be undertaken periodically throughout each day that the hazing program is in place but would be concentrated in the mornings and evenings when gulls are most active on the islands. Gulls would be flushed to move them away from the island. This is expected to have minor energetic costs to gulls because they will need to find alternate roost sites either on the nearby water or other distant land-based locations, such as the Middle or North Farallon Islands or the mainland. Other seabirds such as pelicans and cormorants, shorebirds, and pinnipeds may be alerted, displaced or flushed temporarily but are not likely to experience significant affects from the hazing helicopter.

4.5.5.2 *Personnel activities*

Additional wildlife disturbance could result from personnel traveling by foot across the island (e.g., when hand-broadcasting bait, tending bait stations, monitoring activities, and non-target hazing operations), arriving or departing the island by helicopter, or traveling in small boats in the nearshore waters. Personnel dedicated to mouse eradication would be based at the South Farallones for around four months under Alternatives B and C, including: a small crew for approximately two months preparing for the operation; a larger crew for two months (Alternative B) or 4.5 months (Alternative C) during and immediately after the baiting operation; and a small crew for a month after that. Following eradication, there would be several monitoring visits to the island each year for at least two years post eradication. There are personnel on the Farallones conducting ongoing research, monitoring, and other management activities year-round, but

mouse eradication would increase the number of personnel and the extent of impact to species on the island. Most current monitoring activities take place in discrete and limited areas of the island, whereas mouse eradication operations would require personnel to travel throughout much of the islands. Personnel would be briefed on techniques to reduce wildlife disturbance, although some temporary and unavoidable disturbance events would likely still occur.

4.5.5.3 *Gull Hazing*

Gull hazing activity as described in Section 2.10.7.1 will have minor, medium (Alternative B) to long-term (Alternative C) disturbance impacts (see Section 4.5.6) on western gulls and other gull species by causing them to depart island roost sites. Gulls will either land on the nearby waters surrounding the island or depart for other land-based roost sites on Middle Farallon, North Farallones, or the mainland. Gull hazing is also expected to cause some temporary disturbance to other roosting or foraging bird species and several bird species are expected to be affected during the period of hazing activity, which could span about 6 weeks (Alternative B) to 16 weeks (Alternative C) depending on how long unconsumed bait remains available for gull consumption.

Hazing is not likely to have major impacts on pinnipeds hauled out on the islands but hazing would cause some animals to be alerted, moved, or flushed. During the hazing trial, responses by pinnipeds to hazing activities varied depending on the hazing tool employed and the species present, but only rarely did hazing activities result in pinnipeds being flushed into the water (See Appendix E). Most animals flushed are expected to return to the islands relatively quickly (e.g., within hours). However, some studies have shown that harbor seals flushed by military activities may not return within a short period of time (Holst et al. 2005). Pinnipeds that flush and do not immediately return likely will disperse to at-sea foraging areas or to other haul-outs on the mainland. Based on the hazing trial results, no pinnipeds are expected to suffer injuries or death due to hazing activities.

4.5.6 **Impact Indices**

The following impact indices were utilized to determine the level of risk to non-target individuals of each species assessed from the perspective of:

1. Duration of Risk/Duration of Toxicant Risk – the duration of toxicant risk to individuals of the species based on the amount of time that rodenticide would be available to the species in question through either primary or secondary exposure pathways;
2. Toxicant Sensitivity – the susceptibility of individuals of thespecies in question to the toxicant based on LD_{50} data available for similar species; sensitivity of a species or group of similar organisms to a rodenticide corresponds with ecotoxicity categories for terrestrial and aquatic organisms used by EPA;
3. Toxicant Exposure Risk Level – the number of exposure pathways available (both primary and secondary) to individuals of the species based on feeding ecology and toxicant fate;
4. Overall Toxicant Risk – toxicant risk to to individuals of the species from a combination of duration of risk, exposure, and sensitivity;
5. Disturbance Risk – the sensitivity to disturbance and the amount of disturbance risk that individuals of the species may be exposed to during operations;

6. Duration of Disturbance Risk – the period of time that individuals of the species would be exposed to disturbance risks;
7. Scale of the Negative Risk to the Population – the relative number of individuals (based on population scales) that may be affected from a combination of toxicant and disturbance risks and the resulting effects on the regional or world breeding population; and
8. Significance Determination – the expected significance level of impacts to the regional or world population of the species from the given alternative based on the assessment of the above impact indices.

The following breakdown of the impacts indices provides the framework of analysis utilized for determining the impacts from the two action alternatives:

- Duration of Risk/Duration of Toxicant Risk
    - Short: Bait or animal tissue with toxicant residue available for up to 30 days;
    - Medium: Bait or animal tissue with toxicant residue available for 31 to 90 days;
    - Long: Toxicant available anywhere in the environment for more than 90 days.
- Toxicant Sensitivity (see table below for further explanation)
    - None: No sensitivity to the toxicant
    - Low: Minor sensitivity to the toxicant
    - Medium: Moderate sensitivity to the toxicant
    - High: Major sensitivity to the toxicant
- Toxicant Exposure Risk Level
    - None: Negligible exposure pathway
    - Low: Possible exposure pathway
    - Medium: One exposure pathway
    - High: Multiple exposure pathways
- Overall Toxicant Risk (duration + sensitivity + exposure)
    - None: Negligible overall toxicant risk
    - Low: Minor overall toxicant risk
    - Medium: Moderate overall toxicant risk
    - High: Major overall toxicant risk
- Disturbance Sensitivity
    - None: Negligible sensitivity to disturbance
    - Low: Low sensitivity to disturbance
    - Medium: Moderate sensitivity to disturbance
    - High: Major sensitivity to disturbance
- Duration of Disturbance Risk
    - Short: Disturbance impacts for up to 30 days
    - Medium: Disturbance impacts for 31 to 90 days
    - Long: Disturbance impacts for more than 90 days
- Scale of Toxicant/Disturbance Risk within a Population
    - Individuals: Few individuals affected.
    - Regional population: Many individuals affected with impacts to the regional breeding population of the species
    - World population: Many individuals affected with impacts to the global population of the species

- Significance Determination
    - Negligible: No short- or long-term impact is expected from the alternative;
    - Not Significant: Some short-term negative impacts from the alternative are expected; however, the effects are not expected to be significant to the population in the long-term
    - Significant: Long-term effects are expected for the species from the alternative and the significance threshold (See Section 4.5.2) will be exceeded.

The species that were analyzed for potential impacts from eradication operations were chosen if a clear primary or secondary exposure pathway was identified and if they were expected to be present on the islands during the proposed operational window. For birds, all current breeding seabird species were included in impacts assessments. For the hundreds of non-breeding bird species that have occurred on the islands, daily bird count data collected by island biologists for the ten-year period between 2000 and 2009 (Point Blue, unpublished data) were used. Non-breeding species included in impacts assessments had 1) at least 10 individuals recorded and 2) were recorded in at least five (50%) of the 10 years used for the analysis. Thus, these do not include all species that may occur during the operational period. The operational periods were defined as November-December for Alternative B and November-February for Alternative C. Additionally, we quantified the number of individuals of each species that are likely to visit the islands during the operational period. Because breeding seabirds were not counted regularly, numbers are based on general knowledge of island breeding population sizes (Table 3.1) and seasonal attendance patterns (e.g., Ainley and Boekelheide 1990; Point Blue, unpubl. data). For non-breeding birds, numbers are based on annual minimum and maximum numbers of new arrivals recorded by island biologists the operational periods for Alternatives B and C (i.e., not minimum and maximum daily counts). For information on how numbers of new arrivals are determined, see Pyle and Henderson (1991). The scale of the impact describes the expected impact of the operation on the species in question. For example, there could be as many as 19 black phoebes that visit the islands over the course of the operational period for Alternative B. However, the Service does not expect any impacts to black phoebe and the Scale of the Impact is considered to be negligible.

Brodifacoum and diphacinone are toxic to taxonomic groups or individual species at varying concentrations (see Section 4.5.4.3). Because of this, we made the following assumptions about toxicant sensitivity based on existing information in the literature:

<u>Brodifacoum</u>

- Birds are generally sensitive to brodifacoum exposure, with LD_{50} values ranging from less than 1 to 100 mg/kg-bw for all species with available acute toxicity data; most species have LD_{50} values less than 20 mg/kg-bw. Because of this finding, we assume that all avian species on the South Farallon Islands would have high sensitivity to brodifacoum.
- The EPA has determined the acute toxicity of brodifacoum to most mammals to be high to very high (EPA 1998), with a single 24-hour feeding event often sufficient to be lethal. For this reason, we assume all mammal species on the South Farallon Islands would have a high sensitivity to brodifacoum.

- Based on results from the salamander toxicity study (Witmer 2018; Appendix Q) and other eradication projects where amphibians were present and monitored (see Section 4.5.4.3.2), we assume the Farallon arboreal salamander would have a low sensitivity to brodifacoum.
- Brodifacoum is considered to be highly toxic to fish species tested in laboratory trials in the USA. For example, the 96-hour LC_{50} for rainbow trout has been measured at 0.015 mg/L. We assume that all fish species of the South Farallon Islands would have high sensitivity to brodifacoum.
- Most invertebrates are not susceptible to anti-coagulants because they do not have the same blood clotting systems as vertebrates. However, there are exceptions, where diphacinone and brodifacoum can be moderately to highly toxic to invertebrates, such as in stagnant, freshwater conditions (EPA 1998). Because of the wide variety of anticipated responses among invertebrate species to brodifacoum exposure, we assume medium sensitivity (median of toxicity categories) to brodifacoum, except where justified otherwise, for terrestrial and marine invertebrates.

<u>Diphacinone</u>

- Diphacinone is generally considered to have low to moderate toxicity to birds and mammals, typically requiring consumption of the toxicant multiple times over many days to be lethal. To be conservative, especially considering the paucity of toxicity data for appropriate surrogate bird and mammal species of the South Farallon Island, we assume all bird and mammal species on the Farallon Islands would have a medium sensitivity to diphacinone.
- Based on results from the salamander toxicity study (Witmer 2018; Appendix Q), we assume the Farallon arboreal salamander would have a low sensitivity to brodifacoum.
- Data from toxicity tests using several freshwater fish species used in standard laboratory tests resulted in diphacinone being labeled as moderately toxic to fish. There are no comparable data for marine fish. Based on the toxicity data for freshwater fish, we assume all fish species of the South Farallon Islands would have a medium sensitivity to diphacinone.
- Most invertebrates are not susceptible to anti-coagulants because they do not have the same blood clotting systems as vertebrates. However, there are exceptions, where diphacinone and brodifacoum can be moderately to highly toxic to invertebrates, such as in stagnant, freshwater conditions (EPA 1998). Because of the wide variety of anticipated responses among invertebrate species to diphacinone exposure, we assume medium sensitivity to diphacinone, except where justified otherwise, for terrestrial and marine invertebrates.

The Service developed the action alternatives in Chapter 2 with mitigation measures in order to reduce adverse impacts from the project. Prior to any project implementation, contingency plans will be developed to minimize the risk of unanticipated events (Section 2.10.5). The Service would not implement the project unless favorable environmental and logistical conditions are present and unless funding and staffing resources are available to ensure the successful implementation of mitigation and monitoring efforts. The contingency plans to be developed for the project will include thresholds and trigger points to help the Service identify problems early

on and take swift action (including halting bait distribution) to prevent serious consequences from occurring.

4.5.6.1 *Impacts of Alternative B on Biological Resources: Aerial Brodifacoum-25D Conservation*

4.5.6.1.1 *Impacts on Birds*

A description of the potential impacts of Brodifacoum and other rodenticides to birds can be found in Section 4.5.4.3.1 with additional information in Section 4.5.6. Generally, granivorous birds that primarily eat seeds and grains and omnivorous species such as gulls would initially be most at risk of primary exposure to brodifacoum. Predators and scavengers that feed on mice, birds, mouse or bird carcasses, or large invertebrates that may ingest rodent bait such as crickets or beetles, would initially be at high risk of secondary exposure to brodifacoum.

The risk of acute exposure (either primary or secondary) to susceptible species (granivorous species, many predators and scavengers, and omnivores) would begin to decline rapidly within approximately 30 days of the final bait application as the mouse population declines and bait pellets are consumed or disintegrated. The risk of acute exposure to these high-risk bird species would generally decline to low within 30 days of the final bait application and negligible to low within a few months thereafter, although chronic, low level exposure to brodifacoum could occur over the long-term.

Birds foraging in the intertidal zone would be at a lower risk of primary exposure because areas below the MHST would not be baited; pellets that inadvertently drift into the water would disintegrate and become unavailable within a few hours (Empson and Miskelly 1999, Howald et al. 2010). For the same reason, birds that forage primarily on intertidal invertebrates would initially be at a low risk of secondary exposure. Also, birds that feed primarily on flying insects and “micro-invertebrates” would be at an initially low risk of acute secondary exposure due to the low likelihood that these classes of invertebrates would act as reservoirs of high concentrations of brodifacoum. This risk of acute exposure would steadily decline to negligible within a few months, although chronic, low level exposure to brodifacoum through ingestion of contaminated prey could occur over the long-term, assuming birds are at least seasonal residents. The likelihood of acute exposure in intertidal specialists would decline even more rapidly, becoming negligible within approximately 30 days of the final bait application.

The following is a summary of the direct and indirect toxicant and disturbance impacts to each bird species that has at least a moderate likelihood of occurring on the South Farallon Islands during the possible implementation period of Alternative B (see Table 4.4 for a summary of impacts to biological resources).. For species scientific names not included in the text, see Appendix H. See Section 4.5.6 for a description of methods used for bird impacts assessments. For Alternative B, the operational period is defined as November-December based on target timing for bait broadcasts (November) and the period of time that birds would be expected to be most at risk to exposure to Brodifacoum as well as to disturbance from operations (see Section 2.11 and Table 2.5). Thus, bird data for the November-December period were used. Note that we did not use a less likely, longer period of time that birds could be impacted by Alternative B,

such as in extreme drought conditions. The Scale of the Impact provides an estimate of the projected impact to the population (i.e., individuals only, regional population, or world population).

4.5.6.1.1.1 Raptors:

- **Northern Harrier**

Toxicant risk
The estimated number of northern harriers likely to occur on the islands during operations is between two and 18 birds. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, northern harriers consume small- to medium-sized mammals, small birds, reptiles, and amphibians. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that may present at this time on the island.

Disturbance risk
Northern harriers would be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the medium-term because of potential impacts from hazing, and the scale of impact would be to the few individuals that are present at this time on the island. However, harriers that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely occur during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Sharp-shinned Hawk and American Kestrel**

Toxicant risk
The estimated number of individuals likely to be occur on the islands during operations is zero to eight sharp-shinned hawks and zero to six American kestrels. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, sharp-shinned hawks consume small mammals, small birds, and occasionally large insects (Bildstein

and Meyer 2000); American kestrels primarily consume small vertebrates and terrestrial arthropods (Smallwood and Bird 2002). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Sharp-shinned hawks and American kestrels could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the islands. However, hawks and kestrels that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of these species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **<u>Merlin</u>**

Toxicant risk
The estimated number of individual merlins likely to occur on the islands during operations is between zero and five. If present during eradication implementation, efforts would be made to capture and translocate off-island all individuals. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming other species that have been exposed to the toxicant. Generally, merlins primarily consume small- to medium-sized birds (Warkentin et al. 2005). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the islands.

Disturbance risk
Merlins could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the islands. However, merlins that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release

site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Peregrine Falcon**

Toxicant risk
Peregrine falcons are fairly common on the islands in the fall and winter, with multiple migrants recorded each year. Smaller numbers of over-wintering birds may travel regularly between the islands and mainland (Pyle and Henderson 1991). A breeding pair of falcons were resident on the South Farallones in 2009-2011, with successful breeding in 2009 (Warzybok and Bradley 2011). No breeding attempts have been recorded since 2011 (Point Blue, unpublished data). The estimated number of individuals likely to occur on the islands during operations is 8-30 birds. If present during eradication implementation, efforts would be made to capture and hold all individuals until exposure risk declines to acceptable level, or possibly translocate some or all individuals off-island. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or, more likely, birds that have been exposed to the toxicant. Generally, peregrine falcons consume mostly small- to medium-sized birds and occasionally mammals (White et al. 2002). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high for individuals remaining on the island due to the sensitivity to the toxicant and the number of exposure pathways and negligible for captured individuals. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Peregrine falcons that remain on the islands during eradication operations could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium for individuals that remain on the islands, the duration of the disturbance would be for the medium-term, and the extent of the impact would be to the few individuals that are present at this time on the islands. However, falcons that are captured and taken into captivity would experience high disturbance sensitivity from being captured, transported, and held during operations. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the medium-term to ensure that they are not released back to the Farallones while the toxicant exposure risk is still high.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive

population-level impacts would occur. The significance determination for this species is not significant.

- **Short-eared Owl and Long-eared Owl**

Toxicant risk
Short-eared and long-eared owls occasionally visit the Farallones. The estimated number of individuals likely to occur on the islands during operations is between zero and four short-eared and zero and two long-eared owls. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, both short-eared and long-eared owls consume small mammals and small birds (Marks et al. 1994, Wiggins et al. 2006). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Short-eared and long-eared owls could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low because they are nocturnal and secretive during the day when most operations would occur, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island. However, owls that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Barn Owl**

Toxicant risk
Because of their secretive and nocturnal habits, barn owls can be difficult to locate. Based on available data, the estimated number of individuals likely to occur on the islands during operations is between zero and two birds but actual numbers may be greater. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, barn owls consume primarily small mammals, and to a lesser extent small birds, reptiles, and

arthropods (Marti et al. 2005). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Barn owls could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low because they are nocturnal and secretive during the day when most operations would occur, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island. However, owls that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **<u>Burrowing Owl</u>**

Toxicant risk
Burrowing owls are fairly common on the Farallones during the fall and winter periods. Because of their secretive and nocturnal habits, burrowing owls can be difficult to locate. Based on available data, the estimated number of individuals likely to occur on the islands during operations is between two and 12 birds but actual numbers are likely greater. Efforts would be made to capture, hold and eventually translocate all individuals off-island that are present during eradication implementation. However, it may not be possible to capture all individuals. Burrowing owls not captured could be exposed to brodifacoum through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, burrowing owls are opportunistic feeders and consume small mammals, small birds, and arthropods (Haug et al. 1993). On the Farallones, they feed primarily on house mice, ashy storm-petrels, invertebrates, and other small birds such as (Chandler et al. 2016, Mills 2016). Based on their feeding habits the duration of risk for the remaining few individuals would be for the long - term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high for individuals remaining on the island due to the sensitivity to the toxicant and the number of exposure pathways and negligible for captured individuals. The scale of impact would be to those few individuals that may remain on the island after the eradication team captures and removes as many individuals as possible.

Disturbance risk
Burrowing owls that remain on the island during eradication operations could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the island. The disturbance sensitivity for this alternative is low because they are nocturnal and secretive during the day when most operations would occur, the duration of the disturbance would be for the medium-term, and the extent of the impact would be to the few individuals that are seen at this time on the island. However, owls that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported. The scale of the impact would be to the individuals taken into captivity, and the duration would be for the short term until they are released.

Significance Determination
It is uncertain where burrowing owls at the islands originate from. However, it is likely that most, if not all, are migrants that breed outside the region. Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, and because capture and translocation of owls would limit exposure to toxicant risks, no long-term negative or positive regional or world population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.1.1.2 Passerines Omnivores:

- **<u>Mountain Bluebird, Hermit Thrush, Varied Thrush, American Robin, and Cedar Waxwing</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is: 0-5 mountain bluebirds, 1-22 hermit thrushes, 4-23 varied thrushes, 10-50 American robins, and 2-100 cedar waxwings. These species could be exposed to brodifacoum through secondary exposure pathways. These species consume fruit, insects, and other invertebrates. Based on their feeding habits the duration of risk for these few individuals would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways; however, it is unlikely that omnivorous passerines would consume enough toxic insects to obtain a lethal level of toxicant. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive

population-level impacts would occur. The significance determination for this species is not significant.

- **European Starling**

Toxicant risk
Non-native European starlings are one of the most numerous fall migrant passerines on the islands. The estimated number of individuals likely to occur during operations is between 655 and 1,900 birds. Starlings could be exposed to brodifacoum through primary and secondary exposure pathways. This species has an extremely diverse diet that varies seasonally, including invertebrates, fruits and berries, grains, seeds and insects (Cabe 1993). Based on their feeding habits the duration of risk for starlings would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
European starlings could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative are medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
The significance determination for European starling is not significant since no long-term negative or positive impacts to the population are expected.

- **American Pipit**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between seven and 60 American pipits. American pipits could be exposed to brodifacoum through primary and secondary exposure pathways. Pipits consume primarily terrestrial and freshwater invertebrates and seeds (Verbeek and Hendricks 1994). Based on their feeding habits the duration of risk for these few individuals would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
American pipits could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the

disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.1.1.3 Passerine-like Insectivores:

- **Northern Flicker, Black Phoebe, Say's Phoebe, Brown Creeper, Rock Wren, Nashville Warbler, and Townsend's Warbler**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 0-7 northern flickers, 5-20 black phoebes, 0-4 Say's Phoebes, 0-3 brown creepers, 1-8 rock wrens, 0-3 Nashville warblers, and 0-7 Townsend's warblers. These species could be exposed to brodifacoum through secondary exposure pathways. All species feed primarily on insects and other arthropods either by catching flying insects, gleaning insects and insect larvae from the leaves, trunk or branches of trees and shrubs, or from the ground (e.g, Wolf 1997, Wright et al. 1998). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler and Palm Warbler**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 0-37 golden-crowned kinglets, 1-24 ruby-crowned kinglets, 22-68 yellow-rumped warblers, and

0-12 Palm warblers. Golden-crowned kinglets, ruby-crowned kinglets, yellow-rumped warblers and palm warblers could be exposed to brodifacoum through primary and secondary exposure pathways. These insectivores primarily consume insects and other arthropods, yet seasonally consume some fruit and seeds (see https://birdsna.org/Species-Account/bna/home) . Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.1.1.4 Nectivores/Insectivores:

- **<u>Anna's Hummingbird</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 2 and 23 individuals. Anna's hummingbirds could be exposed to brodifacoum through secondary exposure pathways by consuming insects that have been exposed to the toxicant. Anna's hummingbirds primarily consume nectar and some small insects (Russell 1996). Therefore, based on their feeding habits the duration of risk for these few individuals would be for the long - term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Anna's hummingbirds could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.1.1.5 Passerine Granivores:

- **Horned Lark, Fox Sparrow, White-crowned Sparrow, Golden-crowned Sparrow, Dark-eyed Junco, Lapland Longspur, Western Meadowlark, Savannah Sparrow, White-throated Sparrow, Red-winged Blackbird, Purple Finch, House Finch, Pine Siskin, Lesser Goldfinch**

Toxicant risk
The estimated number of individuals likely to be present on the islands during operations are: 0-6 horned larks, 1-23 fox sparrows, 2-19 white-crowned sparrows, 2-105 golden-crowned sparrows, 4-23 dark-eyed juncos, , 0-6 Lapland longspurs, 7-67 western meadowlarks, 2-13 savannah sparrows, 1-10 white-throated sparrows, 0-6 red-winged blackbirds, 0-5 purple finches, 0-6 house finches, 0-95 pine siskins, and 0-9 lesser goldfinches. These species could be exposed to brodifacoum through primary and secondary exposure pathways. These species consume mostly plant matter including seeds, buds, and fruits but also arthropods, primarily insects. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals on the Farallones.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.1.1.6 Shorebirds:

- **Willet, Wandering Tattler, Ruddy Turnstone, Black Turnstone, Surfbird, and Least Sandpiper (Rocky Intertidal Shorebirds)**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 1-8 willets, 2-13 wandering tattlers, 0-4 surfbirds, 0-4 ruddy turnstones, 88-195 black turnstones, and 0-11 least sandpipers. These species could be exposed to brodifacoum through secondary exposure pathways by consuming other species that have been exposed to the toxicant. They consume intertidal invertebrates and aquatic insects and on the Farallones occur almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these individuals would be for the medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative are high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals on the Farallones.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for these species is not significant.

- **<u>Black Oystercatcher</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 30 and 60 black oystercatchers. Black oystercatchers could be exposed to brodifacoum through secondary exposure pathways. Oystercatchers consume mainly marine invertebrates, primarily bivalves and other mollusks (Andres and Falxa 1995). On the Farallones, they occur mainly along the immediate shoreline but in summer some individuals occasionally forage for terrestrial invertebrates in upland habitats. Based on their feeding habits the duration of risk for these individuals would be for the medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the relatively few individuals present on the islands.

Disturbance risk
Black oystercatchers could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is high because of their high

exposure to gull hazing activities, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the relatively few individuals present on the islands.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Black-bellied Plover, Killdeer, Whimbrel, and Wilson's Snipe**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 0-11 black-bellied plovers, 0-8 killdeer, 7-18 whimbrels, and 0-5 Wilson's snipe. These species could be exposed to brodifacoum through both primary and secondary exposure pathways by consuming other individuals that have consumed the toxicant. All species consume marine or aquatic invertebrates such as crabs, crustaceans, mollusks, and insects (Skeel and Mallory 1996). On the Farallones, they occur mainly along the immediate shoreline but occasionally forage in upland habitats. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for these species is not significant.

4.5.6.1.1.7 Seabirds:

- **Western Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 14,000 and 32,000 western gulls. However, with a successful hazing program the Service will likely keep the number of individuals landing on the Farallones to a minimum level. Western Gulls would be actively hazed during implementation operations to decrease their risk of

exposure to toxicant. However, western gulls not hazed successfully could be exposed to brodifacoum through primary and secondary exposure pathways. Western gulls are generalist predators and opportunistic feeders consuming fish, aquatic invertebrates, adult birds, chicks, eggs, carrion, and human refuse (Pierotti and Annett 1995). On the Farallones, this species is numerous in all habitats but distribution changes seasonally. Additionally, western gulls and the closely related glaucous-winged gull have been documented eating non-toxic placebo bait pellets on the Farallones and on other islands on the Pacific Coast. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. Given the number of western gulls that could be present during project operations, gulls are analyzed at the regional population level. However, gull hazing efforts are expected to reduce the number of gulls likely to be at risk of toxicant exposure to fewer than 1,700, which is below the level at which population-level impacts are expected.

Disturbance risk

Western gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls are very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 29 14,000 and 32,000 western gulls. However, with a successful hazing program the Service will 30 likely keep the number of individuals landing on the Farallones to a minimum level. Because of their long lifespan, population level impacts were considered to be long-term if impacts to the regional population were detectable after 20 years (Section 4.5.4.4, Appendix N). Mortality of more than 1,700 western gulls would have to occur in order to affect the regional population level after 20 years (Appendix N). The hazing program would keep the number of individuals that would experience lethal effects to below 1,700. Therefore, no long-term negative or positive impacts to the regional population are expected. The significance determination for western gulls is not significant.

- **<u>Ring-Billed Gull</u>**

Toxicant risk

The estimated number of individuals likely to occur on the islands during operations is between zero and seven ring-billed gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, ring-billed gulls not successfully hazed could be exposed to brodifacoum through primary and secondary exposure pathways. Ring-billed gulls are omnivorous and opportunistic feeders consuming fish, insects, earthworms, rodents, eggs, and human refuse (Ryder 1993). On the Farallones, this species

occurs almost entirely along the immediate shoreline. Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. Based on their feeding habits the duration of risk for these few individuals would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few on the islands.

Disturbance risk
Ring-billed gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **<u>California Gull</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 380 and 2,800 California gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, California gulls not successfully hazed could be exposed to brodifacoum through primary and secondary exposure pathways. California gulls are omnivorous and opportunistic feeders consuming small mammals, fish, birds, eggs, marine invertebrates, insects, and human refuse (Winkler 1996). Additionally, other omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones in the fall and winter, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of the impact would be to the relatively low numbers of individuals present on the islands. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
California gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls will very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the relatively low numbers of individuals present.

Significance Determination
The numbers of California gulls attending the islands is fairly low relative to the size of the regional population. Also, the hazing program would minimize the number of individuals that would experience lethal effects, thus avoiding long-term impacts to the regional population. The significance determination for California gulls is not significant.

- **<u>Glaucous-winged Gull</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 60 and 1,000 glaucous-wing gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, glaucous-winged gulls not successfully hazed could be exposed to brodifacoum through primary and secondary exposure pathways. Glaucous-winged gulls are omnivorous and opportunistic feeders consuming a variety of fish, marine invertebrates, carrion, eggs, mice, and human refuse (Hayward and Verbeek 2008). Additionally, other omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of the impact would be to the relatively low numbers of individuals present on the islands. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
Glaucous-wing gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls are be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the extent of the impact would be to the relatively low numbers of individuals present.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects thus avoiding long-term impacts to the regional population. The significance determination for Glaucous-winged gulls is not significant.

- **Mew Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and 30 mew gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, mew gulls not successfully hazed could be exposed to brodifacoum through primary and secondary exposure pathways. Mew gulls are omnivorous feeders consuming marine and terrestrial invertebrates, insects, fish, grain, and human refuse (Moskoff and Bevier 2002). Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these few individuals would be for the long -term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of the impact would be to the few individuals present on the islands. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
Mew gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects. No population level impacts would occur. The significance determination for mew gulls is not significant.

- **Herring Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 40 and 320 herring gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, herring gulls not successfully hazed could

be exposed to brodifacoum through primary and secondary exposure pathways. Herring gulls are omnivorous and opportunistic feeders consuming fish, invertebrates, birds, eggs, carrion, and human refuse (Pierotti and Good 1994). Additionally, omnivorous gulls have been known to eat rodenticide bait islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. Given the number of herring gulls that could be present during project operations, gulls are analyzed at the regional population level. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
Herring gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls are very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects thus avoiding long-term impacts to the regional population. The significance determination for herring gulls is not significant.

- **<u>Heermann's Gull and Thayer's Gull</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between one and 65 Heermann's gulls and zero and 70 Thayer's gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, Heermann's gulls and Thayer's gulls not successfully hazed could be exposed to brodifacoum through primary and secondary exposure pathways. Both species are omnivorous and opportunistic feeders consuming mostly a variety of fish, marine invertebrates, crustaceans, insects, and carrion. Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, these species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of the impact would be to the few individuals present on the islands. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
Heermann's gulls and Thayer's gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative are high because gulls are be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects. No population level impacts would occur. The significance determination for Heermann's and Thayer's gulls is not significant.

- **<u>Cassin's Auklet, Ashy Storm-Petrel, Leach's Storm-Petrel</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is expected to be up to 10,000 Cassin's auklets, 500 ashy storm-petrels, and zero Leach's storm-petrels. Cassin's auklet, ashy storm-petrel, and Leach's storm-petrel on the South Farallones are not likely to be exposed to brodifacoum through either primary or secondary exposure pathways. These seabirds breed on the Farallon Islands and feed at sea. Based on their feeding habits the duration of risk for these seabirds would be for the short-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish, their main food source, would consume bait. The overall toxicant risk is low due to the number of exposure pathways. The scale of the impact would be to the regional populations.

Disturbance risk
These species could be exposed to disturbances from ground and air operations. All species are nocturnal. Small numbers of ashy storm-petrels would still be raising young in their rock crevice nests during the implementation phase. Leach's storm-petrels complete breeding activities and depart the islands by mid-October and thus would not be present during operations (Ainley et al. 1995d). Although no longer nesting, Cassin's auklets attend the colony on some nights in the fall months for social purposes. Thus, except for a small number of remaining storm-petrel chicks early in the operational period, these species would most likely be present only at night and not directly susceptible to most ground or air operations. Aside from the possibility of auditory techniques such as predator calls, little gull hazing activity is expected to occur at night. All efforts would be made to minimize disturbance to nesting habitats during ground operations. For cassin's auklet, the disturbance sensitivity for this alternative is low because birds would not be present during most operations and care would be taken to protect breeding habitats. The duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population. For the ashy storm-petrel, the disturbance sensitivity for this alternative is low because the majority of birds would not be present during operations and care would be

taken to protect breeding habitats. The duration of the disturbance would be for the short-term because all nesting birds should have departed by the end of November. The scale of impact would be to the regional population.

Significance Determination
As explained above, it is highly unlikely that any individuals of these species would consume bait directly or indirectly. Those individuals who are present and active during daytime operations could experience disturbance from ground and air operations and from hazing for the duration of the project (about 9 weeks). The significance determination for Cassin's auklet is not significant since no long-term negative or positive impacts to the population are expected. The significance determination for ashy and Leach's storm-petrels is significant since the eradication of mice should have significant, long-term positive benefits to their populations on the Farallones (as further described in Section 1.3.1).

- **Common Murre**

Toxicant risk
The estimated number of common murres likely to occur on the islands during operations is expected to be up to 200,000 individuals. Common murres on the South Farallones are not likely to be exposed to brodifacoum through either primary or secondary exposure pathways. These seabirds breed on the Farallon Islands and feed at sea. Based on their feeding habits the duration of risk for these seabirds would be for the short-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish or invertebrates, their main food sources, would consume bait. The overall toxicant risk is low due to the remote nature of a possible exposure pathway. The scale of the impact would be to the regional population.

Disturbance risk
Common murres sporadically visit their breeding areas during the late fall and winter. Thus, this species likely will be exposed to disturbances from ground and air operations, which would likely cause them to flush the area. Birds may return or depart the area for the remainder of the day. The impacts associated with disturbance sensitivity for this alternative are medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population.

Significance Determination
Because the toxicant risk to this species is low and disturbance impacts are temporary, no long-term negative or positive impacts to the regional population are expected. The significance determination for common murre is not significant.

- **Brown Pelican, Brandt's Cormorant, Pelagic Cormorant, Double-crested Cormorant**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 900 to 3,600 brown pelicans, 2,000 Brandt's cormorants, 100 double-crested cormorants, and 200 pelagic cormorants. Brown pelicans, Brandt's cormorants, pelagic cormorant, and double-crested

cormorants could be exposed to brodifacoum through secondary exposure pathways. These species are primarily piscivorous and their diet consists of fish and some marine invertebrates (Shields 2002). Based on their feeding habits the duration of risk for these birds would be for the short-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish, their main food source, would consume bait. The overall toxicant risk is low due to the number of exposure pathways. The scale of impact would be to the regional population level for all species.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on or away from the islands. The disturbance sensitivity for this alternative is high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population for Brandt's cormorant and to the relatively few individual brown pelicans, pelagic cormorants and double-crested cormorants present on the islands.

Significance Determination
Because the toxicant risk to these species is low and disturbance impacts are temporary, no long-term negative or positive impacts to the regional populations of these species are expected. The significance determination for brown pelican, Brandt's cormorant, pelagic cormorant and double-crested cormorant is not significant.

4.5.6.1.1.8 Waterfowl:

- **<u>Cackling Goose and Green-winged Teal</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and 60 cackling geese and zero to four green-winged teal. Cackling geese and green-winged teal could be exposed to brodifacoum through primary and secondary exposure pathways. Cackling geese are primarily herbivorous and consume grass and grain but also some aquatic invertebrates and insects (Mowbray et al. 2002). Green-winged teal are more opportunistic, feeding on a variety of plant seeds, aquatic vegetation, aquatic insects and larvae, mollusks, and crustaceans (Johnson 1995). On the Farallones, this species occurs both along the shoreline and upland habitats although they mainly occur in uplands. Based on their feeding habits the duration of risk for these geese would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the possibility of primary and secondary toxicant exposure. The overall toxicant risk is high due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Cackling geese and green-winged teal could be exposed to disturbances from both ground and air operations, which would likely cause them to flush from the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is

medium, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Although the toxicant risk to these species is high, cackling geese and green-winged teal are numerous throughout their range and the number of individuals on the Refuge reflects a small percent of their overall populations. Disturbance-related impacts to these species are temporary. As a result, no long-term negative or positive impacts to the regional population of these species are expected. The significance determination for cackling goose is not significant.

- **Brant**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and 10 brant. Brant could be exposed to brodifacoum through primary and secondary exposure pathways. Brant are primarily herbivorous and consume eelgrass, green algae, salt marsh plants, and graze on upland grassland (Reed et al. 1998). Based on their feeding habits the duration of risk for these waterfowl would be for the long-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Brant could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the few individuals that are present at this time on the islands.

Significance Determination
The significance determination for brant is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.2 Impacts on Mammals

4.5.6.1.2.1 Pinnipeds:

- **Steller Sea Lion, California Sea Lion, Northern Fur Seal, and Pacific Harbor Seal**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 145 and 300 Steller sea lions, 70 and 140 Pacific harbor seals, 11,000 and 21,500 California sea lions, and 34 and 125 northern fur seals. Steller sea lions, California sea lions, Northern fur seals, and Pacific harbor seals breed on the Farallones but will not be breeding during the proposed implementation of this alternative. All of these species could be exposed to brodifacoum through

primary and secondary exposure pathways. Pinnipeds primarily consume marine fish and invertebrates. All may feed near the islands, but Northern fur seals mainly feed in pelagic waters far from the islands. Pups, which may be present, have been known to suckle on rocks. On the Farallones, these species are found along the immediate shoreline, although California sea lions and Northern fur seals may venture into upland areas. Based on their feeding habits the duration of risk for pinnipeds would be for the medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low because it is highly unlikely that these pinnipeds or their main food sources, pelagic fish and invertebrates, would consume bait. Also, the overall toxicant risk is low since pinnipeds would need to consume a very large amount of rodent bait to reach a toxic level due to their large size. In addition, we would mitigate impacts to marine fish and invertebrates by utilizing a deflector to prevent bait from entering marine environment. The scale of impact would be to the regional populations for all species.

Disturbance risk
All of these species are particularly sensitive to nearby human activities. Pinnipeds would be exposed to disturbance from ground, air, and gull hazing operations. Prior to initiating aerial bait application, these pinnipeds may be carefully flushed from the islands as a precaution for their safety, resulting in short-term impacts. The impacts of gull hazing actions were assessed during a gull hazing trial undertaken in 2012 (Appendix E). Responses of pinnipeds varied depending on the hazing tool employed and the species present but, only rarely did hazing activities result in pinnipeds being flushed into the water. In summary, little impact to pinnipeds would be expected as a consequence of eradication or hazing activities. The impacts associated with disturbance sensitivity for this alternative are high, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the island population for harbor seal and to the regional populations for all other species.

Significance Determination
Due to their large size and the amount of toxicant consumption that would be required to lead to toxicosis, it is very unlikely that any individual pinniped would be harmed as a result of direct or indirect toxicant consumption. Ground, air and hazing operations would cause disturbances to individual pinnipeds for an expected 6 weeks; however, the disturbance levels from these activities would not reach a Level A harassment under the MMPA, which is statutorily defined as, “any act of pursuit, torment, or annoyance which—Has the potential to injure a marine mammal or marine mammal stock in the wild.” The significance determination for pinnipeds is not significant since no short- or long-term negative or positive impacts to either population is expected.

- **<u>Northern Elephant Seal</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 65 and 135 northern elephant seals. Northern elephant seals begin breeding in late December, during the latter portion of proposed operations. These animals could be exposed to brodifacoum through primary and secondary exposure pathways. They primarily consume marine fish and invertebrates in deep pelagic waters and do not feed near the islands. Pups have been known to suckle on rocks. On the Farallones, these species are mainly found along the immediate

shoreline, but some individuals occasionally wander into low-lying upland areas. Based on their feeding habits, the duration of risk for these pinnipeds would be for the medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low due to the fact that is highly unlikely that elephant seals or their main food sources, pelagic fish and invertebrates, would consume bait. Also, the overall toxicant risk is low since elephant seals would need to consume a very large amount of rodent bait to reach a toxic level due to their large size. In addition, we would mitigate impacts to fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the regional population.

Disturbance risk
Northern elephant seals do not often react to nearby human activity, and thus are unlikely to be disturbed by air or ground operations. However, northern elephant seals may be carefully flushed into the water prior to aerial bait drops, resulting in short term disturbance. They would likely return to the islands within a few hours. Disturbance impacts from hazing were assessed during the gull hazing trial. The impacts of these actions were assessed during a gull hazing trial undertaken in 2012 (Appendix E). Responses of elephant seals varied depending on the hazing tool employed but only rarely did elephant seals react to hazing activities and none were flushed. In summary, little impact to northern elephant seals would be expected as a consequence of eradication or hazing activities. The impacts associated with disturbance sensitivity for this alternative are low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population.

Significance Determination
Due to their large size and the amount of toxicant consumption that would be required to lead to toxicosis, it is very unlikely that any individuals would be harmed as a result of direct or indirect toxicant consumption. Other than being flushed into the water prior to each bait drop, ground, air and hazing operations would rarely disturb elephant seals. The disturbance level would not reach Level A harassment under the MMPA. The significance determination for Northern elephant seals is not significant since no short- or long-term negative or positive impacts to the population are expected.

4.5.6.1.3 *Impacts on Amphibians*

- **Arboreal Salamanders**

Toxicant risk
Arboreal salamanders that are not captured and held during the operation could be exposed to brodifacoum through secondary exposure pathways by consuming insects that have consumed the toxicant. Based on their feeding habits, the duration of risk for these salamanders would be for the long-term, the toxicant sensitivity is considered to be low, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is low due to the sensitivity to the toxicant and toxicity study data (Witmer 2018; Appendix Q) suggesting low risk. The scale of impact would be to the entire world population of this subspecies of arboreal salamander because it is endemic to the South Farallon Islands. Despite anticipated low risk, in an effort to mitigate potential unforeseen impacts to salamanders, about

40 individuals will be captured and held for the duration of risk, to be released once the toxicant risk has decreased to negligible.

Disturbance risk
Arboreal salamanders not captured or held for the duration of risk could be exposed to disturbances from ground operations, which could result in habitat disturbance or cause individuals to flee the immediate area or potentially be preyed upon or injured. Every effort will be taken to limit ground operations and mitigate any known risks to salamanders; however, it is possible that they could be inadvertently crushed by personnel moving around the island at night when they are active. Also, individuals captured and held during the trial (see above) will be subjected to a certain level of disturbance impact (See Section 2.10.7.5). The impacts associated with disturbance sensitivity for this alternative are low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the entire world population of this subspecies of arboreal salamanders since it is endemic to the South Farallon Islands.

Significance Determination
Based on the results of the salamander toxicity trial, no long-term adverse impacts from the eradication operation or the capture/hold program are anticipated. Given their respective diets, mice likely compete with salamanders for food. Salamanders should therefore benefit from mouse eradication. The significance determination for arboreal salamanders is significant for positive impacts.

4.5.6.1.4 *Impacts on Fish*

- **Marine Fish**

Toxicant risk
Depending on the species, marine fish could be exposed to brodifacoum through either primary and secondary exposure pathways by consuming bait pellets, invertebrates, or other fish that have been exposed to the toxicant. However, most fish species around the Farallones are either predators or planktivores that are unlikely to come in contact with or consume a bait pellet. Also, mitigation measures to minimize incidental bait drift into the marine environment, rapid bait degradation in water, and low solubility of brodifacoum minimize exposure pathways for marine fish. Thus, the duration of risk for marine fish would be for the short-term, the toxicant sensitivity would be high, and the toxicant exposure risk is low. The overall toxicant risk is low due to the short duration of potential exposure and the number of likely exposure pathways. The scale of impact would be to a few individuals.

Disturbance risk
Marine fish could be exposed to disturbances from boating operations, which would likely cause them to flee a short distance. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance would be for the short-term, and the scale of impact would be to a few individuals.

Significance Determination
There are no expected long-term negative or positive significant impacts to any of the populations of marine fish, so the significance determination for marine fish is not significant.

4.5.6.1.5 *Impacts on Invertebrates*

4.5.6.1.5.1 *Invertebrates:*

Terrestrial Invertebrates

- **Farallon Camel Crickets**

Toxicant risk
Farallon camel crickets could be exposed to brodifacoum through primary exposure pathways by consuming bait directly. Despite existing information suggesting brodifacoum consumption by insects generally does not cause mortality (Morgan and Wright 1996, Spurr 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001), we chose a more conservative assumption that toxicant sensitivity to Farallon camel crickets would be medium due to the paucity of brodifacoum toxicity data in terrestrial invertebrates and the endemic, rare nature of this species. Based on their feeding habits the duration of risk for camel crickets would be for the medium to long-term and the toxicant exposure risk is medium due to the primary exposure pathway. The overall toxicant risk is medium due to the primary exposure pathway and the species' feeding habits. The scale of impact would be to the total world population since these crickets are endemic to the South Farallon Islands.

Disturbance risk
Camel crickets could be exposed to disturbances from ground operations, which may cause from a few to dozens of individuals to flee the immediate area. Entry into their primary cave habitats will be limited to short visits with a minimal number of personnel in an effort to minimize disturbance impacts. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the total population since these crickets are endemic to the South Farallon Islands.

Significance Determination
The significance determination for camel crickets is significant for the world population because the eradication of mice and the resulting decrease in burrowing owl numbers will likely result in long-term benefits to the cricket population (Sections 1.3.3 and 4.5.3.6). These long-term beneficial impacts outweigh temporary adverse impacts associated with disturbance from project operations and the relatively low risk to this species from brodifacoum.

- **Other Terrestrial Invertebrates**

Toxicant risk
Invertebrates such as corm flies could be exposed to brodifacoum through primary exposure by consuming bait directly, and some species such as dragonflies, butterflies, and damselflies could be exposed secondarily by feeding on other insects. Some invertebrates have been known to

consume rodenticide bait as residues of brodifacoum have been detected in arthropods (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001) and other invertebrates. Brodifacoum consumption by invertebrates generally does not cause mortality, but there is uncertainty due to lack of studies; therefore, the assumption is other terrestrial invertebrates would have medium sensitivity to brodifacoum. Based on their feeding habits and the long fate of brodifacoum in soil the duration of chronic risk for terrestrial invertebrates would be for the long-term. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The overall toxicant risk is low due to the primary exposure pathway. The scale of impact would be to the regional populations.

Disturbance risk
Invertebrates could be exposed to disturbances from ground operations, which could crush individuals or disturb habitat. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance would be for the short-term, and the scale of impact would be to island populations.

Significance Determination
The significance determination for terrestrial invertebrates is significant since the eradication of mice should have significant positive benefits to their populations on the Farallones. These long-term beneficial impacts outweigh the short-term adverse impacts associated with toxicant exposure and disturbance during project implementation.

Intertidal Invertebrates

- **Black Abalone**

Toxicant risk
Black abalones are intertidal gastropod mollusks that feed on marine algae such as kelp. Thus, if an abalone were to come in direct contact with a rodent bait pellet, the abalone may consume all or part of the pellet. Abalone could then be exposed to brodifacoum through a primary exposure pathway. Some terrestrial gastropods have been known to consume rodenticide bait as residues of brodifacoum have been detected in their tissues (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001). Abalone also could be exposed to brodifacoum if a bait pellet incidentally ended up in the immediate vicinity of an individual abalone and toxicant made it into the water column or substrate. However, brodifacoum exposure to abalone is not known to cause mortality (Primus et al. 2005; see Section 4.5.4.3.4). Based on their feeding habits, mitigation measures to minimize bait drift into the marine environment, rapid breakdown of bait pellets in water, insolubility of brodifacoum, and extremely low numbers (if any) of black abalone at the islands, the duration of risk for black abalone would be for the short-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low. The overall toxicant risk is low due to the factors described above. The scale of impact would be to no more than a few individuals.

Black abalone critical habitat could be impacted by such factors as risks to water quality or food. As described in Section 4.4.1, potential impacts to water quality are considered to be negligible. Brodifacoum is not known to have any impacts on plants such as marine algae and thus would

not impact the abalone's food supply. Thus, the toxicant risk to black abalone critical habitat is negligible.

Disturbance risk
Black abalone are not likely to be exposed to disturbance impacts from eradication operations because of their rarity and low levels of operational activity that will occur in intertidal zones. It is not expected that black abalone would be affected by helicopter or gull hazing operations. Therefore, disturbance risk to this species and its critical habitat are negligible.

Significance Determination
Intertidal sampling since the 1990s indicate that black abalone are very rare at the South Farallones. A recent survey for black abalone at the islands did not find any individuals of the species (Roletto et al. 2015).While primary exposure to brodifacoum is possible, a combination of the rarity of the species at the islands, mitigation measures to minimize incidental bait drift into the marine environment, and the toxicant sensitivity of the species to brodifacoum, along with the negligible risk of disturbance impacts, no short- or long-term negative impacts to black abalone (including the take of individuals) or black abalone habitat are expected.

While it is unlikely that mice would prey on adult abalone, it is possible that mice could prey on recently settled juvenile abalone. Thus, the elimination of mice could result in improved habitat conditions by better allowing juvenile abalone that settle in the islands' intertidal zone to survive and reach adulthood. However, given the species status on the islands and the region, benefits from this are expected to be low.

Based on the factors described above, no signifcant short-term or long-term negative or positive impacts to black abalones or their critical habitat are expected, so the significance determination for this species and its critical habitat are not significant.

- **<u>Other Gastropods</u>**

Toxicant risk
Similar to the black abalone (above), other marine gastropods, like owl limpets (*Lottia gigantean*), black turban snails (*Tegula funebralis*), and several dorid nudibranch (family, *Dorididae*) species, could be exposed to brodifacoum through primary exposure pathways. Some terrestrial gastropods have been known to consume rodenticide bait as residues of brodifacoum have been detected in their tissues (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001). However, brodifacoum consumption by abalone (another species of gastropod) is not known not cause mortality (Primus et al. 2005). Based on their feeding habits the duration of risk for gastropods would be for the short-term. The toxicant sensitivity would be medium, and the toxicant exposure risk is low due to the primary exposure pathway and mitigation measures to minimize bait drift into the marine environment. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to a few individuals on the South Farallon Islands.

Disturbance risk
Gastropods are not likely to be exposed to disturbance impacts from eradication operations. They would also not be disturbed by personnel because of the low level of operational activity that will occur in intertidal zones. Therefore, the disturbance risk to these species is negligible.

Significance Determination
There are no expected long-term negative or positive significant impacts to gastropods, so the significance determination for these species is not significant.

- **Other Intertidal Invertebrates**

Toxicant risk
Intertidal invertebrates besides gastropods could be exposed to brodifacoum through primary exposure by consuming bait directly. Invertebrates have been known to consume rodenticide bait as residues of brodifacoum have been detected in arthropods (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001) and other invertebrates. However, brodifacoum consumption by invertebrates generally does not cause mortality. Based on their feeding habits the duration of risk for intertidal invertebrates would be for the short-term. The toxicant sensitivity would be low, and the toxicant exposure risk is low due to the primary exposure pathway and mitigation measures to minimize bait drift into the marine environment. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to individuals.

Disturbance risk
These intertidal invertebrates are not likely to be exposed to disturbance impacts from eradication operations. They would also not be disturbed by personnel because of the low level of operational activity that will occur in intertidal zones. Therefore, the disturbance risk to these species is negligible.

Significance Determination
The significance determination for other intertidal invertebrates is negligible since no long-term negative or positive impacts to these populations are expected.

4.5.6.1.6 Impacts on Vegetation

- **Vegetation**

Toxicant risk
Due to the very low solubility of brodifacoum in water, plant uptake is unlikely to occur (Weldon et al. 2011). Post-application monitoring for the Anacapa Island rat eradication tested negative for brodifacoum residue in all plant samples (Howald et al. 2010). Vegetation is not known to be negatively impacted by rodenticides, and therefore, does not require further analysis of the toxicological impacts.

Disturbance risk

Vegetation could be exposed to disturbances from ground operations, which will result in trampling and damage to individual plants. The impacts associated with disturbance risks for this alternative are low because rodent bait will be applied by helicopter as the primary technique and during ground-based activities staff will make every effort to minimize their impact on vegetation. Plants are also expected to recover from any short-term impacts relatively quickly. The duration of the disturbance would be for the medium-term, and the scale of impact would be to a few plants or areas of the island visited frequently by personnel. The disturbance-related risks from project operations will be offset by the eradication of mice which are known to consume.

Significance Determination

The significance determination for vegetation is significant as the eradication of mice is expected to have significant positive benefits to vegetation on the Farallones since mice are known to consume the seeds and seedlings of native plant species (Sections 1.2.2.4 and 1.3.5).

4.5.6.1.7 Impacts Table for Alternative B: Aerial Broadcast of Brodifacoum:

Table 4.4: Impacts of Alternative B on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance
Raptors[8,9]	Not Significant	Long	High	High	High	Low/Med	Short/Med	Individ.	Individ.
Burrowing Owl[9]	Not Significant	Long	High	High	High	Low/ High	Short/ Medium	Individ.	Individ.
Western Gull	Not Significant	Long	High	High	High	High	Medium	Regional	Regional
Other Gulls[10]	Not Significant	Long	High	High	High	High	Medium	Individ.	Individ.
Ashy and Leach's Storm-petrel	Significant positive effect	Short	High	Low	Low	Low	Short	Regional	Regional
Cassin's Auklet	Not Significant	Short	High	Low	Low	Low	Short	Regional	Regional
Common Murre	Not Significant	Short	High	Low	Low	Medium	Medium	Regional	Regional
Brown Pelican and Cormorants	Not Significant	Short	High	Low	Low	High	Medium	Regional	Regional
Cackling Goose, Green-Winged Teal	Not Significant	Long	High	High	High	Medium	Medium	Individ.	Individ.
Brant	Not Significant	Long	High	High	Medium	Low	Medium	Individ.	Individ.
Rocky Intertidal Shorebirds[11]	Not Significant	Medium	High	Low	Medium	Medium	Medium	Individ.	Individ.
Black Oystercatcher	Not Significant	Medium	High	Low	Medium	High	Medium	Individ.	Individ.
Other Shorebirds[12]	Not Significant	Medium	High	Medium	High	Medium	Medium	Individ.	Individ.
Passerine Omnivores[13]	Not Significant	Long	High	Medium	Medium	Medium	Medium	Individ.	Individ.
Passerine Insectivores[14]	Not Significant	Long	High	Medium	Medium	Medium	Medium	Individ.	Individ.
Passerine Granivores[15]	Not Significant	Long	High	High	High	Medium	Medium	Individ.	Individ.

Table 4.4: Impacts of Alternative B on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance
Anna's Hummingbird	Not Significant	Long	High	Medium	Medium	Medium	Medium	Individ.	Individ.
Northern Elephant Seal	Not Significant	Medium	High	Low	Low	High	Medium	Regional	Regional
Harbor Seal	Not Significant	Medium	High	Low	Low	High	Medium	Regional	Regional
Other Pinnipeds[16]	Not Significant	Medium	High	Low	Low	High	Medium	Regional	Regional
Marine Fish	Not Significant	Short	High	High	Medium	Low	Short	Individ.	Individ.
Salamanders	Significant positive effect	Long	Low	Medium	Medium	Low	Short	World	World
Terrestrial Invertebrates	Significant positive effect	Long	Medium	Low	Medium	Low	Short	Regional	Regional
Other Intertidal Invertebrates	Negligible	Medium	Low	Low	Low	Negligible	Negligible	Individ.	Individ.
Black Abalone	Not Significant	Short	Medium	Low	Low	Negligible	Negligible	Individ.	Individ.
Other Intertidal Gastropods	Not Significant	Short	Medium	Low	Low	Negligible	Negligible	Individ.	Individ.
Camel Cricket	Significant positive effect	Long	Medium	Low	Low	Low	Short	World	World
Vegetation	Significant positive effect	None	None	None	None	Low	Medium	None	Individ.

[1] None: No duration of risk; Short: potential exposure risk for up to 30 days; Medium: potential exposure risk for 31-90 days; Long: potential exposure risk for more than 90 days.
[2] None: No toxicological sensitivity; Low: Minor toxicological sensitivity; Medium: Moderate toxicological sensitivity; High: High toxicological sensitivity.
[3] None: No exposure pathway; Low: Possible exposure pathway; Medium: One exposure pathway; High: Multiple exposure pathways.
[4] None: Negligible risk from toxicant; Low: Low risk from toxicant; Medium: Medium risk from toxicant; High: High risk from toxicant.
[5] None: Negligible sensitivity to disturbance; Low: Low sensitivity to disturbance; Medium: Moderate sensitivity to disturbance; High: High sensitivity to disturbance. For cells containing two values separated by a slash (e.g., Low/High), the upper value is for to non-captured birds lower value is for captured birds.
[6] Short: Potential disturbance risk for 1 – 30 days; Medium: Potential disturbance risk for 30 – 90 days; Long: Potential disturbance risk for more than 90 days.
[7] Individual (Individ.): Few individuals potentially affected; Island population (Island): Many individuals may be affected with potential impacts to the island population; regional population (Regional): Many individuals may be affected with potential impacts to the regional population; Species/Subspecies: Many individuals may be affected with potential impacts to the species or subspecies.
[8] Northern harrier, sharp-shinned hawk, , American kestrel, merlin, peregrine falcon, long-eared owl, short-eared owl, barn owl, .

Table 4.4: Impacts of Alternative B on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance

[9] For Disturbance Senstivity and Duration of Disturbance Risk, two outcomes are listed: First – individuals remaining on island / Second – individuals captured and held in captivity.
[10] Ring-billed gull, California gull, glaucous-winged gull, mew gull, herring gull, Heermann's gull, Thayer's gull.
[11] Wandering tattler, willet, least sandpiper, black turnstone, ruddy turnstone, surfbird.
[12] Whimbrel, black-bellied plover, Wilson's snipe, killdeer.
[13]Hermit thrush, American robin, varied thrush, cedar waxwing, European starling, American pipit, mountain bluebird.
[14] Yellow-rumped warbler, palm warbler, golden-crowned kinglet, ruby-crowned kinglet, Northern flicker, black phoebe, Say's phoebe, brown creeper, rock wren, Nashville warbler, Townsend's warbler.
[15] Horned lark, fox sparrow, savannah sparrow, white-throated sparrow, white-crowned sparrow, golden-crowned sparrow, dark-eyed junco, red-winged blackbird, western meadowlark, Brewer's blackbird, purple finch, pine siskin, lesser goldfinch, horned lark, Lapland longspur, house finch.
[16] Stellar sea lions, California sea lions, northern fur seal, Steller sea lion.

4.5.6.2 *Impacts of Alternative C on Biological Resources: Aerial Diphacinone-50 Conservation*

4.5.6.2.1 Impacts on Birds

The toxicant exposure pathways to birds are expected to be the same for Alternatives C as they are for Alternative B (Section 4.5.6.1.1). However, Diphacinone-50 bait pellets may take longer to degrade than Brodifacoum-25D pellets, the period that birds are expected to at risk is longer for Alternative C than Alternative B. A description of the potential impacts of exposure to diphacinone and other rodenticides to birds can be found in Section 4.5.4.3.1 with additional information in Section 4.5.6.1.1.

The following is a summary of the direct and indirect toxicant and disturbance impacts to each of the identified bird species that have at least a moderate likelihood of occurring on the South Farallon Islands during the possible implementation period of Alternative C (see Table 4.5 for a summary of impacts to biological resources). For species scientific names not included in the text, see Appendix H. See Section 4.5.6 for a description of methods used for bird impacts assessments. For Alternative C, the operational period is defined as November-February based on target timing for bait broadcasts (November) and the period of time that birds would be expected to be most at risk to exposure to Diphacinone as well as to disturbance from operations (see Section 2.11 and Table 2.5). Thus, bird data for the November-February period were used. Note that we did not use a less likely, longer period of time that birds potentially could be negatively impacted from Alternative C, such as in extreme drought conditions. The Scale of the Impact provides an estimate of the projected impact to the population (i.e., individuals only, regional population, or world population).

4.5.6.2.1.1 Raptors:

- **Northern Harrier**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between two and 18 northern harriers. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to diphacinone through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, Northern harriers consume small- to medium-sized mammals, small birds, reptiles, and amphibians(Macwhirter and Bildstein 1996). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Northern harriers would be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the long-term because of potential impacts from hazing, and the scale of impact would be to the few individuals that are present at this time on the island. However, harriers that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Sharp-shinned Hawk and American Kestrel**

Toxicant risk
The estimated number of individuals likely to be occur on the islands during operations is zero to eight sharp-shinned hawks and zero to six American kestrels. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to diphacinone through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, sharp-shinned hawks consume small mammals, small birds, and occasionally large insects (Bildstein and Meyer 2000); American kestrels primarily consume small vertebrates and terrestrial arthropods (Smallwood and Bird 2002). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Sharp-shinned hawks and American kestrels could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the islands. However, hawks and kestrels that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Merlin**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and five merlins. If present during eradication implementation, efforts would be made to capture and translocate off-island all individuals. Individuals not captured could be exposed to diphacinone through secondary exposure pathways by consuming other species that have been exposed to the toxicant. Generally, merlins primarily consume small- to medium-sized birds (Warkentin et al. 2005). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Merlins could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the islands. However, merlins that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported to a release site on the mainland. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the short-term until they are released.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Peregrine Falcon**

Toxicant risk
Peregrine falcons are fairly common on the islands in the fall and winter, with multiple migrants recorded each year. Smaller numbers of over-wintering birds may travel regularly between the islands and mainland (Pyle and Henderson 1991). A breeding pair of falcons were resident on the South Farallones in 2009-2011, with successful breeding in 2009 (Warzybok and Bradley 2011). No breeding attempts have been recorded since 2011 (Point Blue, unpublished data). The estimated number of individuals likely to occur on the islands during operations is between 10

and 30 peregrine falcons. Efforts would be made to capture all individuals present during eradication implementation. Resident birds would be released when the risk of toxic exposure has passed. Migrants would be released on the mainland. However, it may not be possible to capture all individuals. Peregrine falcons not captured could be exposed to diphacinone through secondary exposure pathways by consuming other species that have been exposed to the toxicant. Generally, peregrine falcons consume mostly small- to medium-sized birds and occasionally mammals (White et al. 2002). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium for individuals remaining on the island due to the sensitivity to the toxicant and the number of exposure pathways and negligible for captured individuals. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Peregrine falcons that remain on the islands during eradication operations could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium for individuals that remain on the islands, the duration of the disturbance would be for the long-term, and the extent of the impact would be to the few individuals that are present at this time on the islands. However, falcons that are captured and taken into captivity would experience high disturbance sensitivity from being captured, transported, and held during operations. The scale of impact would be to the few individuals taken into captivity, and the duration would be for the long-term to ensure that they are not released back to the Farallones while the toxicant exposure risk is still high.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **<u>Short-eared Owl and Long-eared Owl</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and four short-eared and zero and two long-eared owls. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to diphacinone through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, both short-eared and long-eared owls consume small mammals and small birds (Marks et al. 1994, Wiggins et al. 2006). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Short-eared and long-eared owls could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the island. The impacts associated with disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Barn Owl**

Toxicant risk
Because of their secretive and nocturnal habits, barn owls can be difficult to locate. Based on available data, the estimated number of individuals likely to occur on the islands during operations is between zero and two barn owls but actual numbers may be greater. If present during eradication implementation, efforts would be made to capture and translocate all individuals off-island. Individuals not captured could be exposed to diphacinone through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, barn owls consume primarily small mammals, and to a lesser extent small birds, reptiles, and arthropods (Marti et al. 2005). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Barn owls could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the island. The impacts associated with disturbance sensitivity for this alternative is low, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Burrowing Owl**

Toxicant risk
Burrowing owls are fairly common on the Farallones during the fall and winter periods. Because of their secretive and nocturnal habits, burrowing owls can be difficult to locate. Based on available data, the estimated number of individuals likely to occur on the islands during operations is between two and 14 birds but actual numbers are likely greater. Burrowing owls are fairly common on the Farallones during the fall period. Efforts would be made to capture, hold and eventually translocate all individuals off-island that are present during eradication implementation. However, it may not be possible to capture all individuals. Burrowing owls not captured could be exposed to diphacinone through secondary exposure pathways by consuming mice or other species that have been exposed to the toxicant. Generally, burrowing owls are opportunistic feeders and consume small mammals, small birds, and arthropods (Haug et al. 1993). On the Farallones, they feed primarily on house mice, ashy storm-petrels, invertebrates, and other small birds (Chandler et al. 2016, Mills 2016). Based on their feeding habits the duration of risk for the remaining few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium for individuals remaining on the island due to the sensitivity to the toxicant and the number of exposure pathways and negligible for captured individuals. The scale of impact would be to those few individuals that may remain on the island after the eradication team captures and removes as many individuals as possible.

Disturbance risk
Burrowing owls that remain on the island during eradication operations could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the island or on the mainland. The impacts associated with disturbance sensitivity for this alternative is low for individuals that remain on the island, the duration of the disturbance would be for the short-term, and the extent of the impact would be to the few individuals that are seen at this time on the island. However, owls that are captured and taken into captivity would experience high disturbance sensitivity from being captured and transported during operations. The scale of impact would be to the individuals taken into captivity, and the duration would be for the short-term until they are released on the mainland.

Significance Determination
It is uncertain where burrowing owls at the islands originate from. However, it is likely that most, if not all, are migrants that breed outside the region. Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, and because capture and translocation of owls would limit exposure to toxicant risks, no long-term negative or positive regional or world population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.2.1.2 Passerines Omnivores:

- **<u>Mountain Bluebird, Hermit Thrush, Varied Thrush, American Robin, and Cedar Waxwing</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is: 0-5 mountain bluebirds, 1-22 hermit thrushes, 5-23 varied thrushes, 10-50 American robins, and 2-100 cedar waxwings, and. Hermit thrushes, varied thrushes, cedar waxwings, and American robins could be exposed to diphacinone through secondary exposure pathways. Hermit thrushes, varied thrushes, cedar waxwings, and American robins consume fruit, insects, and other invertebrates. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways; however, it is unlikely that omnivorous passerines would consume enough toxic insects to obtain a lethal level of toxicant. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

- **<u>European Starling</u>**

Toxicant risk
Non-native European starlings are one of the most numerous fall migrant passerines on the islands. The estimated number of individuals likely to occur during operations is between 800 and 1,900 birds. Starlings could be exposed to diphacinone through primary and secondary exposure pathways. Starlings have an extremely diverse diet that varies seasonally, including invertebrates, fruits and berries, grains, seeds and insects (Cabe 1993). Based on their feeding habits the duration of risk for starlings would be for the long-term, the toxicant sensitivity would be low, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
European starlings could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the

disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 500 and 900 European starlings. The significance determination for European starling is negligible since no long-term negative or positive impacts to the population are expected.

- **American Pipit**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between seven and 60 American pipits. American pipits could be exposed to diphacinone through primary and secondary exposure pathways. Pipits consume primarily terrestrial and freshwater invertebrates and seeds (Verbeek and Hendricks 1994). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium due to the range of toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
American pipits could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

4.5.6.2.1.3 Passerine Insectivores:

- **Northern Flicker, Black Phoebe, Say's Phoebe, Brown Creeper, Rock Wren, Nashville Warbler, and Townsend's Warbler**

The estimated number of individuals likely to occur on the islands during operations is 0-7 northern flickers, 5-20 black phoebes, 0-5 Say's Phoebes, 0-4 brown creepers, 1-8 rock wrens, 0-3 Nashville warblers, and 0-7 Townsend's warblers. These species could be exposed to diphacinone through secondary exposure pathways. All species feed primarily on insects and other arthropods either by catching flying insects, gleaning insects and insect larvae from the leaves, trunk or branches of trees and shrubs, or from the ground (e.g., Wolf 1997, Wright et al. 1998). Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is

medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

- **Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler and Palm Warbler**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 0-37 golden-crowned kinglets, 1-24 ruby-crowned kinglets, 24-72 yellow-rumped warblers, and 0-14 Palm warblers. These species could be exposed to diphacinone through primary and secondary exposure pathways. These insectivores primarily consume insects and other arthropods, yet seasonally consume some fruit and seeds. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

4.5.6.2.1.4 Nectivores/Insectivores:

- **Anna's Hummingbird**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between two and 23 individuals. Anna's hummingbirds could be exposed to diphacinone through secondary exposure pathways by consuming insects that have been exposed to the toxicant. Anna's hummingbirds primarily consume nectar and some small insects (Russell 1996). Therefore, based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Anna's hummingbirds could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

4.5.6.2.1.5 Passerine Granivores:

- **Horned Lark , Fox Sparrow, White-crowned Sparrow, Golden-crowned Sparrow, Dark-eyed Junco, Lapland Longspur, Western Meadowlark, Savannah Sparrow, White-throated Sparrow, Red-winged Blackbird, Purple Finch, House Finch, Pine Siskin, Lesser Goldfinch**

Toxicant risk
The estimated number of individuals likely to be present on the islands during operations is 0-6 horned larks, 1-24 fox sparrows, 2-19 white-crowned sparrows, 2-110 golden-crowned sparrows, 4-24 dark-eyed juncos, 0-6 lapland longspur, 7-67 western meadowlarks, 2-14 savannah sparrows, 1-10 white-throated sparrows, 0-6 red-winged blackbirds, 0-5 purple finches, 0-6 house finches, 0-95 pine siskins, and 0-9 lesser goldfinches. These species could be exposed to diphacinone through primary and secondary exposure pathways. These species consume mostly plant matter including seeds, buds, fruits, and arthropods, primarily insects. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity

to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals on the Farallon Islands.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is medium, the duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the islands.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is negligible.

4.5.6.2.1.6 Shorebirds:

- **Willet, Wandering Tattler, Ruddy Turnstone, Black Turnstone, Surfbird, and Least Sandpiper (Rocky Intertidal Shorebirds)**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 1-12 willets, 2-14 wandering tattlers, 0-5 ruddy turnstones, 80-200 black turnstones, 0-4 surfbirds, and 0-12 least sandpipers. Wandering tattlers and black turnstones could be exposed to diphacinone through both primary and secondary exposure pathways by consuming other species that have been exposed to the toxicant or inadvertently consuming bait pellets while foraging for invertebrates. These species consume intertidal invertebrates and aquatic insects and on the Farallones occur almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these individuals would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to the range of secondary toxicant exposure pathways. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The impacts associated with disturbance sensitivity for this alternative are high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals on the Farallones.

Significance Determination
Because toxicant and disturbance risks are limited to the individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Black Oystercatcher**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 30 and 60 black oystercatchers. Black oystercatchers could be exposed to diphacinone through secondary exposure pathways. Oystercatchers consume marine invertebrates, primarily bivalves and other mollusks (Andres and Falxa 1995). On the Farallones, they occur mainly along the immediate shoreline but in summer occasionally forage in upland habitats. Based on their feeding habits the duration of risk for these individuals would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to the range of secondary toxicant exposure pathways. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the relatively low numbers of individuals present.

Disturbance risk
Black oystercatchers could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The impacts associated with disturbance sensitivity for this alternative are high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals on the Farallones.

Significance Determination
Because toxicant and disturbance risks are limited to the individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **Black-bellied Plover, Killdeer, Whimbrel, and Wilson's Snipe**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is 0-12 black-bellied plovers, 0-8 killdeer, 7-18 whimbrels, and 0-5 Wilson's snipe. These species could be exposed to diphacinone through both primary and secondary exposure pathways by either consuming other individuals that have consumed the toxicant or inadvertently consuming bait pellets while foraging for invertebrates. All species consume marine or aquatic invertebrates such as crabs, crustaceans, mollusks, and insects (Skeel and Mallory 1996). On the Farallones, they occur mainly along the immediate shoreline but occasionally forage in upland habitats. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The impacts associated with disturbance sensitivity for this alternative are high because of their high exposure to gull hazing activities, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals on the Farallones.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

4.5.6.2.1.7 Seabirds:

- **Western Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 14,000 and 32,000 western gulls. With a successful hazing program, the Service will likely keep the number of individuals landing on the Farallones to a minimum level. Western Gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, western gulls not hazed successfully could be exposed to diphacinone through primary and secondary exposure pathways. Western gulls are generalist predators and opportunistic feeders consuming fish, aquatic invertebrates, adult birds, chicks, eggs, carrion, and human refuse (Pierotti and Annett 1995). On the Farallones, this species is numerous in all habitats but distribution changes seasonally. Additionally, western gulls and the closely related glaucous-winged gull have been documented eating non-toxic placebo bait pellets on the Farallones and on other islands on the Pacific Coast. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. Given the number of western gulls that could be present during project operations, gulls are analyzed at the regional population level. However, gull hazing efforts are expected to reduce the number of gulls likely to be at risk of toxicant exposure to fewer than 1,700, which is below the level at which population-level impacts are expected.

Disturbance risk
Western gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during and after aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to the regional population.

Significance Determination
Because of their long lifespan, population level impacts were considered to be long-term if impacts to the regional population were detectable after 20 years (Section 4.5.4.4, Appendix N). Mortality of more than 1,700 western gulls would have to occur in order to affect the regional population level after 20 years (Appendix N). The hazing program would keep the number of individuals that would experience lethal effects to below 1,700. Therefore, no long-term negative or positive impacts to the regional population are expected. The significance determination for western gulls is not significant.

- **Ring-Billed Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and seven ring-billed gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, ring-billed gulls could be exposed to diphacinone through primary and secondary exposure pathways. Ring-billed gulls are omnivorous and opportunistic feeders consuming fish, insects, earthworms, rodents, eggs, and human refuse (Ryder 1993). On the Farallones, this species occurs almost entirely along the immediate shoreline. Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of the primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals present on the islands.

Disturbance risk
Ring-billed gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
Because toxicant and disturbance risks are limited to the few individuals of this species that would likely be present during project implementation, no long-term negative or positive population-level impacts would occur. The significance determination for this species is not significant.

- **California Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 390-2,800 California gulls. All gulls would be actively hazed during implementation operations

to decrease their risk of exposure to toxicant. However, California gulls could be exposed to diphacinone through primary and secondary exposure pathways. California gulls are omnivorous and opportunistic feeders consuming small mammals, fish, birds, eggs, marine invertebrates, insects, and human refuse (Winkler 1996). Additionally, other omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones in the fall and winter, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of the primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the relatively low numbers of individuals present on the islands. However, gull hazing efforts would reduce the number of gulls likely to be at risk of toxicant exposure.

Disturbance risk
California gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative is high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to the relatively low numbers of individuals present on the islands.

Significance Determination
The numbers of California gulls attending the islands is fairly low relative to the size of the regional population. Also, the hazing program would minimize the number of individuals that would experience lethal effects, thus avoiding long-term impacts to the regional population. The significance determination for California gulls is not significant.

- **<u>Glaucous-winged Gull and Glaucous Gull</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 60 and 2,230 glaucous-wing gulls and zero and nine glaucous gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, glaucous-winged and glaucous gulls could be exposed to diphacinone through primary and secondary exposure pathways. Glaucous-winged and glaucous gulls are omnivorous and opportunistic feeders consuming a variety of fish, marine invertebrates, carrion, eggs, mice, and human refuse (e.g., Hayward and Verbeek 2008). Additionally, other omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of the primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to

the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the regional population.

Disturbance risk
Glaucous-wing and glaucous gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the extent of the impact would be to the relatively few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects thus avoiding long-term impacts to the regional population. The significance determination for Glaucous-winged and glaucous gulls is not significant.

- **<u>Mew Gull</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and 70 mew gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, mew gulls could be exposed to diphacinone through primary and secondary exposure pathways. Mew gulls are omnivorous feeders consuming marine and terrestrial invertebrates, insects, fish, grain, and human refuse (Moskoff and Bevier 2002). Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these few individuals would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of the primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the regional population.

Disturbance risk
Mew gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to the few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects. No population level impacts would occur. The significance determination for mew gulls is not significant.

- **Herring Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 50 and 1,000 herring gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, herring gulls could be exposed to diphacinone through primary and secondary exposure pathways. Herring gulls are omnivorous and opportunistic feeders consuming fish, invertebrates, birds, eggs, carrion, and human refuse (Pierotti and Good 1994). Additionally, omnivorous gulls have been known to eat rodenticide bait islands in the region and around the world. On the Farallones, this species occurs almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these gulls would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the relatively few individuals present on the islands.

Disturbance risk
Herring gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The impacts associated with disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to the relatively few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects thus avoiding long-term impacts to the regional population. The significance determination for herring gulls is not significant.

- **Heermann's Gull and Thayer's Gull**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between one and 65 Heermann's gulls and zero and 70 Thayer's gulls. All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, Heermann's gulls and Thayer's gulls could be exposed to diphacinone through primary and secondary exposure pathways. Both species are omnivorous and opportunistic feeders

consuming mostly a variety of fish, marine invertebrates, crustaceans, insects, and carrion. Additionally, omnivorous gulls have been known to eat rodenticide bait on islands in the region and around the world. On the Farallones, these species occur almost entirely along the immediate shoreline. Based on their feeding habits the duration of risk for these few individuals would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the relatively few individuals present on the islands.

Disturbance risk
Heermann's gulls and Thayer's gulls could be exposed to disturbances from ground, air, and gull hazing operations. As described in Section 2.10.7.1, gull hazing would be used as a mitigation measure during aerial baiting operations to help minimize the number of gulls that are likely to consume bait. Hazing and other activities would cause gulls to flush the area or prevent them from landing on the islands, forcing them to find alternate off-island sites to roost. The impacts associated with disturbance sensitivity for this alternative are high because gulls may be very sensitive to hazing causing them to alter their feeding and roosting habits, disrupting their normal behavior. The duration of the disturbance would be for the long-term, and the scale of impact would be to relatively few individuals present on the islands.

Significance Determination
The hazing program would minimize the number of individuals that would experience lethal effects. No population level impacts would occur. The significance determination for Heermann's and Thayer's gulls is not significant.

- **<u>Cassin's Auklet, Ashy Storm-petrel, Leach's Storm-petrel</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is expected to be up to 15,000 Cassin's auklets, 3000 ashy storm-petrels, and 500 Leach's storm-petrels. Cassin's auklet, ashy storm-petrel, and Leach's storm-petrel on the South Farallones are not likely to be exposed to diphacinone through either primary or secondary exposure pathways. These seabirds breed on the South Farallon Islands and feed at sea. Based on their feeding habits the duration of risk for these seabirds would be for the short-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish, their main food source, would consume bait. The overall toxicant risk is low due to the number of exposure pathways. The scale of the impact would be to the regional populations of these species.

Disturbance risk
These species could be exposed to disturbances from ground and air operations. All species are nocturnal. Small numbers of ashy storm-petrels would still be raising young in their rock crevice nests during the early part of the implementation phase. Birds begin attending the colony sporadically (at night only) in January for social purposes in preparation for the next breeding season. Leach's storm-petrels begin pre-breeding attendance in late February (Ainley et al. 1990d). Although no longer nesting, Cassin's auklets attend the colony on some nights in the fall

and winter months for social purposes. Thus, except for a small number of remaining storm-petrel chicks early in the operational period, these species would most likely be present only at night and not directly susceptible to most ground or air operations. Aside from the possibility of auditory techniques such as predator calls, little gull hazing activity is expected to occur at night. All efforts would be made to minimize disturbance to nesting habitats during ground operations.

For cassin's auklet and ashy storm-petrel, the disturbance sensitivity for this alternative is low because birds would not be present during most operations and care would be taken to protect breeding habitats. The duration of the disturbance would be for the long-term, and the scale of impact would be to the regional population. For the Leach's storm-petrel, the disturbance sensitivity for this alternative is low because the majority of birds would not be present during operations and care would be taken to protect breeding habitats. The duration of the disturbance would be for the short-term because birds will only be just beginning to arrive back at the colony at the end of the operational period. The scale of impact would be to the regional population.

Significance Determination
As explained above, it is highly unlikely that any individuals of these species would consume bait directly or indirectly. Those individuals who are present and active during daytime operations could experience disturbance from ground and air operations and from hazing for the duration of the project (about 16 weeks). The significance determination for Cassin's auklet is not significant since no long-term negative or positive impacts to the population are expected. The significance determination for ashy and Leach's storm-petrels is significant since the eradication of mice should have significant, long-term positive benefits to their populations on the Farallones (see Section 1.3.1).

- **<u>Common Murre</u>**

Toxicant risk
The estimated number of common murres likely to occur on the islands during operations is expected to be up to 280,000 individuals. Common murres on the South Farallones are not likely to be exposed to diphacinone through either primary or secondary exposure pathways; however, there is a small chance that they could be secondarily exposed if the toxicant is consumed by their marine fish or invertebrate prey, which is highly unlikely to occur. These seabirds breed on the Farallon Islands and feed at sea. Based on their feeding habits the duration of risk for these seabirds would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish or invertebrates, their main food sources, would consume bait. The overall toxicant risk is low due to the remote nature of a possible exposure pathway. The scale of the impact would be to the regional population.

Disturbance risk
Common murres sporadically visit their breeding areas during the late fall and winter. Thus, this species likely will be exposed to disturbances from ground and air operations, which would likely cause them to flush the area. Birds may return or depart the area for the remainder of the day. The impacts associated with disturbance sensitivity for this alternative are medium, the

duration of the disturbance would be for the long-term, and the scale of impact would be to the regional population.

Significance Determination
Because the toxicant risk to this species is low and disturbance impacts are temporary, no long-term negative or positive impacts to the regional population are expected. The significance determination for common murre is not significant.

- **Brown Pelican, Brandt's Cormorant, Double-crested Cormorant, Pelagic Cormorant,**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is expected to be between 1,000 and 6,000 brown pelicans, and up to 2,000 Brandt's cormorants, 100 double-crested cormorants, and 200 pelagic cormorants. Brown pelicans, Brandt's cormorants, pelagic cormorant, and double-crested cormorants could be exposed to diphacinone through secondary exposure pathways. These species are primarily piscivorous and their diet consists of fish and some marine invertebrates (Shields 2002). Based on their feeding habits the duration of risk for these birds would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low since there is only one exposure pathway. The overall toxicant risk is low due to the number of exposure pathways. The scale of impact for the Brandt's Cormorant would be the regional population, and for the other three species would be to the relatively few individuals present on the islands.

Disturbance risk
These species could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the island or away from the islands. The impacts disturbance sensitivity for this alternative is high, the duration of the disturbance risk would be for the long-term, and the scale of impact would be to the regional population for Brandt's cormorant and the relatively few individuals present on the islands for brown pelicans, pelagic cormorants and double-crested cormorants.

Significance Determination
Because the toxicant risk to these species is low and disturbance impacts are temporary, no long-term negative or positive impacts to the regional populations of these species are expected. The significance determination for brown pelican, Brandt's cormorant, pelagic cormorant and double-crested cormorant is not significant.

4.5.6.2.1.8 Waterfowl:

- **Cackling Goose, Canada Goose, and Green-winged Teal**

Toxicant risk
Cackling geese and green-winged teal mainly occur as fall migrants. Canada geese began nesting on Southeast Farallon Island in 2010; since then, from one to five pairs have bred on the island each year up to 2017 (Point Blue, unpubl. data). Adults typically arrive in February or March. Because of their changed status since publication of the RDEIS, estimates of numbers of Canada

geese that may be on the islands during the operational period are based on count data obtained between the fall-winter seasons of 2011-12 to 2017-18 (Point Blue, unpublished data).

The estimated number of individuals likely to occur on the islands during operations is between zero and 60 Cackling geese, three and 18 Canada geese, and zero and four green-winged teal. Cackling geese and Canada geese could be exposed to diphacinone through primary and secondary exposure pathways. Both geese species are primarily herbivorous and consume grass, grain, aquatic invertebrates, and insects (Mowbray et al. 2002). Green-winged teal are more opportunistic, feeding on a variety of plant seeds, aquatic vegetation, aquatic insects and larvae, molluscs, and crustaceans (Johnson 1995). On the Farallones, cackling and Canada geese occur both along the shoreline and upland habitats. Based on their feeding habits the duration of risk for these geese would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the islands.

Disturbance risk
Cackling geese, Canada geese, and green-winged could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is high, the duration of the disturbance risk would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
Although the toxicant risk to these species is medium. all three species are numerous throughout their ranges and the number of individuals on the Refuge reflects a small percent of their overall populations. Disturbance-related impacts to these species are temporary. As a result, no long-term negative or positive impacts to the regional populations of these species are expected. The significance determination for cackling geese and Canada geese is not significant.

- **<u>Brant</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between zero and 22 brant. Brant could be exposed to diphacinone through primary and secondary exposure pathways. Brant are primarily herbivorous and consume eelgrass, green algae, salt marsh plants, and graze on upland grassland (Reed et al. 1998). Based on their feeding habits the duration of risk for these waterfowl would be for the long-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the range of primary and secondary toxicant exposure pathways. The overall toxicant risk is medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the few individuals that are present at this time on the island.

Disturbance risk
Brant could be exposed to disturbances from both ground and air operations, which would likely cause them to flush the area to an alternate site on the islands or perhaps to depart the islands. The disturbance sensitivity for this alternative is high, the duration of the disturbance risk would be for the long-term, and the scale of impact would be to the few individuals that are present at this time on the island.

Significance Determination
The significance determination for brant is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.2 Impacts on Mammals

4.5.6.2.2.1 Pinnipeds:

- **Steller Sea Lion, California Sea Lion, Northern Fur Seal, and Pacific Harbor Seal**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 145 and 300 Steller sea lions, 70 and 140 Pacific harbor seals, 11,000 and 21,500 California sea lions, and 34 and 125 northern fur seals. Steller sea lions, California sea lions, Northern fur seals, and Pacific harbor seals breed on the Farallones but will not be breeding during the proposed implementation of this alternative. All of these species could be exposed to diphacinone through primary and secondary exposure pathways. Pinnipeds primarily consume marine fish and invertebrates. All may feed near the islands, but Northern fur seals mainly feed in pelagic waters far from the islands. Pups, which may be present, have been known to suckle on rocks. On the Farallones, these species are found along the immediate shoreline, although California sea lions and Northern fur seals may venture into upland areas. Based on their feeding habits the duration of risk for pinnipeds would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish and invertebrates, their main food source, would consume bait. Also, the overall toxicant risk is low since pinnipeds would need to consume a very large amount of rodent bait to reach a toxic level due to their large size. In addition, we would mitigate impacts to marine fish and invertebrates by utilizing a deflector to prevent bait from entering the marine environment. The scale of impact would be to the regional population for harbor seal and to the regional populations for all other species.

Disturbance risk
All of these species are particularly sensitive to nearby human activities. Pinnipeds would be exposed to disturbance from ground, air, and gull hazing operations. Prior to aerial bait applications, these pinnipeds may be flushed carefully as a precaution for their safety, resulting in short-term impacts. The impacts of gull hazing actions were assessed during a gull hazing trial undertaken in 2012 (Appendix E). Responses of pinnipeds varied depending on the hazing tool employed and the species present but, only rarely did hazing activities result in pinnipeds being flushed into the water. In summary, little impact to pinnipeds would be expected as a consequence of eradication or hazing activities. However, every effort will be made to minimize

disturbance risk to pinnipeds. The impacts associated with disturbance sensitivity for this alternative are high, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population for harbor seal and to the regional populations for all other species.

Significance Determination
Due to their large size and the amount of toxicant consumption that would be required to lead to toxicosis, it is very unlikely that any individual pinniped would be harmed as a result of direct or indirect toxicant consumption. Ground, air and hazing operations would cause disturbances to individual pinnipeds for an expected 16 weeks; however, the disturbance levels from these activities would not reach a Level A harassment under the MMPA, which is statutorily defined as, "any act of pursuit, torment, or annoyance which—Has the potential to injure a marine mammal or marine mammal stock in the wild." The significance determination for pinnipeds is not significant since no short- or long-term negative or positive impacts to either population is expected.

- **<u>Northern Elephant Seal</u>**

Toxicant risk
The estimated number of individuals likely to occur on the islands during operations is between 65 and 135 northern elephant seals. Northern elephant seals begin breeding in late December, during the latter portion of proposed operations. These animals could be exposed to diphacinone through primary and secondary exposure pathways. They primarily consume marine fish and invertebrates in deep pelagic waters and do not feed near the islands. Pups have been known to suckle on rocks. On the Farallones, these species are found mainly along the immediate shoreline, but some individuals occasionally wander into low-lying upland areas. Based on their feeding habits the duration of risk for pinnipeds would be for the medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low due to the fact that is highly unlikely that elephant seals or their main food sources, pelagic fish and invertebrates, would consume bait Also, the overall toxicant risk is low since elephant seals would need to consume a very large amount of rodent bait to reach a toxic level due to their large size. In addition, we would mitigate impacts to fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the regional population.

Disturbance risk
Northern elephant seals do not often react to nearby human activity, and thus are unlikely to be disturbed by air or ground operations. However, northern elephant seals may be flushed into the water prior to aerial bait drops as a precaution for their safety, resulting in short term disturbance. They would likely return to the islands in a few hours. Disturbance impacts from hazing were assessed during the gull hazing trial. The impacts of these actions were assessed during a gull hazing trial undertaken in 2012 (Appendix E). Responses of elephant seals varied depending on the hazing tool employed but only rarely did elephant seals react to hazing activities and none were flushed. In summary, little impact to northern elephant seals would be expected as a consequence of eradication or hazing activities. The impacts associated with disturbance sensitivity for this alternative are low, the duration of the disturbance would be for the medium-term, and the scale of impact would be to the regional population.

Significance Determination
Due to their large size and the amount of toxicant consumption that would be required to lead to toxicosis, it is very unlikely that any individuals would be harmed as a result of direct or indirect toxicant consumption. Other than being flushed into the water prior to each bait drop, ground, air and hazing operations would rarely disturb elephant seals. The disturbance level would not reach Level A harassment under the MMPA. The significance determination for Northern elephant seals is not significant since no long-term negative or positive impacts to the regional population are expected.

4.5.6.2.3 *Impacts on Amphibians*

- **Arboreal Salamanders**

Toxicant risk
Arboreal salamanders that are not captured and held during the operation could be exposed to diphacinone through secondary exposure pathways by consuming insects that have consumed the toxicant. Based on their feeding habits the duration of risk for these salamanders would be for the medium-term, the toxicant sensitivity is considered to be low, and the toxicant exposure risk is medium, due to the range of secondary toxicant exposure pathways. The overall toxicant risk is low based on toxicity study data (Witmer 2018; Appendix Q) suggesting low risk. The scale of impact would be to the entire world population of this subspecies of arboreal salamander because it is endemic to the South Farallon Islands. Despite anticipated low risk, in an effort to mitigate potential unforeseen impacts to salamanders, about 40 individuals will be captured and held for the duration of risk, to be released once the toxicant risk has decreased to negligible.

Disturbance risk
Arboreal salamanders not captured or held for the duration of risk could be exposed to disturbances from ground operations, which could result in habitat disturbance or cause individuals to flee the immediate area or potentially be preyed upon or injured. Every effort will be taken to limit ground operations and mitigate any known risks to salamanders; however, it is possible that they could be inadvertently crushed by personnel moving around the island at night when they are active. Also, individuals captured and held during the trial (see above) will be subjected to a certain level of disturbance impact (See Section 2.10.7.5). The impacts associated with disturbance sensitivity for this alternative are low, the duration of the disturbance would be for the long-term, and the scale of impact would be to the entire world population of this subspecies of arboreal salamanders since it is endemic to the South Farallon Islands.

Significance Determination
Based on the results of the salamander toxicity trial, no long-term adverse impacts from the eradication operation or the capture/hold program are anticipated. Given their respective diets, mice likely compete with salamanders for food. Salamanders should therefore benefit from mouse eradication. The significance determination for arboreal salamanders is significant for positive impacts.

4.5.6.2.4 Impacts on Fish

- **Marine Fish**

Toxicant risk
Depending on the species, marine fish could be exposed to diphacinone through either primary or secondary exposure pathways by consuming bait pellets, invertebrates, or other fish that have been exposed to the toxicant. However, most fish species around the Farallones are either predators or planktivores that are unlikely to come in contact with or consume a bait pellet. Also, mitigation measures to minimize incidental bait drift into the marine environment, rapid bait degradation in water, and low solubility of brodifacoum minimize exposure pathways for marine fish. Thus, the duration of risk for marine fish would be for the short-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low. The overall toxicant risk is low due to the short duration of potential exposure and the number of likely exposure pathways. The scale of impact would be to a few individuals.

Disturbance risk
Marine fish could be exposed to disturbances from boating operations, which would likely cause them to flee. The impacts associated with disturbance risks for this alternative are negligible, the duration of the disturbance would be for the short-term, and the scale of impact would be to a few individuals.

Significance Determination
There are no expected long-term negative or positive significant impacts to any of the populations of marine fish, so the significance determination for marine fish is not significant.

4.5.6.2.5 Impacts on Invertebrates

Invertebrates:

Terrestrial Invertebrates

- **Farallon Camel crickets**

Toxicant risk
Farallon camel crickets could be exposed to diphacinone through primary exposure pathways by consuming bait directly. Although, diphacinone consumption by invertebrates generally does not cause mortality (Morgan and Wright 1996, Spurr 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001), we chose a more conservative assumption that toxicant sensitivity to Farallon camel crickets would be medium due to the paucity of diphacinone toxicity data (i.e., uncertainty) in terrestrial invertebrates and the endemic, rare nature of this species. Based on their feeding habits the duration of risk for camel crickets would be for the long-term and the toxicant exposure risk is low due to the primary exposure pathway. The overall toxicant risk is low due to the primary exposure pathway. The scale of impact would be to the total world population since these crickets are endemic to the South Farallon Islands.

Disturbance risk
Camel crickets could be exposed to disturbances from ground operations, which may cause from a few to dozens of individuals to flee the immediate area. Entry into their primary cave habitats will be limited to short visits with a minimal number of personnel in an effort to minimize disturbance impacts. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance would be for the long-term, and the scale of impact would be to the world population since these crickets are endemic to the South Farallon Islands.

Significance Determination
The significance determination for camel crickets is significant for the world population because the eradication of mice and the resulting decrease in burrowing owl numbers will likely result in long-term benefits to the cricket population (Sections 1.3.3 and 4.5.3.6). These long-term beneficial impacts outweigh temporary adverse impacts associated with disturbance from project operations and the low risk to this species from diphacinone.

- **Other Terrestrial Invertebrates**

Toxicant risk
Invertebrates like kelp flies could be exposed to diphacinone through primary exposure by consuming bait directly, and some species such as dragonflies, butterflies, and damselflies could be exposed secondarily by feeding on other insects. Some invertebrates have been known to consume rodenticide bait as residues have been detected in arthropods (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001) and other invertebrates. However, diphacinone consumption by invertebrates generally does not cause mortality. Based on their feeding habits the duration of risk for terrestrial invertebrates would be for the long-term. The toxicant sensitivity would be negligible, and the toxicant exposure risk is low due to the primary exposure pathway. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to regional populations.

Disturbance risk
Invertebrates could be exposed to disturbances from ground operations, which could crush individuals or disturb habitat. The impacts associated with disturbance risks for this alternative are low, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals affected.

Significance Determination
The significance determination for terrestrial invertebrates is significant since the eradication of mice should have significant positive benefits to their populations on the Farallones. These long-term beneficial impacts outweigh the short-term adverse impacts associated with toxicant exposure and disturbance during project implementation.

Intertidal Invertebrates

- **Black Abalone**

Toxicant risk
Black abalones are intertidal gastropod mollusks that feed on marine algae such as kelp. Thus, if an abalone were to come in direct contact with a rodent bait pellet, the abalone may consume all or part of the pellet. Abalone could then be exposed to diphacinone through a primary exposure pathway. Some terrestrial gastropods have been known to consume rodenticide bait as residues of brodifacoum have been detected in their tissues (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001). Abalone also could be exposed to diphacinone if a bait pellet incidentally ended up in the immediate vicinity of an individual abalone and toxicant made it into the water column or substrate. No information could be found on potential impacts of diphacinone to black abalone or other intertidal gastropods. However, exposure to the even more potent anticoagulant brodifacoum to abalone is not known to cause mortality (Primus et al. 2005; see Section 4.5.4.3.4). Based on their feeding habits, mitigation measures to minimize bait drift into the marine environment, rapid breakdown of bait pellets in water, insolubility of diphacinone, and extremely low numbers (if any) of black abalone at the islands, the duration of risk for black abalone would be for the short-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is low. The overall toxicant risk is low due to the factors described above. The scale of impact would be to no more than a few individuals.

Black abalone critical habitat could be impacted by such factors as risks to water quality or food. As described in Section 4.4.1, potential impacts to water quality are considered to be negligible. Diphacinone is not known to have any impacts on plants such as marine algae and thus would not impact the abalone's food supply. Thus, the toxicant risk to black abalone critical habitat is negligible.

Disturbance risk
Black abalone are not likely to be exposed to disturbance impacts from eradication operations because of their rarity and low levels of operational activity that will occur in intertidal zones. It is not expected that black abalone would be affected by helicopter or gull hazing operations. Therefore, disturbance risk to this species and its critical habitat are considered to be negligible.

Significance Determination
Intertidal sampling since the 1990s indicate that black abalone are very rare at the South Farallones. A recent survey for black abalone at the islands did not find any individuals of the species (Roletto et al. 2015).While primary exposure to diphacinone is possible, a combination of the rarity of the species at the islands, mitigation measures to minimize incidental bait drift into the marine environment, and the likely sensitivity of the species to diphacinone, along with the negligible risk of disturbance impacts, no short- or long-term negative impacts to black abalone (including the take of individuals) or black abalone habitat are expected.

While it is unlikely that mice would prey on adult abalone, it is possible that mice could prey on recently settled juvenile abalone. Thus, the elimination of mice could result in improved habitat conditions by better allowing juvenile abalone that settle in the islands' intertidal zone to survive and reach adulthood. However, given the species status on the islands and the region, benefits from this are expected to be low.

Based on the factors described above, no significant short-term or long-term negative or positive impacts to black abalone or their critical habitat are expected, so the significance determination for this species and its critical habitat are not significant.

- **Other Gastropods**

Toxicant risk
Similar to the black abalone (above), other intertidal gastropods like owl limpets, black turban snails, and several dorid nudibranch species, could be exposed to diphacinone through primary exposure pathways. Terrestrial gastropods have been known to consume rodenticide bait as residues have been detected in their tissues (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001). However, brodifacoum (more toxic than diphacinone) consumption by abalone (also a gastropod) is not known to cause mortality (Primus et al. 2005). Based on their feeding habits the duration of risk for other gastropods would be for the short-term. The toxicant sensitivity would be medium, and the toxicant exposure risk is low due to the primary exposure pathway and mitigation measures to minimize bait drift into the marine environment. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to a small number of individuals.

Disturbance risk
Gastropods are not likely to be exposed to disturbance impacts from eradication and personnel would actively avoid disturbing individuals if they are detected. Therefore, disturbance risk to these species is negligible.

Significance Determination
There are no expected long-term negative or positive significant impacts to gastropods, so the significance determination for this species is not significant.

- **Other Intertidal Invertebrates**

Toxicant risk
Intertidal invertebrates besides gastropods could be exposed to diphacinone through primary exposure by consuming bait directly. Invertebrates have been known to consume rodenticide bait as residues have been detected in arthropods (Morgan and Wright 1996, Ogilvie et al. 1997, Pain et al. 2000, Booth et al. 2001) and other invertebrates. However, diphacinone consumption by invertebrates generally does not cause mortality. Based on their feeding habits the duration of risk for intertidal invertebrates would be for the short-term. The toxicant sensitivity would be negligible, and the toxicant exposure risk is low due to the primary exposure pathway and mitigation measures to minimize bait drift into the marine environment. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to individuals.

Disturbance risk
Intertidal invertebrates are not likely to be exposed to disturbance impacts from eradication operations and personnel would actively avoid disturbing individuals if they are detected. Therefore, disturbance risk to these species is negligible.

Significance Determination
The significance determination for other intertidal invertebrates is negligible since no long-term negative or positive impacts to these populations are expected.

4.5.6.2.6 *Impacts on Vegetation*

- **Vegetation**

Toxicant risk
Due to the very low solubility of diphacinone in water, plant uptake is unlikely to occur (Weldon et al. 2011). Post-application monitoring for the Anacapa Island rat eradication tested negative for brodifacoum residue in all plant samples (Howald et al. 2010). Vegetation is not known to be negatively impacted by rodenticides, and therefore, does not require further analysis of the toxicological impacts.

Disturbance risk
Vegetation could be exposed to disturbances from ground operations, which will result in trampling and damage to individual plants. The impacts associated with disturbance risks for this alternative are low because rodent bait will be applied by helicopter as the primary technique and during ground-based activities staff will make every effort to minimize their impact on vegetation. Plants are also expected to recover from any short-term impacts relatively quickly. The duration of the disturbance would be for the medium-term, and the scale of impact would be to a few plants or areas of the island visited frequently by personnel.

Significance Determination
The significance determination for vegetation is significant as the eradication of mice is expected to have significant positive benefits to vegetation on the Farallones since mice are known to consume the seeds and seedlings of native plant species (Sections 1.2.2.4 and 1.3.5).

4.5.6.2.7 *Impacts Table for Alternative C on Biological Resources: Aerial Broadcast of Diphacinone*

Table 4.5: Impacts of Alternative C on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance
Raptors[8,9]	Not Significant	Long	Medium	High	Medium	Low/High	Short/Long	Individ.	Individ.
Burrowing Owl[9]	Not Significant	Long	Medium	High	Medium	Low/ High	Short/ Long	Individ.	Individ.
Western Gull	Not Significant	Long	Medium	High	Medium	High	Long	Regional	Regional
Other Gulls[10]	Not Significant	Long	Medium	High	Medium	High	Long	Individ.	Individ.
Ashy and Leach's Storm-petrel	Significant positive effect	Short	Medium	Low	Low	Low	Short	Regional	Regional
Cassin's Auklet	Not Significant	Short	Medium	Low	Low	High	Long	Regional	Regional
Common Murre	Not Significant	Medium	Medium	Low	Low	Medium	Long	Regional	Regional
Brown Pelican and Cormorants	Not Significant	Medium	Medium	Low	Low	High	Long	Individ.	Individ.
Cackling goose, Canada goose and green-winged teal	Not Significant	Long	Medium	High	Medium	High	Long	Individ.	Individ.
Brant	Not Significant	Long	Medium	High	Medium	High	Long	Individ.	Individ.
Rocky intertidal shorebirds[11]	Not Significant	Medium	Medium	Low	Low	High	Medium	Individ.	Individ.
Black Oystercatcher	Not Significant	Medium	Medium	Low	Low	High	Medium	Individ.	Individ.
Other Shorebirds[12]	Not Significant	Medium	Medium	Medium	Medium	High	Short	Individ.	Individ.
Passerine Omnivores[13]	Negligible	Long	Medium	Medium	Medium	Medium	Long	Individ.	Individ.
Passerine Insectivores[14]	Negligible	Long	Medium	Medium	Medium	Medium	Long	Individ.	Individ.

Table 4.5: Impacts of Alternative C on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance
Passerine Granivores[15]	Negligible	Long	Medium	High	Medium	Medium	Long	Individ.	Individ.
Anna's Hummingbird	Negligible	Long	Medium	Medium	Medium	Medium	Long	Individ.	Individ.
Northern Elephant Seal	Not Significant	Medium	Medium	Low	Low	High	Medium	Regional	Regional
Harbor Seal	Not Significant	Medium	Medium	Low	Low	High	Medium	Regional	Regional
Other Pinnipeds[16]	Not Significant	Medium	Medium	Low	Low	High	Medium	Regional	Regional
Marine Fish	Negligible	Short	Medium	Low	Medium	Low	Short	Individ.	Individ.
Salamanders	Significant positive effect	Medium	Low	Medium	Low	Low	Short	World	World
Terrestrial Invertebrates	Significant positive effect	Medium	None	Low	Low	Low	Short	Island	Island
Other Intertidal Invertebrates	Negligible	Medium	None	Low	Low	Negligible	Negligible	Individ.	Individ.
Black Abalone	Not Significant	Medium	None	Low	Low	Negligible	Negligible	Individ.	Individ.
Other Intertidal Gastropods	Not Significant	Medium	None	Low	Low	Negligible	Negligible	Individ.	Individ.
Camel Cricket	Significant positive effect	Long	Medium	Low	Low	Low	Short	World	World
Vegetation	Significant positive effect	None	None	None	None	Low	Medium	None	Individ.

[1] None: No duration of risk; Short: potential exposure risk for up to 30 days; Medium: potential exposure risk for 31-90 days; Long: potential exposure risk for more than 90 days.
[2] None: No toxicological sensitivity; Low: Minor toxicological sensitivity; Medium: Moderate toxicological sensitivity; High: High toxicological sensitivity.
[3] None: No exposure pathway; Low: Possible exposure pathway; Medium: One exposure pathway; High: Multiple exposure pathways.
[4] None: Negligible risk from toxicant; Low: Low risk from toxicant; Medium: Medium risk from toxicant; High: High risk from toxicant.
[5] None: Negligible sensitivity to disturbance; Low: Low sensitivity to disturbance; Medium: Moderate sensitivity to disturbance; High: High sensitivity to disturbance. For cells containing two values separated by a slash (e.g., Low/High), the upper value is for to non-captured birds lower value is for captured birds.
[6] Short: Potential disturbance risk for 1 – 30 days; Medium: Potential disturbance risk for 30 – 90 days; Long: Potential disturbance risk for more than 90 days.

Table 4.5: Impacts of Alternative C on Biological Resources

Species	Significance determination	Duration of ToxicantRisk[1]	Toxicant Sensitivity[2]	Toxicant exposure risk level[3]	Overall Toxicant Risk (Sensitivity+ Exposure)[4]	Disturbance Sensitivity[5]	Duration of Disturbance risk[6]	Scale of Negative Impact[7]	
								toxicant	disturbance

[7] Individual (Individ.): Few individuals potentially affected; Island population (Island): Many individuals may be affected with potential impacts to the island population; regional population (Regional): Many individuals may be affected with potential impacts to the regional population; Species/Subspecies: Many individuals may be affected with potential impacts to the species or subspecies.
[8] Northern harrier, sharp-shinned hawk, American kestrel, merlin, peregrine falcon, long-eared owl, short-eared owl, barn owl,
[9] For Disturbance Senstivity and Duration of Disturbance Risk, two outcomes are listed: First – individuals remaining on island / Second – individuals captured and held in captivity.
[10] Ring-billed gull, California gull, glaucous-winged gull, glaucous gull, mew gull, herring gull, Heermann's gull, Thayer's gull.
[11] Wandering tattler, willet, least sandpiper, black turnstone, ruddy turnstone, surfbird.
[12] Whimbrel, black-bellied plover, Wilson's snipe, killdeer.
[13]Hermit thrush, American robin, varied thrush, cedar waxwing, European starling, American pipit, mountain bluebird.
[14] Yellow-rumped warbler, palm warbler, golden-crowned kinglet, ruby-crowned kinglet, Northern flicker, black phoebe, Say's phoebe, brown creeper, rock wren, Nashville warbler, Townsend's warbler.
[15] Horned lark, fox sparrow, savannah sparrow, white-throated sparrow, white-crowned sparrow, golden-crowned sparrow, dark-eyed junco, red-winged blackbird, western meadowlark, Brewer's blackbird, purple finch, pine siskin, lesser goldfinch, horned lark, Lapland longspur, house finch.[16] Stellar sea lions, California sea lions, northern fur seal, Steller sea lion.

4.6 Consequences: Social and Cultural Resources

The CEQ guidelines at 40 CFR 1508.14 include the human relationship with the natural environment as a category of potential impacts that must be considered in a NEPA analysis. This is interpreted to mean that a NEPA analysis needs to examine the potential effects of an action on any economic and/or social values that are related to the natural environment.

4.6.1 Personnel Safety

4.6.1.1 *Analysis framework for personnel safety*

The safety of personnel is of highest priority, and therefore, the Service would consider any major injury or the death of any personnel during the implementation of the eradication to be significant.

4.6.1.2 *Alternative A*

Personnel safety is the Service's highest priority. If the No Action alternative is selected, the Service would continue to require the same safety protocols that are currently being implemented on the Farallon Islands. The significance determination for the No Action alternative is not significant since every effort will be made to protect personnel safety.

4.6.1.3 *Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone*

If either Alternative B or Alternative C is selected, the following safety protocols will be apply to operation. The Farallon Islands NWR would be closed to all non-essential personnel during the operational period. Personnel required to be present at these locations would be trained for the roles they would perform. All bait application activities (aerial broadcast, hand broadcast and servicing of bait stations) would be conducted by or under the supervision of one or more pesticide applicators licensed by the State of California. The water catchment pad will be tarped to prevent bait drift into the drinking water supply. In addition, in an effort to preclude direct exposure to the toxicant, all staff and volunteers involved in the project would wear appropriate personal protective equipment (PPE) and receive task specific briefings on managing the risks. PPE would meet or exceed all requirements by the EPA and OSHA. As part of the Operational Plan, a Safety Plan would be developed and would require approval by the Service prior to implementation. This Safety Plan would reference the current Safety Plan for Farallon Islands National Wildlife Refuge (USFWS 2015) but would be tailored to the specific safety needs of the eradication project. The significance determination for both action alternatives is not significant since every effort will be made to prevent injury to personnel.

4.6.2 Recreation and Tourism

4.6.2.1 *Analysis framework for Refuge visitors and recreation*

Although public access to the South Farallones is prohibited, the waters surrounding or near the islands are popular with tour boats and private boaters throughout much of the year for wildlife viewing, recreational fishing, and to enjoy the high-quality scenic panorama the islands provide. This analysis examines potential impacts to the visitor experience as a result of each alternative. The Service would consider any major, long-term changes to the visitor experience to be significant.

4.6.2.2 *Alternative A: No action*

It is unlikely that the impacts that mice would continue to have to the South Farallones ecosystem would be perceptible to boaters near the islands. However, several pelagic bird watching trips to the offshore areas between Cordell Bank and Monterey Bay specifically target searching for ashy storm-petrels. Lower population sizes of ashy storm-petrels may reduce likelihood of seeing storm-petrels or of seeing large numbers. While the ashy and Leach's storm-petrel populations would likely continue to be negatively impacted, these birds are nocturnal at the colony and forage far offshore, and thus are rarely seen by visitors near the island. Overall, taking No Action with regard to invasive mice would be unlikely to have any direct or indirect impacts to the value of the South Farallones to Refuge visitors. The significance determination is negligible.

4.6.2.3 *Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone*

As a safety precaution, the Service likely will seek to have a vessel closure implemented in the area immediately surrounding the South Farallon Islands (within approximately 0.5 miles) during the days of aerial bait application. This likely would equate to from two to four days for Alternative B and three to six days for Alternative C, depending on weather and other operational factors. These closures would be a minor short-term inconvenience to users. This impact would be minor because much of the surrounding waters within 300 feet of the high tide line are already closed as part of the Southeast Farallon Island Special Closure, and all of these waters occur within the Southeast Farallon Island State Marine Reserve where the take of all living marine resources (e.g., fishing) is prohibited. Because of rough sea conditions, visiting boats to the island are few during the November-December period. However, in recent years from one to five permitted recreational shark cage diving ventures operate within 0.5 miles of the islands on many days (weather permitting) from late September until late November. Closures around the island could result in from two to four (Alternative B) or from three to six (Alternative C) lost shark diving days (See Section 3.5.4); however, since shark diving boats are present everyday, the number of days they would be impacted would likely be less.

Flocks of roosting seabirds and shorebirds, particularly gulls, would likely be flushed during helicopter operations and hazing operations and the flocks would be visible to boaters offshore. Also, pinnipeds flushed during helicopter operations and hazing operations may also be visible to boaters offshore. The expected recovery of the South Farallones ecosystem after mouse eradication would likely not be perceptible to boaters near the islands, although sightings of ashy storm-petrels seen by pelagic birdwatchers farther from the islands may increase over time. However, interpretive materials on the islands' ecosystem recovery would be available in San

Francisco Bay National Wildlife Refuge Complex visitor's center and other appropriate venues. The significance determination is not significant. The economic impacts to shark diving operations are expected to be minimal and every effort would be made to keep diving operations informed during the operation to minimize any economic impacts. The significance determination is not significant.

4.6.3 Fishery Resources

4.6.3.1 *Analysis framework for fishing resources*

The Service would consider any noticeable, long-term changes to fishing resources surrounding the South Farallones that could be attributable to the mouse eradication project to be significant.

4.6.3.2 *Alternative A: No action*

Mice on the South Farallones do not currently impact the fisheries of the nearshore waters, nor would the Service expect any future impacts. The significance determination is negligible.

4.6.3.3 *Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone*

The fishery resources in the area near the South Farallon Islands were described in Section 3.5.3. As a safety precaution, the area immediately surrounding the South Farallon Islands (approximately 0.5 miles) may be closed to access by boats during aerial bait application operations. Since the islands are surrounded by the Southeast Farallon Island State Marine Reserve that prohibits the take of all living marine resources, fishing is already prohibited within 0.5 miles of most of the islands. Also, because of frequently rough seas and seasonal fishing closures for many species, fishing boats are rarely observed within 0.5 miles during the proposed operational period. Thus, operations are not expected to impact commercial or recreational fishing in the area.

As most fishery species occurring near the islands are either planktivores or predators, overall toxicant risk is negligible because these species would not be expected to consume bait that has drifted into the marine environment. Some nearshore fishery species, particularly scavenging species such as the Dungeness crab, have the low potential to be exposed directly or secondarily to rodenticide. Crabs or other scavengers may consume bait pellets (primary exposure) or sick or dead wildlife exposed to rodenticide (secondary exposure). However, because benthic habitats immediately surrounding the islands are poor for supporting Dungeness crabs, only small amounts of accidental bait drift are expected to reach the marine environment, and bait will degrade rapidly upon entering the marine environment, the risk of primary exposure to Dungeness crabs or other subtidal species is very low and likely would be limited to a few individuals. Also, because nearly all wildlife (e.g., mice) impacted by the eradication project are expected to occur on the islands, the risk of secondary exposure to any subtidal species is considered to be negligible. In addition, existing toxicity data has shown that most invertebrates (including crabs; see Section 4.5.4.3.4) and marine fish are are not affected by rodenticides or are not acutely sensitive to exposure (Riegerix 2017). Furthermore, eradication efforts at other

islands have not been shown to impact fishery resources, and in many cases rodenticide residues cannot be detected in marine fish following bait application (Masuda et al. 2015). Based on best available information, the significance determination for fishery resources is negligible.

4.6.4 Cultural Resources

4.6.4.1 *Analysis framework for cultural resources*

The National Historic Preservation Act (NHPA) defines the concept of an "adverse impact" to historical resources as any alteration to the characteristics of a historic property qualifying it for inclusion in or eligibility for the National Register. The analysis below considers the impacts to historical and cultural resources according to these definitions. Section 106 of the NHPA requires agencies to consult with the appointed State Historic Preservation Officer(s) if adverse impacts to historical or cultural resources are possible.

4.6.4.2 *Alternative A: No action*

The Service has no direct evidence that mouse activities impact historical and cultural resources on the island. However, mice are burrowing animals, and have gnawed many holes in the existing historic structures on the island. These behaviors have the potential to damage buildings and buried artifacts. Mice may continue to cause damage to the historical buildings on Southeast Farallon, but this damage would likely be minor and would not likely be irreversible. The significance determination is low.

4.6.4.3 *Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone*

Neither Alternative B nor C would involve activities that would require structural or soil disruption or involve any other actions that would impact the historical or cultural resources on the South Farallones.

4.7 Unavoidable Adverse Impacts

The analysis presented in this FEIS has identified the potential for adverse environmental impacts with the implementation of any of the three alternatives. Mitigation measures that would be implemented to either avoid or minimize these impacts have been identified and contingency plans have been developed to address any unexpected negative impacts that could occur during the operation. The adverse impacts that remain after implementing mitigation measures are considered to be unavoidable. These impacts include increased short-term negative impacts on the physical, biological, and social and economic resources on the Farallones. All three alternatives, including the No Action alternative, would have unavoidable adverse impacts on the resources of the South Farallon Islands. However, no long-term adverse effects are anticipated as a consequence of either action alternative (Alternatives B and C). The following is a breakdown of the unavoidable adverse impacts by alternative.

4.7.1 **Alternative A: No Action**

Physical Resources

- Water
  - No unavoidable adverse impacts to water are anticipated.
- Geology and Soil
  - No unavoidable adverse impacts to the islands' geology or soils are anticipated.
- Wilderness
  - House mice negatively impact the natural character of wilderness and these effects would continue.

Biological Resources

- Birds
  - Long-term impacts to ashy and Leach's storm-petrel populations would continue as a result of ongoing hyperpredation by burrowing owls, and indirect impact of mice.
- Mammals
  - No unavoidable adverse impacts to marine mammals are anticipated.
- Amphibians
  - Impacts from prey competition from mice to the island's arboreal salamander population would continue.
- Invertebrates
  - Ongoing adverse impacts to endemic camel crickets and other terrestrial invertebrates from mouse predation would continue if house mice remain on the Farallones.
- Vegetation
  - Ongoing impacts to native plants and modification of the islands' plant species composition by mice is anticipated.

Social and Economic Resources

- Personnel Safety
  - No unavoidable adverse impacts to personnel safety are anticipated.
- Recreation and Tourism
  - No unavoidable adverse impacts to recreation or tourism are anticipated.
- Fisheries
  - No unavoidable adverse impacts to fisheries are anticipated.
- Cultural and Historical Resources
  - No unavoidable adverse impacts to cultural and historical resources.

4.7.2 **Alternative B: Aerial Brodifacoum**

Physical Resources

- Water

    - Bait drift into the marine environment, if it occurs, could lead to a very temporary and localized reduction of water quality. However, the cereal bait would disintegrate and disperse rapidly. Additionally, brodifacoum would not persist in the marine environment and no unavoidable adverse long-term impacts to water are anticipated.
- Geology and Soil
    - The installation and maintenance of bait stations may result in a short-term, localized adverse impact to soil and rocks. Additionally, the soil could be contaminated with brodifacoum for up to one year based on the soil half-life of 152 days.
- Wilderness
    - Helicopter use, bait station installation, and gull hazing would have a short-term adverse impact to some attributes of wilderness character.

Biological Resources

- Birds
    - Individual gulls, raptors, some shorebirds, and granivorous passerines may consume toxic bait and experience either lethal or short-term sublethal effects. However, no population level or long-term adverse impacts are anticipated. In addition, gulls, shorebirds, common murres, cormorants, pelicans, and raptors will likely experience disturbance impacts from bait broadcast, hazing, or captive management operations. Adverse impacts as a result of disturbance are expected to be short-term only.
- Mammals
    - Some disturbance to pinnipeds as a result of bait broadcast and hazing operations is anticipated. However, no long-term adverse impacts as a result of this disturbance are anticipated.
- Amphibians
    - No unavoidable adverse impacts to amphibians are anticipated.
- Invertebrates
    - No unavoidable adverse impacts to invertebrates are anticipated.
- Vegetation
    - Short-term localized disturbance to vegetation as a result of human foot traffic is likely but no long-term adverse impacts are anticipated.

Social and Economic Resources

- Personnel Safety
    - No unavoidable adverse impacts to personnel safety are anticipated.
- Recreation and Tourism
    - During aerial bait broadcast, waters within about 0.5 mi of the islands may be closed to boating. This may impact recreational shark diving ventures on the days of closures.
- Fisheries
    - No unavoidable adverse impacts to fisheries are anticipated.
- Cultural and Historical Resources

- No unavoidable adverse impacts to cultural and historical resources.

4.7.3 **Alternative C: Aerial Diphacinone**

Physical Resources

- Water
  - Bait drift into the marine environment, if it occurs, could lead to a very temporary and localized reduction of water quality. However, the cereal bait would disintegrate and disperse rapidly. Additionally, diphacinone would not persist in the marine environment and no unavoidable adverse long-term impacts to water are anticipated.
- Geology and Soil
  - The installation and maintenance of bait stations may result in a short-term, localized adverse impact to soil and rocks. The soil would only be contaminated for up to a week after the last bait application, which should be for less than 40 days based on soil half-life.
- Wilderness
  - Helicopter use, bait station installation, and gull hazing would have a short-term adverse impact on some attributes of wilderness character.

Biological Resources

- Birds
  - Individual gulls, raptors, some shorebirds, and granivorous passerines may consume toxic bait and experience either lethal or short-term sublethal effects. However, no population level or long-term adverse impacts are anticipated. In addition, gulls, shorebirds, common murres, cormorants, pelicans, and raptors will likely experience disturbance impacts from bait broadcast, hazing, or captive management operations. Adverse impacts as a result of disturbance are expected to be short-term only.
- Mammals
  - Some disturbance to pinnipeds as a result of bait broadcast and hazing operations is anticipated. However, no long-term adverse impacts as a result of this disturbance are anticipated.
- Amphibians
  - No unavoidable adverse impacts to amphibians are anticipated.
- Invertebrates
  - No unavoidable adverse impacts to invertebrates are anticipated.
- Vegetation
  - Short-term localized disturbance to vegetation as a result of human foot traffic is likely but no long-term adverse impacts are anticipated.

Social and Economic Resources

- Personnel Safety
  - No unavoidable adverse impacts to personnel safety are anticipated.
- Recreation and Tourism

  - During aerial bait broadcast, waters within about 0.5 mi of the islands may be closed to boating. This may impact recreational shark diving ventures on the days of closures.
- Fisheries
  - No unavoidable adverse impacts to fisheries are anticipated.
- Cultural and Historical Resources
  - No unavoidable adverse impacts to cultural and historical resources.

4.8 Cumulative Impacts

4.8.1 Assessing Cumulative Impacts

The NEPA regulations require federal agencies to consider cumulative impacts. Cumulative impacts are impacts that may result from the incremental impact of the action under consideration when added to other past, present, and reasonably foreseeable future actions whether undertaken by the Service or other entities, 40 CFR Section 1508.7. As a result, analyzing cumulative impacts on the South Farallon Islands requires consideration of other impacts that have occurred in the past, are occurring simultaneously to the same resources, or that are likely to occur in the foreseeable future.

Much of the biodiversity of the Farallones is still recovering from past impacts, including the effects of introduced rabbits and cats on the South Farallones, seal hunting and egg collecting that occurred on the islands, and past oil spills and other pollution. Also, many of the marine species that utilize the South Farallones have large foraging and non-breeding ranges across the ocean. These marine species may be exposed to impacts within distant parts of their range, either in the past, present, or foreseeable future.

The following is a summary of the past, present, and foreseeable future actions that would likely contribute to the cumulative impacts associated with the three identified alternatives. Direct and indirect impacts from each alternative would be analyzed with the following list of activities to determine the cumulative impacts for the given alternative.

4.8.2 Past Actions

Past actions are activities that occurred in the past but have lasting impacts that could contribute to the impacts associated with the proposed action.

- Seal hunting – Hunting by American and Russian sealers extirpated, at minimum, elephant seals and Northern fur seals from the Farallon Islands. Other species, including Steller sea lions, California sea lions, and harbor seals, were either extirpated or drastically reduced in numbers. Most of these species have increased their populations over the last half century and are not experiencing any critical threats at this time. For example, Northern fur seals recolonized the islands in 1996 and are increasing rapidly. Sealers may also have been the first to introduce the invasive house mouse to the islands. The lasting impacts of house mouse introduction have negatively impacted nearly all aspects of the terrestrial ecosystem.

- Invasive Species Removal - European rabbits and domestic cats introduced in the 19th and 20th centuries severely impacted native vegetation and birds, and possibly other natural resources such as salamanders and invertebrates. Both cats and rabbits were removed from the islands in the early 1970s. Cats largely impacted birds by preying upon them, while rabbits impacted vegetation through direct consumption and competition with certain burrow nesting seabirds (e.g., rhinoceros auklet) for burrow and crevice habitats (Ainley and Lewis 1974). After rabbits were removed from the Farallones, vegetation began to grow back in areas of the islands that rabbits were removed them, and nesting seabird populations benefitted without the predation pressure from cats and habitat competition from rabbits.

- Commercial seabird egg collection – Seabird eggs, mainly common murres, were collected during the nineteenth century (*ca.*1849 – 1900), severely impacting murre breeding success during that time. The disturbance caused by the eggers also would have severely impacted breeding success of other species. Although common murres have partially recovered from these and other impacts, their current breeding population of about 280,000 (Point Blue and USFWS, unpubl. data) is still well below the estimated 1,000,000 or more present when egging began (Carter et al. 2001).

- Lighthouse – The lighthouse and first lightkeeper's house (Stonehouse)were constructed in 1853-1855. Two other lightkeeper's houses were built in 1878-1880. The light was maintained and managed by on-island staff from the U.S. Lighthouse Service and U.S. Coast Guard until it was automated in 1972. Lighthouse and Stonehouse construction, which used rocks quarried from the island, caused substantial disturbance to island habitats. Although the extent of the impacts are unclear, construction of these buildings certainly resulted in both disruption and loss of nesting habitat for crevice-nesting seabirds such as storm-petrels and Cassin's auklets and cover for salamanders and various invertebrate species. The difference between lost and gained habitat is unknown. Activities of previous lighthouse keepers reduced bird and pinniped numbers on the islands through disturbance, shooting, and introduced animals including European rabbits and cats (Ainley and Lewis 1974, DeSante and Ainley 1980). Some species of native seabirds are still recovering from these impacts. Mice also may have been introduced by lighthouse keepers. Introduced garden plants, especially New Zealand spinach, have become widespread, outcompete native plants, and have modified the island's habitats.

- Navy construction – The U.S. Navy built several structures on SEFI from about 1905 through WWII that were used as a radio facility, barracks, and offices. Of those, only the building known as the Carpenter's Shop still exists. All others were removed prior to refuge establishment although remains of many buildings still exist. Impacts from their construction are unknown, but probably resulted in substantial disturbance and destruction of seabird nesting habitat, salamander habitat, and plant habitat. The personnel stationed on the island during that time likely caused substantial damage to the islands' resources. Removal of structures has largely restored breeding habitat for seabirds, especially for western gulls. In areas where building foundations still exist, the structures are taking up potential habitat for burrow nesters, although those areas are limited, and some degraded foundations provide some crevice nesting habitat.

Data from the 2010 and 2011 seasons indicate that birds nesting in certain areas on the Refuge remain at risk to the impacts of lead exposure. Given the relationship between lead concentrations in soil and feathers, the primary route of exposure to chicks is likely ingestion of lead particles during feeding or while preening in the nest. While overt signs of lead poisoning are not routinely observed, some feather samples did contain lead concentrations comparable to those found at Midway Atoll (~ 30 ppm), an island with significant lead poisoning events due to a history of lead-based paint use (Aceituno and Maurer 2013).

- Rock wall construction – An extensive system of rock walls were constructed in the 19th century mainly as part of trail construction (such as for the Lighthouse Hill trail, described above) but also for temporary structures, such as for seabird egg storage and to surround the water catchment pads. Rocks used were obtained locally and would have resulted in removal of habitat for rock crevice-nesting seabirds such as storm-petrels and auklets and cover for salamanders and various invertebrate species. However, crevices in the rock walls provide a substantial amount of habitat for these same species. The difference between lost and gained habitat is unknown. Thus, the long-term impacts of the rock wall construction on island resources appear to be not significant and possibly even beneficial.

- Water collection system construction – Two water collection systems were constructed in the early 20th century to collect drinking water including two water catchment pads, a settling tank, a 120,000-gallon cistern, and two smaller water storage tanks. In particular, the water catchment pads displaced seabird breeding habitat, mainly for small numbers of western gulls and Cassin's auklets. The water collection system is still in place.

- House mouse population dynamics – A study to document the population cycle of house mice on SEFI was conducted from March 2001 through February 2003 and from 2010 through 2012 to add additional data. Four transects, each consisting of 12 trapping sites, were established in various habitat types around the accessible portions of SEFI. There are no long-term impacts from this study.

- Boardwalk burrow study – A study of Cassin's and rhinoceros auklets colonizing newly protected habitat around SEFI buildings was initiated in 2000. It was funded by the *Apex Houston* oil spill restoration fund through 2010. Objectives were to quantify the number of auklets nesting under 812 feet of boardwalks that were constructed in September 2000 to replace old dilapidated boardwalks and compare burrow density to the density of natural sites. Of particular interest was whether the "auklet-friendly" design (i.e. providing gaps between boards to permit auklets passage) encourages nesting. The boardwalks were built to protect auklet burrows from human trampling along essential pathways. Studies demonstrated that more auklets nested under the boardwalks than in immediately adjacent habitat, and thus benefit the auklets. The boardwalks continue to benefit auklets.

- Murre Habitat Ledge Construction – The murre habitat ledge is an integrated observation blind (12 ft by ~ 8ft- covered in copper plating), rock wall, and common murre habitat ledges built as part of an oil spill restoration project to protect an expanding murre and cormorant colony from human disturbance. The colony had expanded within view of a frequently traveled pathway. The observation blind has allowed for monitoring of the colony. Data show that the numbers of murres within the murre ledge area increased by about 17 percent between 2007 and 2012 (Point Blue, unpubl. data), a demonstration of the positive effects of the project.

- Insect and Spider Inventories – In 2013 and 2014, an baseline inventory of terrestrial insects and spiders was conducted on Southeast Farallon Island. A study of Farallon camel cricket basic breeding ecology (not yet completed) was also conducted during the same period to provide information on the species and help guide a newly established monitoring effort.

4.8.3 Current and Ongoing Actions

Current actions are activities that are occurring within the same timeframe as the proposed action, or within the planning and compliance phase of the proposed action and could contribute to the impacts from the proposed action.

- Anthropogenic climate change – The three areas of impact linked to global climate change that may have the greatest potential effect on the Farallon Islands are sea level rise, weather changes, and oceanic chemical composition change (often called ocean acidification). Regional predictions (IPCC 2007) for North Central Pacific Gyre area calls for increases of sea surface temperature of 0.5 to 1.0°C by 2090. More recently, New et al. (2011) indicate the likelihood of temperature rise of three or four degrees Celsius within this century. The Farallones terrestrial ecology would be affected by changes in rainfall patterns that likely will include more frequent El Niño events and associated heavy rainfall as well as more severe droughts. Localized variations in subsidence and emergence of the sea floor and plate-tectonics prevent extrapolations in sea level fluctuations and trends between different regions. Thus is may not be possible to discuss uniform changes in sea level on a global scale, or the magnitude of greenhouse gas-forced changes as these changes may vary regionally (Michener et al. 1997) but it is certain that sea level rise would contribute to shoreline erosion and salt water intrusion into subsurface freshwater aquifers as have already been noted throughout the Pacific (Shae et al. 2001). Oceanic chemical composition would likely impact the structure and ecosystem services of the intertidal community. Climate Change Impacts, developed by a joint working group of the Greater Farallones National Marine Sanctuary (GFNMS) and Cordell Bank (CBNMS) National Marine Sanctuary Advisory Councils, identified and synthesized potential climate change impacts to habitats and biological communities along the north-central California coast (Largier et al. 2010).

  The Farallon Islands are located within to the California Current Upwelling System, one of the world's most productive ocean ecosystems. Climate change is expected to have several far-reaching consequences for the California Current System, stemming from

alterations in water-column stability, timing and intensity of upwelling favorable winds, and the sources and chemical properties of water that is advected horizontally and vertically into the system (Doney et al. 2012). A warming ocean is projected to reduce nutrient inputs and primary productivity as the thermocline deepens and stratification intensifies. The likely impacts of a warming California Current on ecosystem function and upper-trophic level consumers can be estimated by using observed declines in nutrient supply and primary production as proxies (Doney et al. 2012). Both of these changes were observed during strong El Niños and as the system transitioned into the 1977–1998 warm phase of the Pacific Decadal Oscillation (McGowan et al. 2003), and in both instances, declines in primary production propagated up the food web from zooplankton to upper-trophic-level consumers, including seabirds (Veit et al. 1996, Sydeman et al. 2009). There is also strong evidence that the trophic impacts of climate change can extend from changes in both the mean and variance of production at the base of the food web. In the southern California Current, Kim et al. (2009) demonstrated increasing chlorophyll a concentrations, as well as advancement in the timing of the spring bloom. In the northern California Current, the peak biomass of *Neocalanus plumchrus*, a large copepod, has both narrowed and advanced by nearly six weeks over 30 years (Mackas et al. 2007). Asynchronies between prey availability and demand can have particularly strong consequences for consumers such as migrating juvenile salmon, or breeding seabirds that undergo critical life-history transitions over narrow timing windows. For example, seabird reproductive failures have been attributed to spatial and temporal mismatches in the availability of and demand for prey (Sydeman et al. 2006).

The following list represents the potential impacts to the Farallon Islands from climate change:

- Observed increases in sea level (100-year record at mouth of San Francisco Bay);
- Expected increases in coastal erosion associated with changes in sea level and storm waves;
- Observed decreases in spring runoff of freshwater through San Francisco Bay resulting from decreased Sierra snowpack. Observed increases in precipitation variability (drier dry years, wetter wet years);
- Observed increases in surface ocean temperature offshore of the continental shelf (50-year record);
- Observed increases in winds driving coastal upwelling of nutrient-rich waters and associated observed decreases in surface ocean temperature over the continental shelf (30-year record);
- Observed increases in extreme weather events (winds, waves, storms);
- Expected decreases in seawater pH (i.e., acidification), due to uptake of CO_2 by the ocean;
- Observed northward shift of key species (including Humboldt squid *Dosidicus gigas,* volcano barnacle *Tetraclita serrata*, gray whales, bottlenose dolphins *Tursiops truncatus*);
- Possible shift in dominant phytoplankton from diatom to dinoflagellate;
- Potential for effects of climate change to be compounded by parallel environmental changes associated with local human activities.
- Potential breeding of tropical seabird species like Brown Booby

Based on data collected daily in the field, maximum annual air temperatures have significantly increased by over 4ºC on Southeast Farallon Island over the last 45 years (Point Blue, unpubl. data). Mean annual daytime air temperate has increased by almost 1ºC during this period as well (Point Blue, unpubl. data).

Projected sea level rise off northern and central California has the potential to significantly alter island habitats and cause a redistribution of wildlife populations. Digital elevation models have demonstrated that a rise of 0.5 m would result in permanent flooding of 23,000 m^2 of habitat at the South Farallon Islands (Point Blue, unpubl. data). This represents approximately five percent of the islands' surface area and would alter low lying habitats, including intertidal areas, pocket beaches and gulches around the islands. These areas are important for intertidal invertebrates, fish and algae, as haul-outs for pinnipeds, foraging areas for shorebirds, and roosting areas for gulls and cormorants. As a result, these areas would become inaccessible. Pinnipeds would be forced to move higher up onto current upland habitats. This redistribution of pinnipeds would, in turn, impact seabird habitat by reducing the available nesting areas and causing the destruction of some nest sites. Furthermore, during extreme high tides and storm events, waves would be expected to extend higher still, leading to increased erosion, flooding, and loss of habitat.

- Radioactive Waste Disposal – Between 1946 and 1970, nearly 50,000 drums of hazardous and radioactive wastes were dumped over the 350 square nautical mile acres that overlaps the GFNMS. However, precise locations of these drums are unknown, with only 15 percent of the potentially contaminated area mapped. The extent of contamination in the waters surrounding the Refuge is unknown (see Section 3.3.1).

- Scientific Research – The combination of its location, rich biological system, and relative accessibility make the Farallon Islands an exceptional and unique location for a wide range of research pertaining to biodiversity, conservation, ecosystem restoration, marine ecosystem dynamics, and climate dynamics. Point Blue Conservation Science conducts the majority of the scientific research on the Farallon Islands in conjunction with the Refuge staff and visiting researchers. Point Blue has been conducting research daily on the Farallon Islands since 1968. The following are the current research projects that may contribute to the cumulative impacts of the proposed actions. None of the studies listed below are likely to contribute negative cumulative impacts to the Farallon Island resources.
    - Productivity, population demography, and foraging studies of western gulls – Examines survival, breeding biology, and breeding site fidelity in relation to life history traits, reproductive life span, and reproductive performance. Monitoring known-age gulls provides the core of this project. Tracking studies using Global Positioning System (GPS) tags began in 2013.Tracking studies using Global Location Sensing (GLS) tags and Global Positioning Systems tags began in 2015.

    - Productivity, demography, population dynamics, and food habits of common murres – Three study plots are monitored daily during the breeding season to determine number and location of breeding sites, phenology, and breeding success. Birds are monitored within study plots in an unobtrusive way, and all but

one plot is monitored from an observation blind. At the Shubrick Point plot, intensive observations are made of parental care, chick diet, feeding intervals, and foraging trip duration; diurnal feeding rates are determined by conducting four all-day censuses. Studies of the prey adults feed to chicks have shown that northern anchovy (*Engraulis mordax*) and juvenile rockfish (*Sebaste*s spp.) have been the most important provisioning items through different periods of the long-term time series.

- Productivity, demography, population dynamics, and food habits of Brandt's cormorants – Breeding productivity studies are conducted from an observation blinds at Corm Blind Hill and Sea Lion Cove (Murre Ledge). Reproductive success of known-age birds is being investigated to determine parameters such as age at maturity, fecundity, longevity, site fidelity, survival, and how these factors relate to reproductive performance and population trends. Cormorant diet is determined by collection of regurgitated pellets in breeding colonies before and after the breeding season when nesting birds are not present.

- Productivity, demography, population dynamics, foraging ecology and diet of pigeon guillemots – Breeding productivity studies are conducted by monitoring nests primarily in natural rock crevices but also in some artificial nest boxes. Survivorship and parental care is studied by observing color-banded birds. Diet watches are conducted unobtrusively in two monitored areas by observing birds flying into nest sites with prey items. Observers record site number, band markings, time, and the prey species being taken to breeding site. Tracking studies using Global Location Sensing (GLS) tags began in 2017.

- Productivity, demography, population and diet of rhinoceros auklets – Breeding productivity studies are conducted mainly by monitoring nests in artificial nest boxes; a smaller number of nests are monitored in natural burrows by using a burrow camera. A mark and recapture study began in 1987 and has been ongoing since that time. The objectives of this study are to track changes in adult survival through time. Birds are mistnetted at four sites, and food items carried in by netted birds are collected and identified. Tracking studies using Global Location Sensing (GLS) tags and Global Positioning Systems tags began in 2014.

- Productivity, demography, population dynamics, and food habits of Cassin's auklets – Age-specific reproductive performance and survival, lifetime reproductive success, and recruitment patterns of Cassin's auklets are studied by banding birds and monitoring known-age individuals nesting in artificial nest boxes. A smaller sample of nests is monitored within the Habitat Sculpture. Regurgitations are collected from adults captured by hand to determine food items brought back to chicks. Dive behavior studies utilizing Time Depth Recorder (TDR) tags began in 2008. Tracking studies using Global Location Sensing (GLS) tags and Global Positioning System (GPS) tags began in 2015.

- Colony formation in Cassin's auklet – This study was initiated in 1990 to investigate the impacts of western gull predation on Cassin's auklets. Ten 100-square-meter plots are monitored during peak incubation. Specifically, it was designed to address the question of whether gulls prevent auklets from colonizing areas that have previously supported high densities of nest burrows. However, it has been valuable to tracking changes in the annual numbers of auklets nesting on the island. Occupancy in plots is assessed approximately every 3 years,

- Population status, productivity, and survivorship of ashy storm-petrel – A mark-recapture study using mist-netting was initiated in 1992 to estimate population size and assess population trends and survivorship. Mist-netting is conducted from standardized locations about two nights per month per site from April to August. Productivity monitoring is conducted at breeding sites in natural and manmade habitat using burrow cameras.

- Ashy storm-petrel predation monitoring – Standardized collection of depredated ashy storm-petrel wings along island paths and collection of owl pellets from known roosting sites were initiated in 2003 to quantify predation by western gulls and burrowing owls and other predators.

- Burrowing Owl abundance – The intent of this study is to monitor changes in the numbers of owls visiting the island and length of stay while on the island. Personnel count the number of individuals on the island with established and standardized searches.

- Burrowing owl fall and winter attendance patterns – Owls are captured in mist-nets or traps and banded during the fall season in a study of use patterns by migrating and overwintering birds. Searches of roost sites are conducted during the day to locate both banded and unbanded birds. In the fall of 2009 and 2010, several captured owls were also affixed with radio transmitters to assist tracking.

- Migrant Bird Monitoring – Standardized area searches are used through the fall (mid-August to early December) to assess bird migration, surveying daily for all non-breeding birds. Banding and color banding of landbird species is used to assess stopover duration. At other times of year, incidental observations and counts of all non-breeding birds observed are recorded daily.

- Aerial census of murre and cormorant colonies – Aerial photographic surveys are conducted cooperatively by the Refuge, University of California Santa Cruz, CDFW, and Humboldt State University as part of a statewide survey of common murre, Brandt's cormorant and double-crested cormorant breeding colonies. Colonies are photographed using digital cameras with 200-300 mm lenses from a twin-engine airplane. Photographs are taken at an altitude of 700–1,000 feet above the islands. Nest and bird counts are obtained later.

- Pinniped and cetacean monitoring – Objectives include assessments of population change and reproduction in Steller sea lions, California sea lions, harbor seals, northern elephant seals, and northern fur seals through weekly ground and lighthouse-based censuses since the early 1970s and fall ground surveys on West End Island for fur seals. Incidental counts of cetaceans are conducted throughout the year, as well as standardized lighthouse watches during the winter and summer when weather conditions permit. Diet Studies of California sea lions from scat samples began in 2014 and tagging of Northern fur seal pups began in 2017.

- Reproductive ecology and survival of northern elephant seal – Multiple objectives focus on changes in breeding population size and productivity, the effects of age on reproductive success, and the effects of white shark predation on juvenile elephant seal survival. Methods included tagging, marking, and censusing elephant seals during the winter breeding season. Studies have been conducted annually since the Farallones were recolonized by breeding seals in 1972.

- Biology of the white shark at SEFI – This study is being conducted in the waters around the Refuge using the Refuge as an observation point. During fall months (September 1–November 30), observers conduct all-day watches from Lighthouse Hill, collecting data on shark attacks on pinnipeds and identifying individual sharks by distinctive markings when possible. Objectives of the study include determining the frequency of predatory attack, determining the species and size/age composition of white shark prey. A satellite tagging component, which tracked shark movements, was conducted from the island between 1999 and 2004. Researchers tagged and filmed sharks from a small boat launched from Southeast Farallon Island.

- Arboreal salamander surveys – A study was initiated in 2006 to assess the life history characteristics of salamanders on Southeast Farallon Island. Seasonal surveys begin October 1 (or the first fall rain) and end when salamanders retreat underground following the rainy season. Salamanders are captured every 2 weeks under artificial cover boards in the northwest quadrant of the island, measured, weighed, sexed, and checked for injuries and eggs. In initial years, individuals were toe-clipped to identify recaptures. This technique was replaced with photo-identification of individuals. New salamander studies to monitor the abundance of salamanders across island habitats and assess the relative abundance of juveniles before and after mouse removal were initiated in fall 2012. Two hundred new standard cover board pairs (about 30 x 30 cm plywood boards used to create artificial habitat), plus smaller boards to encourage juvenile presence were added to the study. These new boards cover a diverse range of habitats across SEFI and are checked once monthly October to April, recording only abundance of animals by size classes.

- Migratory bat monitoring – During known bat "waves", bats have traditionally been surveyed by searching trees and shrubs for rooting individuals. Surveys have

been standardized in recent years to assess several bat species on SEFI: hoary bat (primarily), western red bat, free-tailed bat, little brown bat, and Eurasian pipistrellus (*Pipistrellus sp.*). Surveys take place between August 15th and November 1st. The goals of the survey are to determine roosting locations on the Refuge, assess the number of bats using the Refuge during migration, assess interaction between male and female bats on the Refuge, and assess the effects of weather conditions on bat arrival at and departure from the Farallones. In addition to searches, an audio recording device installed on Lighthouse Hill records bat calls at night.

- Monitoring of intertidal communities within the GFNMS – In 1992, the GFNMS biologists began monitoring the density and diversity of intertidal species (invertebrates and algae) at six locations on the South Farallon Islands. Point and photographic quadrants were visited one to two times annually or less frequently. Surveys were conducted during minus tides, typically in February, August, and/or November). The goals were to: 1) establish a baseline and long-term dataset of algal and invertebrate species, including species abundance, diversity and distribution on the islands; 2) characterize the rocky intertidal community and understand changes resulting from anthropogenic impacts such as oil spills and changes due to climate change; and 3) reveal variations in intertidal communities and individual species as a result of global climate change. In 2004 and 2005, the GFNMS added components to integrate the Farallon monitoring with a large-scale research project called the PISCO Coastal Biodiversity Survey Program. The goals of the PISCO study include assessing long-term influences such as climate change and coastal development on intertidal communities and examining patterns of biogeography. Then, during winter 2017-18, GFNMS further modified their intertidal monitoring program to convert monitoring quadrats to be more comparable with mainland monitoring sites using MARINE protocols. The intention is to conduct surveys annually during the winter months.

- Vegetation Monitoring – This study was initiated in 2012-2014 to monitor changes in relative abundance and species composition of vegetation over time. Thirty-three circular plots of 10 m diameter across the breadth of habitats on Southeast Farallon Island will be assessed periodically, as time and funds permit, through observational surveys. In 2018, an additional study design is being added to monitor efficacy of invasive plant control efforts, using both 50 m and 100 m grids. This study is unlikely to contribute significant cumulative impacts to the islands resources.

- Cricket Surveys – Cricket surveys are intended to determine the relative abundance of crickets before and after mouse removal. Weekly surveys at sample caves around the island were conducted in 2012 and 2013. Visual surveys are conducted to count numbers of individuals within standardized plots. These methods were replaced with more intensive visual inventories of caves at a lower time frequency (quarterly). These visual surveys likely only cause short-term

impacts to individuals and allow collection of key monitoring data to assess seasonal and interannual trends.

- Regularly/Ongoing Maintenance – The following is a list of regularly scheduled major maintenance projects that are conducted on an annual or semiannual basis. These projects are usually conducted during the fall and winter to avoid the seabird breeding season:
    - East Landing and North Landing derricks annual maintenance - Usually conducted in fall and winter. Takes three to five days to complete. Includes greasing, corrosion removal, and other servicing or repairs as needed.

    - Invasive Vegetation Control – Regular removal of invasive vegetation covering burrows for nesting seabirds was conducted in the late 1980s. A weed management plan has been in place since 2004 to control the spread of New Zealand spinach and cheeseweed (*Malva* spp.), conducted mainly by the Service. In more recent years, other invasive plants have been added to control efforts, including *Plantago coronopus*, sow thistle *Sonchus* spp., *Erharta erecta*, and *Chenopodium murale*. The use of herbicides and hand-pulling are regularly utilized to remove and control the spread of invasive vegetation.

    - Annual inspection and maintenance of photovoltaic system - Includes PV panels (outside), electrical connections (inside and out), PV batteries (inside), PV generator (inside), and inverters (inside). Usually in fall and winter or spring depending on scheduling and contracting.

    - Semi-annual inspection and maintenance of septic system - One day about every six months, usually fall and spring.

    - Other – In most years there are some fairly major repair projects, such as repairing buildings, operation systems, and derrick(s). Most major repair projects are conducted in fall and winter when impacts to island wildlife are minimal.

4.8.4 **Future Actions**

- Invasive plant control – The majority of effort to control invasive plants includes: a) a one week effort in late March to early April, five to seven personnel, treating priority invasive plants on SEFI, especially New Zealand spinach and Malva spp.; b) a one-week effort between late July and mid-August each year, five to seven personnel, treating invasive plants on SEFI, especially New Zealand spinach; c) low level efforts to treat priority invasive plants by one to two personnel during the period of May to mid-July. Most work is on slopes and marine terrace on the south side of island; and d) low level plant pulling efforts that can occur at any time, but mainly in winter-spring. Intensity varies from year to year based on staffing and funding availability.

- Burrow and crevice-nesting seabird nest site improvements – This nest site improvement project is funded by the Cosco Busan Trustee Council. The specific aspects of the project are as follows:

- This project aims to provide high quality nesting sites for rhinoceros auklets, Cassin's auklets, and ashy storm-petrels. The first two are burrow nesters and would utilize nest boxes placed in the ground, while the latter nests in rock crevices.

- This project was initiated in 2015. Currently on Southeast Farallon Island there are 450 Cassin's auklet and 80 rhinoceros auklet nest boxes. These boxes have provided secure nest sites for these burrow-nesting seabirds. However, because of the thin materials and locations of the boxes, they have been subject to overheating. The island has experienced unusually warm days in recent summers and this phenomenon is expected to increase due to climate change. This has resulted in some adult birds dying in their nest boxes due to the heat. While mitigation to provide shade-covers to existing boxes has proved effective, a better long-term solution is needed. This project would replace all of these current boxes with higher quality habitat. The project includes redesigning the boxes and building new ones with better insulation and more durable materials to buffer the impacts of extreme temperature events. Multiple years of nest box design and physical testing have been conducted and a final design chosen. Installation of all new artificial nest structures is expected to be completed by 2021.

- The second component of the project is to create nesting habitat for ashy storm-petrels by using old concrete slabs and associated materials that have no current use. The materials would be broken up and arranged into rock piles for nesting habitat. The project goal is to provide 60 additional nesting sites for storm-petrels. This project is expected to be completed in early 2019.

4.8.5 <u>Summary of Effects from Past, Present, and Future Projects</u>

Physical Resources

- Water
  - The effects of past oil spills in the GFNMS have had at least short-term impacts on water quality. In the future, climate change impacts such as from ocean acidification, leakage from radioactive waste disposal, as well as oil spills and other contaminant spills may negatively affect water quality in the future.
- Geology/Soil
  - The construction of the lighthouse trail removed tons of rock from lighthouse hill to create the trail. This project negatively affected the soil and rocks on lighthouse hill.
  - Lead and asbestos were used to construct many of the historical structures on the islands. Lead has remained persistent in the soils around construction sites. Most asbestos from the two quarters houses was removed from the islands in 1999.
  - Construction of the water and helicopter catchment pads permanently altered the landscape affecting rocks and soil in those areas.
  - Sea level rise due to climate change could alter shoreline habitats and result in extreme high tides that together with large storm events that could increase erosion.

- Wilderness
    - Past actions by sealers and eggers and past predation by cats and rabbits led to long-term, adverse effects on the natural qualities of wilderness by altering native habitats and species population dynamics. The ongoing presence of mice degrades the natural quality of wilderness. (Section 4.4.2.3) Future projects to control invasive plants and improve nests could benefit the natural quality of wilderness by enhancing conditions for native plant and animal species. Climate change could however adversely affect wilderness by altering natural conditions.

Biological Resources

- Birds
    - Introduced rabbits may have contributed to the extirpation of the Rhinoceros auklet in the 19th century. This species recolonized the islands in the early 1970s when rabbits were being removed. The Farallon population increased dramatically since that time.
    - Construction of the lighthouse destroyed habitat for one of only two Farallon subcolonies of Double-crested Cormorants.
    - The lighthouse attracts migrating birds that would be unlikely to stop at the Farallon Islands. A smaller, dimmer light was installed in 2010.
    - Lighthouse trail construction altered seabird breeding habitat to an unknown extent, although rock walls built to support the trail created many nesting sites for crevice nesting seabirds.
    - The two catchment pads, built in the mid-19th century, have permanently altered nesting habitat for breeding seabirds. Only small numbers of western gulls are able to breed on the catchment pads.
    - Construction of the houses and other buildings removed habitat for nesting seabirds. Most buildings have been removed, partially replacing lost habitat. Some burrow and crevice-nesting seabirds nest underneath the houses and Carpenter Shop, showing some benefits to these structures.
    - Common murres were nearly wiped out from the Farallon Islands from over 50 years of egg collection in the mid-to-late-19th century combined with oil pollution. The common murre population numbered nearly one million birds prior to commercial egg harvesting. Gill-net fishing and oil spills offshore also have impacted the Farallon murre population. The population has been increasing and now numbers about 280,000 breeding individuals.
    - Climate change has the potential to indirectly impact the birds of the Farallones in many different ways that for some species could result in the loss of suitable breeding habitat and food resources, a reduction in the foraging or breeding ranges, and a decrease in the overall population size in the region. Climate change would likely alter the food web of seabirds and pinnipeds, which could affect all of the species found on the Farallon Islands. Increased temperatures could push populations to a more suitable climate and impact adult survival and breeding. Ocean acidification could contribute to the decline in fish and marine invertebrate populations causing increased competition for resources that could impact adult and juvenile seabird survival. Sea level rise could render many areas on the Farallones inaccessible to seabirds for roosting, nesting, and breeding; this is of

particular concern of burrow nesting seabirds such as Cassin's auklet. Additionally, climate change could alter the food web of seabirds and pinnipeds, which could affect all of the species found on the Farallon Islands.
    - The construction of several rock walls both destroyed and created habitat crevice-nesting seabirds and salamanders. The net effect of rock wall construction is unknown.
    - Nest-site improvement has had only positive impacts on cavity nesting seabirds.
- Mammals
    - Fur seals were extirpated from the Farallon Islands in the mid-19th century from intensive seal hunting. The first individual returned to breed on the Farallones in 1996 and the population has steadily been increasing well over 1,000 pups born in recent years. Negative impacts from seal hunting have lingered since the original fur seal population likely numbered in the tens of thousands or more.
    - Coastal erosion caused by storm surges has reduced habitat for Northern elephant seals. Sea level rise due to climate change could flood pinniped breeding and haul-out sites negatively impacting breeding success.
    - Construction of the murre habitat ledge caused short-term negative impacts to pinnipeds with no long-term effects.
- Amphibians
    - Cats likely consumed salamanders while on the Farallon Islands; however, cats have been eradicated and are having no lingering effects on amphibians.
- Invertebrates
    - Cats likely consumed invertebrates while on the Farallon Islands; however, cats have been eradicated and are having no lingering effects on invertebrates.
- Vegetation
    - Rabbits greatly impacted vegetation cover; however, vegetation cover has largely recovered from rabbit impacts since the eradication of rabbits in the 1970s.
    - Lighthouse keepers introduced the invasive New Zealand spinach as a garden vegetable. This species now grows over much of Southeast Farallon Island. Other invasive plants also have inadvertently been introduced on the islands. Efforts are conducted to control the spread and cover of invasive plants.
    - Climate change could change the composition and distribution of vegetation on the Farallon Islands.

Social and Economic Resources

- Personnel Safety
    - Lead and asbestos still pose a potential threat to personnel safety; however, there have been no recorded incidences of lead poisoning or asbestos impacts.
- Recreation/Tourism
    - None of the past, present, or foreseeable future projects have or are likely to have any negative or positive effects on recreation and tourism.
- Fisheries
    - Climate change could change the distribution and composition of the fish communities surrounding the South Farallon Islands.
- Cultural Resources

- Past construction projects (e.g., prior to Refuge establishment) on the Farallon Islands could have caused some damage to cultural resources; however, none of the recent, current or future projects are expected to cause any impact to cultural resources.

4.8.6 Incremental Effect of the Action Alternative to Cumulative Impacts

- In defining the contribution or incremental effect contributed by each alternative to cumulative impacts, the following terminology is used:
  - **Imperceptible**: The added effect contributed by the alternative to the cumulative impact is so small that it is impossible or extremely difficult to detect.
  - **Noticeable**: The added effect contributed by the alternative, while evident and observable, is relatively small in proportion to the cumulative impact.
  - **Substantial**: The added effect contributed by the alternative is evident and observable and constitutes a large portion of the cumulative impact.

4.8.7 Summary of Cumulative Impacts Under Alternative A (No Action)

4.8.7.1 *Summary of Combined Affects with Alternative A*

The impacts that mice are having to the environment of the South Farallones, particularly on the islands' biological resources, would continue under the No Action alternative. As discussed below, these impacts could be additive to the impacts from the past, present, and reasonably foreseeable project discussed in the previous sections.

Physical Resources

- Water
  - The No Action alternative could not result in any changes to water resources. Ongoing impacts from cumulative actions such as global climate change and leakage from drums containing radioactive waste would continue to affect water resources. Ongoing and future scientific research, monitoring, and maintenance projects on the islands would not result in any noticeable impacts to water quality. The incremental contribution of the No Action alternative to the impacts of these other actions would be imperceptible.
- Geology/Soil
  - Continued mouse presence under the No Action alternative would not affect geology but there could be negligible impacts to soils from a possible decrease in nutrients deposited in soil from birds. Ongoing and future scientific research projects would not have any perceptible impacts on geology or soils. Future invasive plant control and nest site improvements could temporarily disturb soils. Sea level rise could permanently erode soils from low lying parts of the Refuge. The No Action alternative would not result in any perceptible change to this cumulative impact scenario.
- Wilderness

  - Mice adversely impact the natural character of wilderness on the Farallon Islands. Ongoing and future scientific research projects would not cause any adverse impacts to wilderness character and could lead to efforts to further restore natural species composition which would enhance wilderness character. Ongoing and future invasive plant control efforts would also enhance wilderness character by restoring more natural conditions. The continued presence of mice under the No Action alternative would offset some of the benefits from these cumulative actions.

Biological Resources

- Birds
  - Climate change could have long-term and wide-ranging adverse impacts on the birds of the Farallon Islands from ocean acidification, loss of breeding habitat, sea level rise, and increased temperatures. The Service's future nest site improvement projects could improve nesting success rates for auklets and storm-petrels. The No Action alternative would result in significant adverse impacts to storm-petrels and less than significant adverse impacts to other birds. Climate change affects combined with the indirect and direct adverse impacts from mice would likely contribute to the expected decline in the storm-petrel populations on the Farallones. These impacts would likely not be offset by nest site improvement efforts.
  - The incremental contribution of the No Action alternative to projected climate change-related effects on other bird species is noticeable, while the incremental contribution of the No Action alternative for storm-petrels is substantial.
- Mammals
  - The primary threat to marine mammals on the Farallon Islands is from loss of habitat and potential changes in food supply due to climate change. The incremental contribution of the No Action alternative to projected climate change-related effects on mammals is imperceptible.
- Amphibians
  - Increased temperatures, changes in rainfall patterns and changes in the food supply due to climate change, and the possible introduction of the detrimental fungal pathogen *Batrachochytrium dendrobatidis*, are the major threats to amphibians on the Farallon Islands. The incremental contribution of the impacts of the No Action alternative (competition for food and possible predation by mice) on salamanders would be noticeable.
- Marine Fish
  - The primary threats to marine fish are increased temperatures, changes is ocean currents, and ocean acidification from climate change and overfishing. Because the No Action alternative would not cause any long-term impacts on marine fish, the incremental contribution of the No Action alternative on marine fish is imperceptible.
- Invertebrates
  - Increased temperatures, changes in rainfall patterns and changes in the food supply due to climate change are the major threats to invertebrates on the Farallon

Islands. The incremental contribution of predation by mice under the No Action alternative on invertebrates is noticeable, particularly for endemic camel crickets.

- Vegetation
    - The effects of climate change including increased temperatures and changes in rainfall patterns could change the composition and distribution of vegetation on the Farallon Islands, with the effects from climate change being more pronounced and widespread over the long-term. Ongoing invasive plant control efforts would lead to beneficial impacts to the island's vegetation communities. In this context, the incremental contribution of continued consumption of seeds and plants by mice under the No Action alternative would be noticeable.

Social and Cultural Resources

- Personnel Safety
    - The primary existing threat to personnel safety is from lead in the soil on some parts of the islands. While no impacts to date are known, mice are vectors for certain diseases and may be a future threat. Staff and cooperators engaged in ongoing and future scientific research projects and in other improvement or maintenance projects would continue comply with existing safety protocols. Possible risks to personnel safety from eradication operations would not occur under the No Action alternative, therefore cumulative impacts to personnel safety would be imperceptible.
- Recreation/Tourism
    - No anticipated impacts are expected for recreation and tourism from either the No Action alternative or any of the past, present or future projects on the Farallon Islands. The contribution of the No Action alternative to cumulative impacts to recreation/tourism would be imperceptible.
- Fisheries
    - The primary threats to the fisheries surrounding the Farallon Islands are from overharvesting, habitat alterations (especially for anadromous fish), climate change, which could alter the composition, abundance and distribution of fish around the islands, marine pollution, and poisoning from natural toxins . The presence of mice on the islands does not affect fisheries resources. The contribution of the No Action alternative to cumulative impacts to fisheries would be imperceptible.
- Cultural and Economic Resources
    - The majority of the threats to cultural and economic resources came from past projects to remove structures. The added effect from the No Acton Alternative is imperceptible. Continued mouse presence on the islands could not affect these resources. Therefore, there would be no added cumulative impacts from the No Action alternative.

4.8.8 Summary of Cumulative Impacts under Alternative B

4.8.8.1 *Summary of Combined Effects with Alternative B*

There would be no major long-term negative impacts to the biological, physical, or cultural resources of the Farallon Islands under Alternative B. The minor negative impacts to biological, physical, and cultural resources as a result of implementing Alternative B would not contribute significantly to the adverse cumulative impacts that persist from past actions. Similarly, the expected positive long-term impacts of Alternative B to the Farallones biological resources would contribute incrementally to the beneficial cumulative impacts from present and future restoration projects. The long-term effects of climate change could offset some of these beneficial impacts.

Physical Resources

- Water
    - The primary threat to water resources from implementation of Alternative B is from incidental bait drift during aerial broadcast of rodenticide. However, both the rodent bait and the toxicant are not expected to persist in the water column for any length of time and because of the insolubility of brodifacoum the threat to water is considered not significant. Mitigation measures would also reduce the possibility of bait drift. Leakage from drums containing radioactive waste offshore of the Farallones may adversely affect water resources. Possible future oil spills would adversely affect water resources. Global climate change would result in adverse impacts to water resources. Ongoing and future scientific research, monitoring, and maintenance projects on the islands would not result in any noticeable impacts to water quality. The incremental contribution of Alternative B to the impacts of these other actions would be imperceptible.
- Geology/Soil
    - Under Alternative B, there are expected to be short-term impacts to soil from the installation and maintenance of bait stations on the Farallon Islands. Brodifacoum may be detectible in the soil for a relatively short period of time, and will likely be biologically available in the soil for as long as 350 days (USEPA 2008). Brodifacoum is not soluble in water and has very low mobility rate in soil making it a very low risk to the biological resources on the Farallon Islands (USEPA 2008). Past activities on the island have resulted in impacts to soil from lead and arsenic. These impacts would persist into the future. Ongoing and future scientific research projects would not result in any perceptible impacts on geology or soils, nor would future invasive plant control or nest site improvement projects. The contribution of Alternative B to cumulative impacts to soils and geology would be imperceptible.
- Wilderness
    - The primary threats to wilderness from Alternative B are the short-term impacts from helicopter use, bait station installation and maintenance, and gull hazing. However, Alternative B would also result in long-term beneficial impacts to the natural character of wilderness by removing an invasive species which would also result in benefits to native species. The long-term benefits to wilderness would outweigh the short-term adverse effects of this alternative. On-going and future scientific research projects would not have any lasting adverse impacts on wilderness character and could lead to efforts to further enhance natural species composition which would restore wilderness character. Invasive plant control

efforts would enhance wilderness character by restoring more natural conditions. The incremental contribution of Alternative B to the impacts of these other actions would be substantial.

Biological Resources

- Birds
  - The primary threats to the birds from Alternative B include potential medium- to long-term term risk to gulls, raptors, granivorous and insectivorous songbirds, and some shorebirds from the use of a toxicant and from hazing, bait broadcast, and other personnel activity. There are also long-term threats to birds from climate change that could result in changes to the composition and distribution of birds on the Farallon Islands, as well as threats to the breeding success of many seabirds. By contrast, the Service is planning to undertake nest site improvements for auklets and storm-petrels in the future which would increase nesting habitat and/or nesting success rates. The short-term impacts from Alternative B are not expected to have any long-term effects on the breeding populations on the Farallon Islands. Furthermore, the long-term positive impacts to ashy and Leach's storm-petrels are likely to offset the long-term negative effects to these birds from climate change. The long-term incremental contribution of Alternative B to the impacts of these other actions would be substantial for storm-petrels and noticeable for other birds.
- Mammals
  - The primary threats to marine mammals from Alternative B include medium-term disturbance impacts from hazing, bait broadcast, and personnel activity. Additionally, there are expected to be long-term impacts to marine mammals from climate change that could alter their composition and distribution on the Farallon Islands. The incremental contribution of the Alternative B to projected climate change-related effects on marine mammals is imperceptible.
- Amphibians
  - The primary threat to salamanders from Alternative B is exposure to rodenticide for a medium-term duration. However, no anticipated negative impacts are expected for amphibians from Alternative B, partially due to mitigation measures. Salamanders may experience some disturbance associated with ongoing survey and monitoring efforts and climate change.
  - Positive impacts may ensue as a result of reduced food competition and the removal of a potential predator with the implementation of Alternative B. Overall Alternative B is expected to have a positive effect on the salamanders on the Farallon Islands. The incremental contribution of Alternative B to the impacts of these other actions would be noticeable.
- Marine Fish
  - No long-term negative impacts are expected for marine fish from Alternative B. The primary threat to marine fish are increased temperatures, changes is ocean currents, and ocean acidification from climate change, and overfishing. The incremental contribution of Alternative B to the impacts of these other actions would be imperceptible.
- Invertebrates

    - No long-term negative impacts are expected for invertebrates from Alternative B. There are likely to be significant positive effects to terrestrial invertebrates with the removal of mice from the Farallon Islands that could offset the negative effects of climate change. Overall Alternative B is expected to have a positive effect on the terrestrial invertebrates on the South Farallon Islands. The incremental contribution of Alternative B to the impacts of these other actions would be substantial.
- Vegetation
    - The primary threats to vegetation on the Farallon Islands include some short-term disturbance impacts from personnel activity and potential long-term impacts to the composition and distribution of plants on the islands from climate change. Ongoing and future efforts to remove invasive vegetation offset some of these adverse effects. Eradication of mice under Alternative B is anticipated to result in significant beneficial impacts to native island vegetation. The incremental contribution of Alternative B to the overall cumulative effect would be substantial.

Social and Cultural Resources

- Personnel Safety
    - The primary existing threat to personnel safety is from lead in the soil on some parts of the islands. Staff and cooperators engaged in ongoing and future scientific research projects and in other improvement or maintenance projects would continue to comply with existing safety protocols. While no impacts to date are known, mice are vectors for certain diseases and may be a future threat. In the short-term, safety protocols would be put in place for all staff engaged in eradication operations, and appropriate staff training would be conducted to minimize risks to personnel safety. The island's water supply would also be protected from bait contamination. The contribution of the Alternative B to cumulative impacts to personnel safety would be imperceptible in the long-term although there would be a noticeable contribution to short-term safety concerns due to increased personnel activity as part of the eradication operation.
- Recreation/Tourism
    - Closures that may occur during aerial bait broadcast operations could produce short-term impacts to recreational shark diving ventures. Climate change may alter recreational use patterns in the future. Under Alternative B, storm-petrel populations are projected to increase, which may benefit pelagic birding trips searching for storm-petrels in the region. The incremental contribution of Alternative B to recreation and tourism cumulative impacts is likely to be noticeable.
- Fisheries
    - The primary threats to the fisheries surrounding the Farallon Islands are from overharvesting, habitat alterations (especially for anadromous fish), and climate change, which could alter the composition and distribution of fish around the islands. None of the other ongoing or future on-island projects would affect fisheries resources. Eradication of mice from the islands would not affect

fisheries. Therefore, the contribution of Alternative B to cumulative fisheries impacts is likely to be imperceptible.

- Cultural and Economic Resources
  - The majority of the threats to cultural and historical resources are from past projects to remove structures. No impacts to cultural resources are expected as a result of implementing Alternative B. The incremental effect from Alternative B and cumulative impacts to cultural and economic resources is likely to be imperceptible.

4.8.9 Summary of Cumulative Impacts under Alternative C

4.8.9.1 *Summary of Combined Effects with Alternative C*

There would be no major long-term negative impacts to the biological, physical, or cultural resources of the Farallon Islands under Alternative C. The minor negative impacts to biological, physical, and cultural resources as a result of implementing Alternative C would not contribute significantly to the impacts related to past, present, and reasonably foreseeable future projects. Similarly, the expected positive long-term impacts of Alternative C to the Farallones biological resources would contribute incrementally to the cumulative impacts from past, present, and future projects.

Physical Resources

- Water
  - The primary threat to water resources from implementation of Alternative C is from incidental bait drift during aerial broadcast of rodenticide. However, both the rodent bait and the toxicant are not expected to persist in the water column for any length of time and because of the insolubility of diphacinone the threat to water is considered not significant. Mitigation measures would also reduce the possibility of bait drift. Leakage from drums containing radioactive waste offshore of the Farallones may adversely affect water resources. Possible future oil spills would adversely affect water resources. Global climate change would result in adverse impacts to water resources. Ongoing and future scientific research, monitoring, and maintenance projects on the islands would not result in any noticeable impacts to water quality. The incremental contribution of Alternative C to the impacts of these other actions would be imperceptible.
- Geology/Soil
  - Under Alternative C, there are expected to be short-term impacts to soil from the installation and maintenance of bait stations on the Farallon Islands. Additionally, diphacinone will likely be detectible in the soil for a very short period of time, and will likely be biologically available in the soil for approximately 10 days (USEPA 2008). Diphacinone is not soluble in water and has very low mobility rate in soil making it a very low risk to the biological resources on the Farallon Islands (USEPA 2008). Past activities on the island have resulted in impacts to soil from lead. These impacts would persist into the future. Ongoing and future scientific research projects would not result in any perceptible impacts on geology or soils, nor would future invasive plant control or nest site improvement projects. The

contribution of Alternative B to cumulative impacts to soils and geology would be imperceptible.

- Wilderness

  The primary threats to wilderness from Alternative C are the short-term impacts from helicopter use, bait station installation and maintenance, and gull hazing. However, Alternative C would also result in long-term beneficial impacts to the natural qualities of wilderness by removing an invasive species and benefitting a native species. The long-term benefits to wilderness would outweigh the short-term adverse effects of this alternative. Ongoing and future scientific research projects would not have any lasting adverse impacts on wilderness character and could lead to efforts to further enhance natural species composition which would restore wilderness character. Invasive plant control efforts would enhance wilderness character by restoring more natural conditions. The incremental contribution of Alternative C to the impacts of these other actions would be substantial.

Biological Resources

- Birds
  - The primary threats to the birds from Alternative C include potential medium-term risk to gulls, raptors, granivorous and insectivorous songbirds, and some shorebirds from the use of a toxicant and from hazing, bait broadcast, and personnel activity. There are also long-term threats to birds from climate change that could result in changes to the composition and distribution of birds on the Farallon Islands, as well as threats to the breeding success of many seabirds. By contrast, the Service is planning to undertake nest site improvements for auklets and storm-petrels in the future which would increase nesting habitat and/or success rates. The short-term impacts from Alternative C are not expected to have any long-term effects on the breeding populations on the Farallon Islands. Furthermore, the long-term positive impacts to ashy and Leach's storm-petrels are likely to offset the long-term negative effects to these birds from climate change. The long-term incremental contribution of Alternative C to the impacts of these other actions would be substantial for storm-petrels and noticeable for other birds.
- Mammals
  - The primary threats to marine mammals from Alternative C include medium-term disturbance impacts from hazing, bait broadcast, and personnel activity. Additionally, there are expected to be long-term impacts to marine mammals from climate change that could alter their composition and distribution on the Farallon Islands. The incremental contribution of the Alternative C to projected climate change-related effects on marine mammals is noticeable.
- Amphibians
  - The primary threat to salamanders from Alternative C is exposure to rodenticide for a medium-term duration. However, no anticipated negative impacts are expected for amphibians from Alternative C, partially due to mitigation measures. Salamanders may experience some disturbance associated with ongoing survey and monitoring efforts and climate change.

    - Positive impacts may ensue as a result of reduced food competition and the removal of a potential predator with the implementation of Alternative C. Overall Alternative C is expected to have a positive effect on the salamanders on the Farallon Islands. The incremental contribution of Alternative C to the impacts of these other actions would be noticeable.
- Marine Fish
    - No anticipated negative impacts are expected for marine fish from Alternative C. The primary threat to marine fish are increased temperatures, changes is ocean currents, and ocean acidification from climate change, and overfishing. The incremental contribution of Alternative C to the impacts of these other actions would be imperceptible
- Invertebrates
    - No anticipated negative impacts are expected for invertebrates from Alternative C. There are likely to be significant positive effects to invertebrates with the removal of mice from the Farallon Islands that could offset the negative effects of climate change. Overall Alternative C is expected to have a positive effect on the invertebrates on the Farallon Islands. The incremental contribution of Alternative C to the impacts of these other actions would be substantial.
- Vegetation
    - The primary threats to vegetation on the Farallon Islands include some short-term disturbance impacts from personnel activity and potential long-term impacts to the composition and distribution of plants on the islands from climate change. On-going and future efforts to remove invasive vegetation offset some of these adverse effects. Eradication of mice under Alternative C is anticipated to result in significant beneficial impacts to native island vegetation. The incremental contribution of Alternative C to the overall cumulative effect would be substantial.

Social and Economic Resources

- Personnel Safety
    - The primary existing threat to personnel safety is from lead in the soil on some parts of the islands. Staff and cooperators engaged in ongoing and future scientific research projects and in other improvement or maintenance projects would continue to comply with existing safety protocols. While no impacts to date are known, mice are vectors for certain diseases and may be a future threat. In the short-term, safety protocols would be put in place for all staff engaged in eradication operations, and appropriate staff training would be conducted to minimize risks to personnel safety. The island's water supply would also be protected from bait contamination. The contribution of the Alternative C to cumulative impacts to personnel safety would be imperceptible in the long-term although there would be a noticeable contribution to short-term safety concerns due to increased personnel activity as part of the eradication operation.
- Recreation/Tourism
    - Closures that may occur during aerial bait broadcast operations could produce short-term impacts to recreational shark diving ventures. Climate change may alter recreational use patterns in the future. Under Alternative C, storm-petrel

populations are projected to increase, which may benefit pelagic birding trips searching for storm-petrels in the region. The incremental contribution of Alternative C to recreation and tourism cumulative impacts is likely to be noticeable.

- Fisheries
  - The primary threats to the fisheries surrounding the Farallon Islands are from overharvesting, habitat alterations (especially for anadromous fish), and climate change, which could alter the composition and distribution of fish in and around the islands. None of the other ongoing or future on-island projects would affect fisheries resources. Eradication of mice from the islands would not affect fisheries. Therefore, the contribution of Alternative C to cumulative fisheries impacts is likely to be imperceptible.
- Cultural and Historical Resources
  - The majority of the threats to cultural and historical resources are from past projects to remove. No impacts are expected as a result of implementing Alternative C. Personnel would avoid contact with cultural resources to avoid negatively affecting them. The incremental effect from Alternative C to cultural resources is likely to be imperceptible.

4.9 Irreversible and Irretrievable Impacts

4.9.1 Alternative A

Pressure from invasive house mice could contribute to declines in the native biological resources of the South Farallones to below the level of population viability. For ashy and Leach's storm-petrels in particular, their recent population declines indicate a risk for an irreversible decline in the future if the No Action alternative is chosen.

4.9.2 Alternatives B and C

Mouse eradication is expected to reduce the overwintering burrowing owl population on the South Farallones, likely resulting in positive population-level changes for ashy and Leach's storm-petrels (Nur et al. 2013a), as well as arboreal salamanders and possibly insects such as the Farallon camel cricket may also increase in numbers and distribution in the absence of mice as predators and competitors.

Project activities under Alternative B and Alternative C would require a partial commitment of funds that would then be unavailable for use on other projects. At some point, commitment of funds (for purchase of supplies, payments to contractors, etc.) would be irreversible; once used, these funds would be irretrievable. Nonrenewable or nonrecyclable resources committed to the project (such as helicopter fuel, bait, and some bait stations) would also represent an irreversible or irretrievable commitment of resources.

4.10 Short-term Uses and Long-term Ecological Productivity

An important goal of the Service is to maintain the long-term ecological productivity and integrity of the natural resources on the Refuge. The action alternatives are designed to contribute to the long-term ecological productivity and integrity of the South Farallones and would not result in short-term uses of the resources that would counteract these goals. Any short-term negative impacts to the islands' natural resources would be outweighed by the ecosystem's long-term restoration through the eradication of mice.

5 Consultation and Coordination

5.1 Introduction

This chapter summarizes the agency and public consultation and coordination conducted throughout the NEPA process. Section 5.2 describes the regulatory environment within which the proposed action would be implemented. This section lists the federal and state laws that are relevant to the proposed action and by extension, the federal and state agencies involved in coordinating and permitting the proposed action. Section 5.3 describes the Agency Consultation in preparing the Final EIS, and section 5.4 contains a summary of public scoping and review. A short summary of public comments received on the Draft and Revised Draft EIS can be found in section 5.5, and a list of preparers and primary contributors is in section 5.6.

5.2 Regulatory Framework of the Alternatives

5.2.1 Federal Laws

The following federal laws, proclamations, and executive orders are the most relevant to eradicating mice from the Farallon Islands:

- Archaeological Resources Protection Act of 1979, as amended, 16 USC 47;
- Clean Water Act of 1972 (CWA), as amended (33 USC §1251 et seq.);
- Coastal Zone Management Act (CZMA) of 1972, as amended;
- Endangered Species Act of 1973, as amended (16 USC § 1531 et seq.);
- Executive Order 13112 of 1999 on Invasive Species;
- Executive Order 13186 of 2001 Responsibility of Federal Agencies to Protect Migratory Birds;
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, as amended (7 USC § 136 et seq.);
- Fish and Wildlife Act of 1956 (16 USC § 742f);
- Fish and Wildlife Improvement Act of 1978 (16 USC § 7421);
- Fish and Wildlife Coordination Act of 1980, as amended
- Marine Mammal Protection Act of 1972 (16 USC § 1361 et seq.);
- Migratory Bird Treaty Act of 1918, as amended (16 USC §§ 703-712, July 3, 1918);

- National Environmental Policy Act of 1969, as amended (42 USC § 4331 et seq.);
- National Historic Preservation Act of 1966, as amended through 2000 (16 USC § 470 et seq.)
- National Wildlife Refuge System Administration Act of 1966, as amended (16 USC §§ 668dd-ee);
- National Marine Sanctuaries Act of 2000 (16 USC § 1433)
- Refuge Recreation Act (16 USC §§ 460k-3)
- Wilderness Act of 1964 (16 USC § 1131-1136)

5.2.2 **California State Laws and Authorities**

California Coastal Commission – The California Coastal Commission was established in 1972 and was later made permanent by the Legislature through the adoption of the California Coastal Act of 1976. The mission of the Coastal Commission is to "Protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations".
The federal Coastal Zone Management Act requires federal agencies to seek consistency determinations for federal activities affecting a state's coastal zone when a federal action occurs in a state that has a federally-approved coastal management program. California has an approved program. The federal government certified the California Coastal Management Program (CCMP) in 1977. Once a plan is certified, a federal agency must conduct its activities (including federal development projects, permits and licenses, and assistance to state and local governments) in a manner consistent with the enforceable policies of a state's certified program. The enforceable policies of California's CCMP are found in Chapter 3 of the California Coastal Act of 1976. The Service will therefore prepare a Consistency Determination for this action, if an action alternative is selected by the Service. The Commission will use the federal consistency process to provide open communication and coordination with the Service and provide the public with an opportunity to participate in the process.

Regional Water Quality Control Board – The State Water Resources Control Board (State Water Board) was created by the Legislature in 1967. The joint authority of water allocation and water quality protection enables the State Water Board to provide comprehensive protection for California's waters. The State Water Board's mission is to "preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations." There are nine Regional Water Quality Control Boards (Regional Boards). The mission of the Regional Boards is to develop and enforce water quality objectives and implementation plans that would best protect the State's waters, recognizing local differences in climate, topography, geology and hydrology.

California Department of Pesticide Regulations – The mission is to protect human health and the environment by regulating pesticide sales and use, and by fostering reduced-risk pest

management. DPR monitors the use of pesticides from agriculture, commercial, conservation, and residential uses to assure the safety of workers and the public. DPR's responsibilities include:

- Evaluating and registering of pesticide products before sale or use in California.
- Statewide licensing of commercial applicators, dealers, consultants, and other pesticide professionals to ensure they are adequately trained to use pesticides safely.
- Evaluating the health impacts of pesticides through risk assessment and illness surveillance.
- Determining practices to ensure a safe pesticide workplace.
- Monitoring potential health and environmental impacts of previously registered pesticides, helping find ways to prevent future contamination.
- Residue testing of fresh fruit and vegetables, sampling domestic and imported produce from wholesale and retail outlets, distribution centers, and farmers markets.

California Department of Fish and Wildlife – The California Department of Fish and Wildlife (CDFW) has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and the habitats necessary for biologically sustainable populations of those species (California Fish and Wildlife Code Section 1802). California's fish and wildlife resources, including their habitats, are held in trust for the people of the California by the CDFW (California Fish and Wildlife Code Section 711.7). The CDFW's fish and wildlife management functions are implemented through its administration and enforcement of the Fish and Game Code (Fish and Wildlife Code Section 702). The CDFW is entrusted to protect state-listed threatened and endangered species under the California Endangered Species Act (Fish and Wildlife Code Sections 2050-2115.5) (CESA).

The CDFW generally does not have jurisdiction to manage or regulate natural resources on federal lands, such as the Farallon Islands. It also does not regulate federal government agency activities. Regardless, the Service regularly coordinates with the CDFW to ensure the proper protection of the island's natural resources. Thus, while CESA restrictions do not apply to the proposed restoration project on the South Farallones, the Service would continue to coordinate with CDFW regarding actions that could potentially affect state-listed species and the proposed conservation measures designed to avoid or minimize adverse effects.

California Office of Historic Preservation – Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires Federal agencies to take into account the effects of their undertakings on historic properties. Historic properties are properties that are included in the National Register of Historic Places or that meet the criteria for the National Register. If historic properties will be affected by a federal agency undertaking, the federal agency must consult with the State Historic Preservation Officer, and identify other potential consulting parties. The Service will comply with Section 106 by consulting with the California Office of Historic Preservation, if an action alternative is selected by the Service.

5.3 Agency Consultation

A planning and work team consisting of the Service, U.S. Department of Interior, Point Blue Conservation Science, and Environmental Policy Solutions, LLC staff held regular meetings to

respond to comments on the DEIS and prepare the FEIS. The team involved and consulted with the USDA/APHIS, EPA, NMFS, GFNMS, and CDFW throughout the process and provided drafts of various documents prepared during the process.

5.4 Public Scoping and Review

In April 2006, the Service initiated the National Environmental Policy Act (NEPA) process and subsequently held a public scoping meeting on May 17, 2006 to define the range of issues to be addressed and to identify whether there were any significant issues related to the proposed eradication project. At that time, the Service was proposing to prepare an environmental assessment (EA) for the project. Based on information gathered and initial analysis during preparation of the EA, the Service decided to prepare an environmental impact statement (EIS) for the project. The Service published a Notice of Intent (NOI) to prepare an EIS in the Federal Register on April 13, 2011 (76 FR 20706) and held a public scoping meeting on May 12, 2011. The public scoping process closed on June 10, 2011. Subsequently, an interagency scoping meeting was held on July 29, 2011.

As part of the project scoping process, the Service held two public comment periods. The first took place from April 14, 2006 through May 29, 2006 for the original EA, and the second took place from April 13, 2011 through June 10, 2011 for the current EIS (76 FR 20706). During the two scoping periods, interested members of the public and interested agencies were encouraged to comment on the scope of the project and identify environmental issues to be addressed in NEPA analysis. During the first scoping period, the Service conducted a public meeting and received substantive comments from 15 individuals or organizations, as well as at least three requests to be added to a distribution list for future information on the proposed project. During the second scoping period, the Service conducted another public meeting and received substantive comments from 56 individuals, as well as two petitions signed by 2,750 individuals with 497 included comments. The Service considered all substantive comments during the preparation of the Draft EIS. The updated Scoping Report in Appendix O provides an in-depth review of the public scoping process. The Draft EIS was prepared and released on August 16, 2013. A revised Draft EIS was issued on October 25, 2013.

After the comment period for the revised Draft EIS closed on December 9, 2013, the Service analyzed and assessed substantive comments received, conducted additional studies, literature reviews and assessments, and made appropriate changes to the EIS as necessary. The Service is now circulating the Final EIS along with a summary of public comments received during the Public Comment Period. Appendix P summarizes the substantive comments we received along with our responses to these public comments.

The final step in the NEPA process is the preparation of the Record of Decision (ROD), which presents a concise summary of the decision made by the Service. The ROD will summarize the selected action and other alternatives considered in the FEIS; identify and discuss factors considered in the Service's decision and state how these consideration entered into the final decision. The ROD will also describe any associated mitigation measures. The Service will publish and notify the public of the availability of the ROD.

5.5 Comments Received on the DEIS

Public review of the Draft EIS began on August 16, 2013 (78 FR 50082 and 78 FR52524), with a request for comments by September 30, 2013. The Service held a public meeting on August 29, 2013, during which Service staff and partners were available to provide information and answer questions in person. On October 25, 2013 we issued a Federal Register notice informing the public that a Revised Draft EIS was available for review (78 FR 64002 and 78 FR 63997), and requested comments by December 9, 2013 (78 FR 64002 and 78 FR 63977). The Service issued the Revised Draft EIS in order to clarify language on the population status of the ashy storm-petrel and to revise the assessment of impacts to the ash storm-petrel under the no action alternative. Both the Draft EIS and Revised Draft EIS were available to the public electronically at http://www.regulations.gov; docket number FWS-R8-NWRS-2013-0036. A paper copy of the Draft and Revised Draft EIS were also available to the public at the San Francisco Public Library in San Francisco, California and at the San Francisco Bay National Wildlife Refuge Complex office in Fremont, California. In addition to the Federal Register notice, the Service mailed notices to all parties who had requested information and submitted a press release to local media informing them of the availability of both the Draft and revised Draft EIS.

Following the comment period, the Service addressed all substantive comments received, conducted additional studies, and made changes to the RDEIS as necessary. The Final EIS includes an Appendix that summarizes the substantive comments received along with our responses to these public comments. Additional information on the recipients of the Draft and Revised Draft EIS can be found in Appendix P, the Public Comment and Response Report.

The public submitted a total of 553 correspondences on the Revised Draft EIS. Each comment letter was reviewed for substantive comments. Substantive comments were classified by a comment theme with a specific comment concern. Representative quotes for each comment concerns were then identified by specific comment letter. The comment themes identified include the following:

1. Objectivity of the Revised Draft EIS.
2. DEIS didn't explain lessons learned.
3. Rodenticides could persist in the island's ecosystem for the long-term.
4. The risk to the marine environment is not properly evaluated.
5. The need for this project is not clear.
6. There is no guarantee that a successful mouse eradication will minimize the indirect impacts of mice on petrels.
7. Sublethal effects not evaluated properly.
8. How many gulls will die?
9. Gull Hazing is unclear.
10. Economic impacts were not properly evaluated.
11. Does FWS have the money or the means to get the money necessary to mitigate for the duration of risk?
12. The bait application plan is not appropriate.
13. The EIS needs a detailed monitoring plan.

14. The EIS needs a detailed mitigation plan.
15. The Gull Risk Assessment should be reparametrized.
16. Swift 1998 was incorrectly cited.
17. Choose the diphacinone alternative or the No Action alternative.
18. Forgo the use of rodenticide on the Farallon Islands.
19. Not a good range of alternatives considered.
20. This project is unlikely to be successful.
21. Supporting reports are insufficient.
22. Cumulative Impacts are not properly evaluated.
23. Toxicant impacts are not properly evaluated.
24. How many individuals will die?
25. Animal Capture, how will it be done?
26. Operational Impacts not properly evaluated.
27. Tradeoffs not assessed properly.
28. Diphacinone is not evaluated properly.
29. Mice below ground values are questionable.
30. Table 2.5 does not reflect the language in the DEIS.
31. The Service should invest in innovative eradication tools.
32. The Service should get the States permission to use rodenticides.
33. EPA's pesticide comments.
34. Bird Capture is unclear.
35. Best Management Practices should be incorporated.
36. Significance needs to be reevaluated.
37. Salamander impacts are not properly evaluated.
38. Do gulls or other species consume mice?
39. The premise of the project and the accurate assessment of impacts relies on predictions of how the ecosystem will respond.

5.6 Preparers and Primary Contributors

Gerry McChesney	Manager, Farallon Islands NWR, U.S. Fish & Wildlife Service • B.A. Biology, University of California - Santa Cruz • M.S. Biological Sciences, Sacramento State University	Draft and Final
Jonathan Shore	Assistant Manager, Farallon Islands NWR, U.S. Fish & Wildlife Service • B.S. Wildlife Ecology and Conservation, University of Florida	Draft and Final
Patricia Roberson	Refuge Program Specialist, U.S. Fish & Wildlife Service Natural Resources Division, Pacific Southwest Region • B.A. Environmental Studies, California State University, Sacramento	Final
Dr. Carolyn Marn	Fish and Wildlife Biologist, Environmental Contaminants Division, U.S. Fish and Wildlife Service • M.S. Wildlife Management, Auburn University • Ph.D. Wildlife Sciences, Oregon State University	Draft

Dr. John Isanhart	Ecotoxicologist, Department of Interior Office of Restoration and Damage Assessment, Restoration Support Unit • B.S. Environmental Science, University of Central Arkansas • M.S. and Ph.D. Environmental Toxicology, Texas Tech University	Final
Dr. Gabrielle Feldman	Owner/Principal Consultant, Environmental Policy Solutions, LLC • B.S. Zoology/Ecology, Washington State University • M.S. Environmental Science and Regional Planning, Washington State University • Ph.D. Environmental Policy Analysis, University of Idaho	Draft and Final
Russ Bradley	Farallon Program Manager, Point Blue Conservation Science • B.S. Biological Sciences, Simon Fraser University • M.S. Wildlife Ecology, Simon Fraser University	Draft and Final
Jim Tietz	Farallon Program Biologist, Point Blue Conservation Science • M.S. Wildlife Biology, Humboldt State University	Draft
Brad Keitt	Director of Conservation, Island Conservation • B.S. Biology, University of California – Santa Cruz • M.S. Marine Sciences, University of California – Santa Cruz	Draft
Richard Griffiths	Project Director, Island Conservation • B.S. Physics, Victoria University • Post Graduate Environmental Science, Canterbury University • M.S. Ecology, Lincoln University	Draft
Dan Grout	Project Manager, Island Conservation • B.S. Wildlife Ecology, University of Wisconsin-Madison	Draft
Jan Roletto	Research Coordinator, National Oceanic and Atmospheric Administration – Greater Farallones National Marine Sanctuary • M.S. Marine Biology	Draft

This page intentionally left blank

6 References

Aceituno, K. A. and T. C. Maurer. 2013. Heavy metal and polyhalogenated aromatic hydrocarbon contaminants in marine birds on the Farallon National Wildlife Refuge. Unpublished report, U.S. Fish and Wildlife Service, Region 8, Sacramento, CA. Project ID: FFS# 8N04, DEC ID#2009.80002.

Ainley, D.G. 1980. Birds as marine organisms: a review. California Cooperative Oceanic Fisheries Investigations 21.

Ainley, D.G. and S.A. Allen. 1992. Abundance and distribution of seabirds and marine mammals in the Gulf of the Farallones. Point Reyes Bird Observatory, Stinson Beach, CA.

Ainley, D.G. and R.J. Boekelheide (Editors). 1990. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Ainley, D.G. and T.J. Lewis. 1974. The history of the Farallon Island marine bird populations, 1854-1972. *Condor* 76:432-446.

Ainley, D.,G., C.S. Strong, T. Penniman, and R.J. Boekelheide. 1990a. The feeding ecology of Farallon seabirds.*in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: ecology, dynamics, and structure of an upwelling-system community. Stanford Univerity Press, Stanford, CA.

Ainley, D. G., R. J. Boekelheide, S. H. Morrell, and C. S. Strong. 1990b. Cassin's auklet. Pages 306-338 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Ainley, D. G., R. J. Boekelheide, S. H. Morrell, and C. S. Strong. 1990c. Pigeon guillemot. Pages 276-305 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Ainley, D. G., R. P. Henderson, and C. S. Strong. 1990d. Leach's Storm-Petrel and Ashy Storm-Petrel. Pages 128-162 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, dynamics, and structure of an upwelling-system community. Stanford University Press, Stanford, CA.

Ainley, D. G., S. H. Morrell, and R. J. Boekelheide. 1990e. Rhinoceros auklet and tufted puffin. Pages 339-348 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Ainley, D. G., D. N. Nettleship, H. R. Carter, and A. E. Storey. 2002. Common murre (*Uria aalge*).*in* A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY.

Alifano, A. 2012. Final operational report for the eradiation of house mice (*Mus musculus*) from Allen Cay, Exuma Islands, Bahamas. Unpublished report for the Bamas National Trust, Nassau, Bahamas.

Alifano, A., A. Wegmann, B. Puschner, and G. Howald. 2012. Migration of brodifacoum and diphacinone from bait pellets into topsoil at Palmyra Atoll National Wildlife Refuge. Proceedings of the 25th Vertebrate Pest Conference. March 2012. Monterey, CA.

Anderson, P. 1960. Ecology and evolution in island populations of salamanders in the San Francisco Bay region. Ecological Monographs 30:359-386.

Anderson, W. B., & Polis, G. A. 1999. Nutrient fluxes from water to land: seabirds affect plant nutrient status on Gulf of California islands. Oecologia 118:324-332.

Andres, B. and G. Falxa. 1995. Black oystercatcher (*Haematopus bachmani*).*in* A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Retrieved from the Birds of North America Online http://bna.birds.cornell.edu/bna/species/155, Ithaca, NY.

Angel, A., R. Wanless, and J. Cooper. 2008. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? Biological Invasions 11:1743-1754.

Anthony, E. L. P. and T. H. Kunz. 1977. Feeding strategies of the little brown bat, *Myotis lucifugus,* in southern New Hampshire. Ecology 58:775-786.

Apps, P. 1983. Aspects of the ecology of feral cats on Dassen Island, South Africa. South African Journal of Zoology 18:393-400.

Ashton, A., W. Jackson, and H. Peters. 1987. Comparative evaluation of LD_{50} values for various anticoagulant rodenticides.*in* C. Richards and T. Ku, editors. Control of mammal pests. Taylor and Francis, London, England.

Atkinson, I. 1985. The spread of commensal species of *Rattus* to oceanic island and their effect on island avifaunas.*in* P. Moors, editor. Conservation of Island Birds. International Council for Bird Preservation, Cambridge, UK.

Atkinson, I. 1989. Introduced animals and extinctions. Pages pp. 54-75 *in* D. Western and M. Pearl, editors. Conservation for the Twenty-first Century. Oxford University Press, New York, USA.

Atkinson, I. and T. Atkinson. 2000. Land vertebrates as invasive species on islands served by the South Pacific Regional Environmental Programme. Pages 19-84 *in* G. Sherley, editor. Invasive Species in the Pacific: A Technical Review and Draft Regional Strategy. South Pacific Regional Environmental Programme, Apia, Samoa.

Avenant, N. and V. Smith. 2003. The microenvironmenta of house mice on Marion Island (sub-Antarctic). Polar Biology 26:129-141.

Baber, M., K. Babbitt, R. Brejaart, G. Ussher, N. DiManno, and G. Sexton. 2007. Does mammalian pest control benefit New Zealand's Hachstetter's from (*Leiopelma hochstetteri*).*in* Conserv-Vision: the next 50 years, University of Waikato, Hamilton, New Zealand.

Badzik, B. 2010. Farallon Islands National Wildlife Refuge preliminary structural rodent exclusion assessment. Unpublished report prepared for the U.S. Fish and Wildlife Service.

Bahamas National Trust and Island Conservation. 2013. Efficacy assessment for the removal of mice one year after implementation. Unpublished Report prepared by the Bahamas National Trust and Island Conservation for the Allen Cay Restoration Project. 05 June 2013.

Bancroft, W., M. Garkaklis, and J. Roberts. 2005. Burrow building in seabird colonies: a soil-forming process in island ecosystems. Pedobiologia 49:149-165.

Barlow, J., J. Robert L. Brownell, D. P. DeMaster, K. A. Forney, M. S. Lowry, S. Osmek, T. J. Ragen, R. R. Reeves, and R. J. Small. 1995. U.S. Pacific Marine Mammal Stock Assessments.*in* S. La Jolla Laboratory, editor., La Jolla, California.

Baxter, A. and J. Allan. 2007. Use of lethal control to reduce habituation to blank rounds by scavengering birds. DOI: 10.2193/2007-458.

Bechard, M. J. and J. K. Schmutz. 1995. Ferruginous hawk (*Buteo regalis*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/172.

Bechard, M. J. and T. R. Swem. 2002. Rough-legged hawk (*Buteo lagopus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/641.

Beck, K., K. Zimmerman, J. Schardt, J. Stone, R. Lukens, S. Reichard, J. Randall, A. Cangelosi, D. Cooper, and J. Thompson. 2008. Invasive species defined in a policy context: recommendations from the Federal Invasive Species Advisory Committee. Invasive Plant Science and Management 1:414-421.

Belant, J., and S. Ickes. 1997. Mylar flags as gull deterrents. Wildlife Damage Management, Internet Center. Great Plains Wildlife Damage Control Workshop Proceedings. University of Nebraska, Lincoln.

Bellingham, P., D. Towns, E. Cameron, J. Davis, D. Wardle, J. Wilmhurst, and C. Mulder. 2010. New Zealand island restoration: seabirds, predatorsk, and the importance of history. New Zealand Journal of Ecology 34:115-136.

Berger, R. 2012a. Population size and reproductive performance of northern elephant seals on the South Farallon Islands. Unpublished Report to the U.S. Fish and Wildlife Service. PRBO Science, Petaluma, California. PRBO Contribution Number 1879.

Berger, R. 2012b. Population size of steller sea lions on the South Farallon Islands, 1970-2011. Unpublished Report to the U.S. Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1864.

Berger, R. W., R. W. Bradley, G. J. McChesney J.R. Tietz and M.S. Lowry. 2014. Comparison of aerial photographic and land-based surveys of Northern fur seals on the South Farallon Islands, 1998-2013. Unpublished report to the US Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California.

Berry, R. 1970. The natural history of the house mouse. Field Studies 3:219-262.

Berry, R. J. 1968. The ecology of an island population of the house mouse. Journal of Animal Ecology 37:445-470.

Beyer, W. N., Connor, E. E., & Gerould, S. (1994). Estimates of soil ingestion by wildlife. The Journal of Wildlife Management, 375-382.

Bhattacharyya, B., R.K. Borah. 2016. Comparative evaluation of second generation anticoagulant rodenticides against Mus musculus. Indian Journal of Agricultural Research 50(1): 51-55.

Bildstein, K. L. and K. Meyer. 2000. Sharp-shinned hawk (*Accipiter striatus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/482.

Birdlife International. 2012. IUCN Red List for birds. http://www.birdlife.org on 7/25/2012.

Blankinship, J. and C. Keeler. 1892. On the natural history of the Farallon Islands. Zoe 3:144-186.

Blackwell, B., G. Bernjardt, J. Cepek, and R. Dolbeer. 2002. Lasers and non-lethal avian repellents: potential applications in the airport environment. USDA/APHIS, National Wildlife Research Center. Presented for the 2002 FAA Technology Transfer Conference. February 2002.

Boarman, W. I. and B. Heinrich. 1999. Common raven (*Corvus corax*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/476.

Boekelheide, R. 1975. Notes on the arboreal salamander of the Farallon Islands. Unpublished report to USFWS. Petaluma, CA.

Boekelheide, R. J., D. G. Ainley, H. R. Huber, and T. J. Lewis. 1990a. Pelagic cormorant and double-crested cormorant. Pages 195-217 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Boekelheide, R. J., D. G. Ainley, S. H. Morrell, and T. J. Lewis. 1990b. Brandt's cormorant. Pages 163-194 *in* D. G. Ainley and R. J. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Bomford, M. and P. O'Brien. 1995. Eradication or control fro vertebrate pests. Wildlife Society Bulletin 23:249-255.

Bonnot, P., G. Clark, and S. Hatton. 1938. California sea lion census for 1938. Cal Fish and Game 24:415-419.

Bonnot, P. and W. Ripley. 1948. The California sea lion census for 1947. Cal Fish and Game 34:89-92.

Booth, L., C. Eason, and E. Spurr. 2001. Literature review of the acute toxicity and persistence of brodifacoum to invertebrates. Science for Conservation 177A:1-9.

Booth, L. H., P. Fisher, V. Heppelthwaite, and C. T. Eason. 2003. Toxicity and residues of brodifacoum in snails and earthworms. Science Internal Series 143, New Zealand Department of Conservation, Wellington, NZ.

Booth, L. H., S. C. Ogilvie, and C. T. Eason. 1999. Persistence of sodium monofluoroacetate (1080), pindone, cholecalciferol, and brodifacoum in possum baits under simulated rainfall. New Zealand Journal of Agricultural Research 42:107-112.

Bowie, M. and J. Ross. 2006. Identification of weta on brodifacoum bait and the risk of secondary poisoning for birds on Quail Island, Canterbury. New Zealand Journal of Ecology. 30(2):219-228.

Bradley, R., P. Warzybok, D. Lee, and J. Jahncke. 2011. Assessing an index of population trends of the ashy strom-petrel on Southeast Farallon Island, California, 1992-2010. Report to the US Fish and Wildlife Service. April 18, 2011.

Brooke, M., R. Cuthbert, A. Henricson, N. Torr, P. Warren, and S. O'Keefe. 2010. Towards rat eradication on Henderson Island fieldwork report, August-September 2009. Royal Society for the Protection of Birds.

Brooke, M. d. L., R. J. Cuthbert, R. Mateo, and M. A. Taggart. 2011. An experimental test of the toxicity of cereal pellets containing brodifacoum to the snails of Henderson Island, South Pacific. Wildlife Research 38:34-38.

Brooke, M. de L., E. Bonnaud, B. J. Dilley, E. N. Flint, N. D. Holmes, H. P. Jones, P. Provost, G. Rocamora, P. G. Ryan, C. Surman, and R. T. Buxton. 2017. Seabird population changes following mammal eradications on islands. Animal Conservation doi:10.1111/acv.12344.

Broome, K. and D. Brown. 2010. Current agreed best practive for rat eradication, hand broadcasting poison bait (version 1.1). New Zealand Department of Conseravation

internal document DOCDM-458533. Department of Conservation, Wellington, New Zealand.

Broome, K.G.; Golding, C.; Brown, K.P.; Horn, S.; Corson P.; Bell, P.; 2017: Mouse eradication using aerial baiting: Current agreed best practice used in New Zealand (Version 1.0). New Zealand Department of Conservation internal document DOC-3034281, Wellington, New Zealand.

Brown, A. and E. Elias. 2008. Extralimital records of the otter (*Enhydra lutris)* in northern California. Northwestern Naturalist 89:54-56.

Brown, A., D. Lee, R. Bradley, and S. Anderson. 2010. Dynamics of white shark predation on pinnipeds in California: effects of prey abundance. Copea 2010:232-238.

Brown, C. R., A. M. Knott, and E. J. Damrose. 1992. Violet-green swallow (*Tachycineta thalassina*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/014.

Bruyn, P. d., A. Bastos, C. Eadie, C. Tosh, and M. Bester. 2008. Mass mortality of adult male Subantarctic fur seals; are alien mice the culprits. PLoS ONE 3.

Buckelew, S., J. Curl, M. McKown, and K. Newton. 2009. Preliminary ecosystem response following invasive rat eradiation on Rat Island, Aleution Islands, Alaska. Report to the USFWS. Island Conservation, Santa Cruz, CA.

Buckelew, S., G. Howald, S. MacLean, S. Ebbert, and T. Primus. 2008. Progress in restoration of the Aleutian Islands: Trial rat eradication, Bay of Islands, Adak Alaska, 2006. Report to USFWS. Island Conservation, Santa Cruz, CA.

Buckelew, S., G. Howald, A. Wegmann, J. Sheppard, J. Curl, P. McClelland, B. Tershey, K. Swift, E. Campbell, and B. Flint. 2005. Progress in Palmyra Atoll restoration: rat eradication trial 2005. Report to the US Fish and Wildlife Service. Island Conservation, Santa Cruz, CA.

Buckle, A. and C. Prescott. 2012. The current status of anticoagulant resistance in rats and mice in the UK. A report to HSE from the Rodenticide Resistance Action Group 17th May 2012.

Buckle, A. and R. Smith. 1994. Rodent Pests and their Control. CAB International, Bristol, UK

Burgiel, S. and A. Muir. 2010. Invasive species, climate change and ecosystem adaptation: addressing multiple drivers of global change. Global Invasive Species Programme (GISP), Washington DC, US, and Nairobi, Kenya.

Buxton, R., C. Jones, H. Moller, and D. Towns. 2014. Drivers of seabird population recovery on New Zealand Islands after predator eradications. Conservation Biology, 28(2) 333-344.

Cabe, P. R. 1993. European starling (*Sturnus vulgaris*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/048.

California Coastkeeper Alliance. 2011. Farallon Islands: Area of Biological Significance. Fremont, CA.

California Department of Fish and Game. 2010. Guide to the North-Central California Marine Protected Areas: Alder Creek to Pigeon Point. Sacramento, CA.

California Department of Fish and Game. 2011. Marine Life Protection Act Initiative North Central Coast Study Region.

California Department of Fish and Game. 2003. Annual status of the fisheries report through 2003. Report to the California Fish and Game Commission. California Department of Fish and Game.

California Department of Fish and Wildlife. 2013. Status of the fisheries report: an update through 2011. Report to the California Fish and Game Commission, California Department of Fish and Wildlife, Marine Region.

California Department of Fish and Game. 2005. Abalone recovery and management Plan. California Department of Fish and Wildlife, Marine Region. https://www.wildlife.ca.gov/Conservation/Marine/ARMP

California Department of Fish and Wildlife. 2017. State & federally listed endangered & threatened animals of California. Available online at https://www.wildlife.ca.gov/Conservation.

California State Water Resources Control Board. 1979. California marine waters, areas of special bilogical significance reconnaissance survey report, Farallon Islands, San Francisco County. Water Quality Monitoring Report No . 79-13. California State Water Resources Control Board, Division of Planning and Research, Surveillance and Monitoring Setion. May 1979.

Campbell, K., G. Harper, D. Algar, C. Hanson, B. Keitt, and S. Robinson. 2011. Island invasives: eradication and management. In: Veitch, C; Clout, M. and Towns, D. (eds.). IUCN, Gland, Switzerland:37-46.

Campbell, K., J. Beek, C. Eason, A. Glen, J. Godwin, Fred Gould, Nick D. Holmes, Gregg R. Howald, F. Madden, J. Ponder, D. Threadgill, A. Wegmann, G. Baxter. 2014. The next generation of rodent eradications: Innovative technologies and tools to improve species specificity and increase their feasibility on islands. Biological Conservation 185:47-58.

Cameron, D. G. 1966. Blood Group Polymorphism in an Insular Population of Rabbits, *Oryctolagus caniculatus*. Unpublished PhD dissertation, Stanford University, Palo Alto, CA.

Carter, H. R. 2003. Oil and California's seabirds: and overview. Marine Ornithology 31:1-7.

Carter, H. R., U. W.Wilson, R. W. Lowe, M. S. Rodway, D. A. Manuwal, J. E. Takekawa, and J. L. Yee. 2001. Population trends of Common Murre (*Uria aalge californica*) *in* D. A. Manuwal, H. R. Carter, T. S. Zimmerman, and D. L. Orthmeyer, editors. Biology and conservation of the Common Murre in California, Oregon, Wasington, and Brithish Columbia. United States Geological Survey, Information and Technology Report USGS/BRD/ITR-2000-0012, Washington, D.C.

Carter, H. R., W. R. McIver, and G. J. McChesney. 2008. Ashy Storm-Petrel (*Oceanodroma homochroa*). *In* Shuford, W. D., and Gardali, T., editors. 2008. California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento.

Castege, I., E. Milton, Y. Lalanne, and J. d'Elbbee. 2016. Colonization of the yellow-legged gull in southeastern Bay of Biscay and efficacy of deterring systems on landfill site. Estuarine, Coastal and Shelf Science. 179: 207-214.

Chandler SL, Tietz JR, Bradley RW, Trulio L. 2016. Burrowing Owl Diet at a Migratory Stopover Site and Wintering Ground on Southeast Farallon Island, California. Journal of Raptor Research 50:391-403.

Chapple, T., S. Jorgensen, S. Anderson, P. Kanive, A. Klimley, L. Botsford, and B. Block. 2011. A first estimate of white shark, *Carchadon carcharias*, abundance off Central California. Royal Society Biology Letters. Published online at doi:10.1098/rsbl.2011.0124.

Cheng, T. L., S. M. Rovito, D. B. Wake, and V. T. Vredenburg. 2011. Coincident mass extirpation of neotropical amphibians with the emergence of the infectious fungal pathogen *Batrachochytrium dendrobatidis*. Proceedings of the National Academy of Sciences 108:9502-9507.

Clapperton, K. 2006 A review of the current knowledge of rodent behavior in relation to control devces. Science and Technology Publishing, Wellington, New Zealand.

Clavero, N. and E. Garcia-Berthou. 2005. Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution 20:110.

Cohen, N. 1952. Comparative rates of dehydration and hydration in some California salamanders. Ecology 33:462-479.

Cole, F., L. Loope, A. Medieros, C. Howe, and L. ANderson. 2000. Food habits of introduced rodents in high-elevation shrubland of Haleakala National Park, Maui, Hawaii. Pacific Science 54:313-329.

Comrack, L. and R. Logsdon. 2008. The status review of the American peregrine falcon in California. Report to the California Fish and Game Commission. October 2008.

Cook, A., S. Rushton, and J. Allan. 2008. An evaluation of techniques to control problem bird species on landfill sites. Environmental Management. 41: 834-843.

Coonan, T. 2011. Thirteenth annual meeting Island Fox Working Group: summary report. Prepared for the National Park Service.

Coulter, M. 1971. A flora of the Farallon Islands, California. *Madroño* 21: 131-137.

Coulter, M. 1978. Additions to the flora of the Farallon Islands, California. *Madroño* 25: 234-236.

Coulter, M. and J. Irwin. 2005. General comments on the Farallon flora. Unpublished report to USFWS-FNWR. 16 pages. SIS, Chocorua, NH.

Courchamp, F., M. Langlais, and G. Sugihara. 1999. Control of rabbits to protect island birds from cat predation. Biological Conservation 89:219-225.

Courchamp, F., M. Langlais, and G. Sugihara. 2000. Rabbits killing birds: modeling the hyperpredation process. Journal of Animal Ecology 69:154-164.

Craddock, P. 2003. Environmental breakdown of Pestoff poison bait (20 ppm) brodifacoum at Tawharanui Regional Park, north of Auckland, New Zealand. Unpublished Report prepared for Northern Regional Parks, Auckland Regional Council. Entomologia Consulting, New Zealand. pp.

Crafford, J. 1990. The role of feral houce mice in ecosystem functioning on Marion Island.*in* K. Kerry and G. Hemple, editors. Antarctic Ecosystems: Ecological Change and Conservation. Springer-Verlag, Berlin, Heidelberg, Germany.

Crawford, D., R. Ornduff, and M. Vasey. 1985. Allozyme variation within and between *Lasthenia minor* and its derivative species, *L. maritima* (Asteraceae). American Journal of Botany 72:1177-1184.

Croll, D. and K. Newton. 2012. Potential non-target impacts of Anacap rat eradication on slender salamanders (*Batrachoseps pacificus*). 2012. Technical Report. Coastal Conservation Action Laboratory, UC Santa Cruz. Santa Cruz, CA. 21 November, 2012.

Cromarty, P., K. Broome, A. Cox, R. Empson, W. Hutchinson, and I. McFadden. 2002. Eradication planning for invasive alien species on islands - the approach developed by

the New Zealand Department of Conservation.*in* Turning the Tide: The Eradication of Invasive Species. IUCN SSC Invasive Specialist Group, Gland, Switzerland.

Crowcroft, P. and J. Jeffers. 1961. Variability in the behavior of wild house mice (*Mus musculus L.*) towards live traps. Proceedings of the Zoological Society of London 137.

Cryan, P. and A. Brown. 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation 139:1-11.

Curtis, O. E., R. N. Rosenfield, and J. Bielefeldt. 2006. Cooper's hawk (*Accipiter cooperii*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/075.

Cuthbert, R. and G. Hilton. 2004. Introduced house mice *Mus musculus*: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? Biological Conservation 117:483-489.

Cuthbert, R.J., H. Louw, J. Lurling, G. Parker, K. Rexer-Huber, E. Sommer, P. Visser and P. G. Ryan. 2013. Low burrow occupancy and breeding success of burrowing petrels at Gough Island: a consequence of mouse predation. Bird Conservation International 23:113–124.

Cuthbert, R.J., R. M. Wanless, A. Angel, M.-H. Burle, G.M. Hilton, H. Louw, P. Visser, J.W. Wilson, and P.G. Ryan. 2016. Drivers of predatory behavior and extreme size in house mice *Mus musculus* on Gough Island. Journal of Mammalogy 97:533–544.

Daltry, J. C. 2006. Control of the black rat *Rattus rattus* for the conservation of the Antiguan racer *Alsophis antiguae* on Great Bird Island, Antigua. Conservation Evidence 3:28-29.

Daniel, R., L. Jemison, S. Pendleton, and S. Crowley. 2003. Molting phenologyof harbor seals on Tugidak Island, AK. Marine Mammal Science 19:128-140.

de Bruyn, P., A. Bastos, C. Eadie, C. Tosh, and M. Bester. 2008. Mass mortality of adult male subantarctic fur seals: are alien mice the culprits. PLoS ONE 3:1-5.

DeSante, D. 1983. Annual variability in the abundance of migrant landbirds on southeast Farallon Island, California. Auk 100:826-852.

DeSante, D. and D. Ainley. 1980. The Avifauna of the South Farallon Islands, California. Studies in Avian Biology No. 4 Cooper Ornithological Society, Lawrence, KS.

Deyle, E., M. Forgarty, C. Hsieh, L. Kaufman, A. MacCall, S. Munch, C. Perretti, H. Ye, and G. Sugihara. 2013. Predicting climate effects on Pacific sardine. Proceedings of the National Academy of Sciences 110:6430-6435.

Diamond, J. 1985. Populations processes in island birds: immigration, extinction, and fluctuations. Pages 17-21 *in* P. Moors, editor. Conservation of Island Birds: Case Studies for the Management of Threatened Island Birds. International Council for Bird Preservation, Cambridge.

Diamond, J. 1989. Overview of recent extinctions. Pages 37-41 *in* D. Western and M. Pearl, editors. Conservation for the Twenty-first Century. Oxford University Press, New York.

Didion, J., D. Threadgill, and F. Pardo-Manuel de Villena. 2012. Origins of invasive house mouse population on Southeast Farallon Island. 1. University of North Carolina, Chapel Hill, NC, USA; 2. North Carolina State University, Raleigh, NC, USA. Presentation to the EBM meeting Marseille, France.

DIISE. 2015. The Database of Island Invasive Species Eradications, developed by Island Conservation, Coastal Conservation Action Laboratory UCSC, IUCN SSC Invasive Species Specialist Group, University of Auckland and Landcare Research New Zealand. http://diise.islandconservation.org.

Doney, S., M. Ruckelshaus, J. Duffy, J. Barry, F. Chan, C. English, H. Galindo, J. Grebmeier, A. Hollowed, N. knowlton, J. Polovina, N. Rabalais, W. Sydeman, and L. Talley. 2012. Climate change impacts on marine ecosystems. Annual Review of Marine Science 4:11-37.

Drost, C. and G. Fellers. 1991. Density cycles in an island population of deer mice, *Peromyscus maniculatus*. Oikos 60:351-364.

Drost, C. and R. McCloskey. 1992. Extirpation of altenrative prey during a small rodent crash. Oecologia 92:301-304.

Dunk, J. R. 1995. White-tailed kite (*Elanus leucurus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/178.

Earnheart-Gold, S. and P. Pyle. 2001. Occurrence patterns of peregrine falcons on Southeast Farallon Island, California, by subspecies, age and sex. Western Birds 32:119-126.

Eason, C., E. Murphy, G. Wright, and E. Spurr. 2002. Assessment of risks of brodifacoum to nontarget birds and mammals in New Zealand. Ecotoxicology. 11:35-48.

Eason, C. and S. Ogilvie. 2009. A re-evaluation of potential rodenticides for aerial control of rodents. Research & Development Series DOC Research & Development Series 312, New Zealand Department of Conservation Wellington, NZ.

Eason, C. and E. Spurr. 1995. Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. New Zealand Journal of Zoology 22:371-379.

Efford, M., B. Karl, and H. Moller. 1988. Population ecology of *Mus musculus* on Mana Island, New Zealand. Journal of Zoology (London) 216:539-564.

Efroymson, R. and G. Suter II. 2001. Ecological risk assesment framework for low-altitude aircraft overflights: II. Estimating effects on wildlife and estimating exposure. Risk Analysis 21:263-274.

Ehrlich, P. 1988. The loss of diversity: causes and consequences.*in* E. Wilson, editor. Biodiversity. National Academy Press, Washington D.C.

Eisemann, J. and C. Swift. 2006. Ecological and human health hazards from broadcast application of 0.005? diphacinone rodenticide baits in native Hawaiian ecosystems. Proceedings of the Vertebrate Pest Conference 22:413-433.

Ells, S. 1976. Kinetics of 'aged' diphacinone in a model aquatic system. Unpublished study. EPA Accession No. 40151, E. G. & G. Bionomics for Velsicol Chemical Corp.

Empson, R. A. and C. M. Miskelly. 1999. The risks, costs and benefits of using brodifacoum to eradicate rats from Kapiti Island, New Zealand. New Zealand Journal of Ecology 23:241-254.

Erickson, W. and D. Urban. 2004. Potential risks of nine rodenticides to birds and non-target mammals: a comparitive approach. US Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances. Washington, D.C. .

Ewins, P. J. 1993. Pigeon Guillemot (*Cepphus columba*).*in* A. Poole, editor. The Birds of North America Online: http://bna.birds.cornell.edu/bna/species/049. Cornell Lab of Ornithology, Ithaca, NY.

Extoxnet. 1996. Pesticide information profile: diphacione. Extension Toxicology Network. Corvalis, OR.

Ferencz L and DL Muntean. 2015. Identification of new superwarfarin-type rodenticides by structural similarity. The docking of ligands on the vitamin K epoxide reductase enzyme's active site Agriculture and Environment 7:108-122.

Fishbase. 2013. Online database of fish information. Last accessed May 10, 2013. www.fishbase.org.

Fisher, P. 2005. Reveiw of house mouse (*Mus musculus)* susceptibility to anticoagulant poisons. DOC Science Internal Service Report 198, New Zealand Department of Conservation, Wellington, NZ.

Fisher, P. 2009. Residual concentrations and persistence of the anticoagulant rodenticides brodifacoum and diphacinone in Fauna. Lincoln University.

Fisher, P. and K. Broome. 2010. Diphacinone, a review of current knowledge. Pesticide Information Review No. 3. Department of Conservation, Wellington, New Zealand.

Fisher, P., R. Griffiths, C. Speedy, and K. Broome. 2011. Environmental monitoring for brodifacoum residues after aerial application of baits for rodent eradiation. Island Invasives: Eradication and Management. IUCN, Gland, Switzerland.

Foose, T., R. Lande, N. Flesness, G. Rabb, and B. Read. 1986. Propagation plans. Zoo Biology 5:139-146.

Frost, C., R. Naude, W. Oelofsen, and B. Jacobson. 1999. Comparative blood coagulation studies in the ostrich. Immunopharmacology 45:75-81.

Gabriel, M., L. Woods, R. Poppenga, R. Sweitzer, C. Thompson, S. Matthews, J. Higley, S. Keller, K. Purcell, R. Barrett, G. Wengert, B. Sacks, and D. Clifford. 2012. Anticoagulant rodenticides on our public and community lands: spatial distribution of exposure and poisoning or a rare forest carnivore. PLoS ONE 7:e40163.

Gagliardi, A., A. Martinoli, D. Preatoni, L. Wauters, G. Tosi. 2006. Behavioral responses of wintering great crested grebes to dissuasion experiments: implication for management. Waterbirds. 29:105-114.

Gale, R., M. Tanner, and C. Orazio. 2008. Determination of diphacinone in sea water, vertebrates, invertebrates, and bait pellet formulations following aerial broadcast on Mokapu Island, Molokai, Hawaii. Prepared in cooperation with the U.S. Fish and Wildlife Service, Region 1. Open-File Report 2008-1285.

Gerlach, J. 2005. The impact of rodent eradication on the larger invertebrates of Fregate island, Seychelles. Phelsuma 13:44-54.

Gerlach, J. and V. Florens. 2000. Considering molluscs in rodent eradication projects. Tentacle 9:7-8.

Giese, M. and R. Gales. 2008. King Penguin Helicopter over flight disturbance trial report. Interim Draft Report. Macquarie Island; April 2007 and March 2008.

Giuliani, D. 1982. Notes on a collection of intertidal beetles from the Farallon Islands, California. Pan-Pacific Entomologist 58:163.

Godfrey, M. 1986. An evaluation of the acute oral toxicity of brodifacoum to birds. Proceedings of the 12th Vertebrate Pest Conference, pp. 78-81.

Griffiths, R. 2008. Rangitoto and Motutapu pest eradication - feasibility study. Department of Conservation, New Zealand.

Grivetti, L. 1962. Recent intertidal foraminifera of the Farallon Islands. University of California, Berkeley, Berkeley, CA.

Grote, F. and R. Brown. 1971. Conditioned taste aversions: two-stimulus tests are more sensitive than one-stimulus test. Behavioral Research Methods 3:311-312.

Grout, D. and R. Griffiths. 2012. Farallon Islands restoration project - a report on the trials undertaken to inform project feasibility and non-target risk assessment. Islands Conservation, Santa Cruz, CA.

Grout, D., R. Griffiths, M. Pott, R. Bradley, P. Warzybok, W. Vickers, D. Milsaps, and G. McChesney. 2013. Hazing Western Gulls on the South Farallon Islands. Unpublished report, Island Conservation, Santa Cruz, California.

Hadler, M. and R. Shadbolt. 1975. Novel 4-hydroxycoumarin anticoagulants active against resistant rats. Nature 253:275-277.

Hagen, A. 2003. An evaluation of house mouse diet on Southeast Farallon Island. Report prepared by the Department of Wildlife Management, Humbolt State University, Arcata, CA, USA.

Hampton, S., R. Ford, H. Carter, C. Abraham, and D. Humple. 2003. Chronic oiling and seabird mortality from the sunken vessel S.S. Jacob *Luckenback* in central California. Marine Ornithology 31:35-41.

Hankin D. and R.W. Warner. 2001. Dungeness crab. *In* California's Living Marine Resources: a status report, pages 107-111. California Department of Fish and Game.

Harvell, C., K. Kim, M. Burkholder, R. Colwell, and P. Epstein. 1999. Emerging marine disease-climate links and anthropogenic factors. Science 185:1505-1510.

Hastings, K. and W. Sydeman. 2002. Population status, seasonal variation in abundance, and long-term population trends of Steller sea lions (*Eumetopias jubatus)* at the South Farallon Islands, California. Fishery Bulletin 100:51-62.

Haug, E., B. Millsap, and M. Martell. 1993. Burrowing owl (*Athene cunicularia) in* A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornitholgy. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/061, Ithaca, New York.

Hawk, J. 2015. Classification, Vegetation-Environment Relationships, and Distribution of Plant Communities on Southeast Farallon Island, California. Unpublished M.S. Thesis, San Francisco State University, San Francisco, California.

Hawkins, K. 2011. Operational Report for kiore eradication in the Taranga (Hen) Island: 19 May 2011 - 29 May 2011. New Zealand Department of Conservation.

Hayes, W. and E. Laws. 1990. Diphacinone Harcourt Brace Jovanovich, New York, New York.

Hayward, J. L. and N. A. Verbeek. 2008. Glaucous-winged gull (*Larus glaucescens*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/059.

Holland, D. and R. Goodman. 1998. A guide to the amphibians and reptiles of MCB Camp Pendleton, San Diego, CA. Report to AC/S Environmental Security, United States Marine Corps, Camp Pendleton, CA.

Holmes, N., R. Griffiths, M. Pott, A. Alifano, D. Will, A. Weg,amm. and J. Russell. 2015. Factors associated with rodent eradication failure. Biological Conservation. 185: 8-16.

Holst, M. J.W. Lawson, W.J. Richardson, S.J. Schwartz, and G. Smith. Pinniped responses during Navy missile launches at San Nicolas Island, California. Pages 485—498 in (D.K. Garcelon and C.A. Schwemm, Editors). Proceedings of the Sixth California Islands Symposium. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California.

Holt, R. 1977. Predation, apparent competition, and the structure of prey communities. Theoretical Population Biology 12:197-229.

Holzman, B.A., Q.J. Clark, G.J. McChesney, and G. Block. 2016. Farallon Islands 2016 invasive plant inventory. Unpublished report, San Francisco State University, San Francisco, CA, and U.S. Fish and Wildlife Service, Fremont, CA.

Holzman, B.A., Q.J. Clark, G.J. McChesney, and G. Block. 2017. Farallon Islands 2016 invasive plant inventory. Unpublished report, San Francisco State University, San Francisco, CA, and U.S. Fish and Wildlife Service, Fremont, CA.

Honda, J., Robinson, B., Valainis, M., Vetter, R. and Jahncke, J., 2017. Southeast Farallon Island arthropod survey. Insect Mundi 0532:1-15

Hone, J. and H. Mulligan. 1982. Vertebrate pesticides. Australia Department of Agriculture, New South Wales.

Howald, G., C. J. Donlan, K. R. Faulkner, S. Ortega, H. Gellerman, D. Croll, and B. Tershy. 2010. Eradication of black rats *Rattus rattus* from Anacapa Island. Oryx 44:30-40.

Howald, G., C. Donlan, J. Galvan, J. Russell, J. Parkes, A. Samaniego, Y. Wang, D. Vietch, P. Genovesi, M. Pascal, A. Saunders, and B. Tershy. 2007. Invasive rodent eradication on islands. Conservation Biology 21:1258-1268.

Howald, G., A. Samaniego, S. Buckelew, P. McClelland, B. Keitt, A. Wegmann, W. Pitt, D. Vice, E. Campbell, K. Swift, and S. Barclay. 2004. Palmyra Atoll rat eradication assessment trip report. August 2004. Island Conservation, Santa Cruz, CA.

Howald, G., A. Samaniego, B. Tershy, P. Pyle, J. Buffa, B. Keitt, and H. Jones. 2003. Options for removing house mice (*Mus musculus*) from the Farallon Islands, Farallon Islands National Wildlife Refuge, California. Report for the U.S. Fish and Wildife Service.

Howald, G., B. Tershy, B. Keitt, H. Gellerman, and D. Croll. 2001. Progress in rat eradication, Anacapa Island, Channel Islands National Park, California.

Howald, G.R. 1997. The risk of non-target species poisoning from brodifacoum used to eradicate rats from Langara Island, British Columbia, Canada. M.Sc. Thesis. University of British Columbia, Vancouver, BC. 159 pp

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: The physical science basis. *.in* S. Solomon, M. Quin, Z. Chen, M. Marquis, K. Averyt, M. Tignor, and H. Miller, editors. Contribution of Working Group I to the 4th Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univeristy Press, Cambridge, United Kingdom and New York, New York, USA.

Irwin, J. 2006. The impact of house mice on ashy-storm petrels on Southeast Farallon Island, Unpublished report to U.S. Fish and Wildlife Service. Farallon Islands National Wildlife Refuge, Freemont, CA.

Island Conservation. 2010. The ecotoxicology and palatability of two rodenticide bait products: field-based assessment at Palmyra Atoll. Prepared by: A. Alifano and A. Wegmann, Santa Cruz, CA.

Island Conservation. 2012. Desecheo bait application operational report. Unpublished report prepard for U.S. Fish and Wildlife Service. June 2012.

Jarman, W., C. Bacon, J. Estes, M. Simon, and R. Norstrom. 1996. Organochlorine contaminants in sea otters: the sea otter as a bio-indicator. Endangered Species Update 13:20-22.

Johnson, K. 1995. Green-winged Teal (Anas crecca), version 2.0. In The Birds of North America (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bna.193.

Jones, D. G., P. D. Roberts, and J. Limburg. 2001a. Measuring radioactivity from waste dumps on the sea floor.*in* H. A. Karl, J. L. Chin, E. Ueber, P. H. Stauffer, and J. W. H. II, editors. Beyond the Golden Gate: Oceanography, Geography, Biology, and Environmental Issues in the Gulf of the Farallons. USGS Circular 1198.

Jones, D. G., P. D. Roberts, J. Limburg, H. Karl, J. L. Chin, W. C. Shanks, R. Hall, and D. Howard. 2001b. Measurement of Seafloor Radioactivity at the Farallon Islands Radioactive Waste Dump Site, California. U.S. Geological Survey, U.S. Dept. of the Interior.

Jones, M. and R. Golightly. 2006. Annual variation in the diet of house mice (*Mus musculus)* on Southeast Farallon Island. Unpublished report. Department of Wildlife, Humbolt State University, Arcata, California. 48 pp.

Jones, M. G. W. and P. G. Ryan. 2010. Evidence of mouse attacks on albatross chicks on sub-Antarctic Marion Island. Antarctic Science 22:39-42.

Jorgensen, S., C. Reeb, T. Chapple, S. Anderson, C. Perle, S. Van Sommeran, C. Fitz-Cope, A. Brown, A. Klimley, and B. Block. 2009. Philopatry and migration of Pacific white sharkds. Proceeding of the Royal Society B 1155:1-10.

Kalvass, P. and L. Rogers-Bennett. 2001. Red sea urchin. In California's Living Marine Resources: a status report, pages 101-104. California Department of Fish and Game. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=34330&inline

Karl, H. A. 2001. Search for containers of radioactive waste on the sea floor. Pages 207-210 *in* H. A. Karl, J. L. Chin, E. Ueber, P. H. Stauffer, and J. W. H. II, editors. Beyond the Golden Gate: Oceanography, Geography, Biology, and Environmental Issues in the Gulf of the Farallons. USGS Circular 1198.

Keitt, B., R. Griffiths, S. Boudjelas, K. Broome, S. Cranwell, J. Millett, W. Pitt, and A. Samaniego-Herrera. Best practice guidelines for rat eradication on tropical islands. Biological Conservation. 185: 17-26.

Kim, H., A. Miller, J. McGowan, and M. Carter. 2009. Coastal phytoplankton blooms in the Southern California Bight. Progress in Oceonography 82:137-147.

Kimball, B., J. Taylor, K. Perry, and C. Capelli. 2009. Deer responses to repellent stimuli. Journal of Chemical Ecology. 35:1461-1470.

King, C. 2005. The handbook of New Zealand mammals: Second Edition, Auckland, New Zealand.

Klimley, A. and D. Ainley. 1998. Great white sharks: the biology of *Carcharodon carcharias*. Academic Press.

Klontz, S. 1989. Ecology and systematics of the intertidal sponges of the Southeast Farallon Islands. San Francisco State University, San Francisco, CA.

Kosmin, M. and J. Barlow. 1976. Rodent control using a novel formulation of diphacinone, Ramik. Proceedings of the 1st Afro/Asian Vertebrate Pest Conference. Cairo, Egypt.

Kubalek, S., R. Mischke, and M. Fehr. 2002. Investigations on blood coagulation in the green iguana. Journal of Veterinary Medicine 49:210-216.

Kusano, T. 1974. The toxicity of diphacinone to laboratory rats and mice. Japan Journal of Sanitary Zoology 24:207-213.

Landress, P., C. Barns, J. Dennis, T. Devine, P. Geissler, C. McCasland, L. Merigliano, J. Seastrand, and R. Swain. 2008. Keeping it wild: an interagency strategy to monitor trends in wilderness character across the National Wilderness Preservartion System. General Technical Report RMRS-GTR-212. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 77p.

Largier, J., B. Cheng, and K. Higgason. 2010. Climate change impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the

Gulf of the Farallones and Cordell Bank national Marine Sanctuaries Advisory Councils, June 2010.

Le Boeuf, B. and R. Laws. 1994. Elephant seals: an introduction to the genus. Pages 1-26 *in* B. Le Boeuf and R. Laws, editors. Elephant Seals: Population Ecology, Behavior and Physiology. University of California Press, Berkeley, CA.

Lecker, C., M. Parsons, D. Lecker, R. Samo, and F. Parsons. 2015. The temporal multimodal influence of optical and auditory cues on the repellent behavior of ring-billed gulls (*Larus delewarensis*). Wildlife Research. 42: 232-240.

Ledec, G. and R. Goodland. 1988. Wildlands: their protection and management in economic development. World Bank, Washington D.C.

Lee, D. 2008. Farallon salamander report 2008. Page 7 Unpublished report to U.S. Fish and Wildlife Service. PRBO Conservation Science, Petaluma, CA.

Lee, D., J. Bettaso, M. Bond, R. Bradley, J. Tietz, and P. Warzybok. 2012. Growth, age at maturity, and age-specific survival of the arboreal salamander (*Aneides lugubris*) on Southeast Farallopn Island, California. Journal of Herpetology 46:64-71.

Lee, D. E. 2010. Farallon Salamander Report 2010. PRBO Conservation Science, Petaluma, California.

Lindholm, J., J.F. Moye, D. Kline, H. Kelley, and D. Rosen. 2014. North central California coast marine protected areas baseline characterization and monitoring of mid-depth rock and soft-bottom ecosystems (20 – 116 m). Unpublished report to California Sea Grant, Project # R/MPA-8.

Lindsay, J. 1992. Draft summary report on the NOAA cruises in the Gulf of the Farallones, November 1991 and June 1992 for submission to the EPA. Prepared by EPA San Francisco, CA.

Lips, K. R., F. Brem, R. Brenes, J. D. Reeve, R. A. Alford, J. Voyles, C. Carey, L. Livo, A. P. Pessier, and J. P. Collins. 2006. Emerging infectious disease and the loss of biodiversity in a Neotropical amphibian community. Proceedings of the National Academy of Sciences of the United States of America 103:3165-3170.

Littin, K., C. O'Connor, and C. Eason. 2000. Comparative effects of brodifacoum on rats and possums. New Zealand Plant Protection 53:310-315.

Long, Ronald D, James Foster, Kimberly A Hoxter, Gregory J Smith, and Susan M Campbell. 1992. "Diphacinone Technical: A Dietary LC50 Study with the Mallard." 284–101A. Easton, Maryland: Wildlife International Ltd.

Love, M., M. Yaklavich, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Berkeley and Los Angeles, CA.

Lowe, S., M. Browne, S. Boudjelas, and M. D. Poorter. 2000. 100 of the world's worst invasive alien spcies: a selection from the Global Invasive Species Database. Published by the Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN):1-12.

Lukis, K. 2009. Returning an endemic frog to the New Zealand mainland: transfer and adaptive management of *Leiopelma pakeka* at Karori Sanctuary, Wellington. Victoria University of Wellington, Wellington, New Zealand.

Mackas, D., S. Batten, and M. Trudel. 2007. Effects on zoolankton of a warmer ocean: recent evidence from the Northeast Pacific. Progress in Oceonography 75:223-252.

Mackay, J. 2011. Improving the success of mouse eradication attempts on islands. Ph.D. Thesis, Univeristy of Auckland, Auckland, New Zealand.

Mackay, J., E. Murphey, S. Anderson, J. Russell, M. Hauber, D. Wilson, and M. Clout. 2011. A successful mouse erdication explained by site-specific pupulation data. .*in* C. Veitch, M. Clout, and D. Towns, editors. Island invasives: erdication and management. IUCN (International Union for Conservation of Nature), Gland, Switzerland.

MacKay, J. W. B., J. C. Russell, and E. C. Murphy. 2007. Eradication house mice from islands: successes, failures and the way forward.*in* USDA National Wildlife Research Center Symposia: Managing Vertebrate Invasive Species, University of Nebraska-Lincoln.

Mackin, W. 2007. Conservation of Audubon's shearwater in the Bahamas: status, threats, and practical solutions.*in* B. Rathcke and W. Hayes, editors. The 11th Symposium on the Natural History of the Bahamas, San Salvador, Bahamas.

Macwhirter, R. B. and K. L. Bildstein. 1996. Northern harrier (*Circus cyaneus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/210.

Marine Applied Research and Exploration and Pacific States Marine Fisheries Commission. 2012. Marine resource assessment: ROV-based deep water quantitative survey of the North Central Coast marine protected areas. Unpublished report, Marine Applied Research and Exploration and Pacific States Marine Fisheries Commission. Unpublished Report, Marine Applied Research and Exploration and Pacific States Marine Fisheries Commission.

Marks, J. S., D. L. Evans, and D. W. Holt. 1994. Long-eared owl (*Asio otus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/133.

Maron, J., J. Estes, D. Croll, E. Danner, S. Elmendorf, and S. Buckelew. 2006. An introduced predator alters Aleutian Island plant communities by thwarting nutrient subsides. Ecological Monographs 76:3-24.

Marsh, R., W. Howard, and W. Jackson. 1980. Bromadiolone: a new toxicant for rodent control. Pest Control 48:22-28.

Marti, C. D., A. F. Poole, and L. R. Bevier. 2005. Barn owl (*Tyto alba*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/001.

Martin, A.R. and M.G. Richardson. 2017. Rodent eradication scaled up: clearing rats and mice from South Georgia. Oryx, doi:10.1017/S003060531700028X.

Masuda BM, Fisher P, and Beaven B. 2015. Residue profiles of brodifacoum in coastal marine species following an island rodent eradication. Ecotoxicology and Environmental Safety. 113: 1-8

McGowan, J., S. Bogard, R. Lynn, and A. Miller. 2003. The biological response to the 1977 regime shift in the California Current. Deep-Sea Res. Part II 50.

McChesney, G.J., H.R. Carter, C.A. Bechaver, S.J. Rhoades, R.W. Bradley, P.M. Warzybok, R.T. Golightly, and P.J. Capitolo. 2013. Seabird breeding population sizes within the North Central Coast Study Region of the California Marine Life Protection Act Initiative, 2010-2012. Pages 78-110 i*n* (G.J. McChesney and D. Robinette, Eds.), Baseline characterization of newly established marine protected areas within the North Central California Study Region - seabird colony and foraging studies. Unpublished report, U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Fremont, California, and Point Blue Conservation Science, Petaluma, California.

Merton, D. 1987. Eradication of rabbits from Round Island, Mauritius: a conservation success story. Dodo 24.

Michener, W. K., E. R. Blood, K. L. Bildstein, M. M. Brinson, and L. R. Gardner. 1997. Climate change, hurricanes and tropical storms and rising sea level in coastal wetlands. ecological Applications 7:770-801.

Miller, A. 1999. Ecological energetics of feral house mice (*Mus musculus)* inhabiting coastal sand dunes University of Otago, Dunedin, New Zealand.

Mills. 2006. Owl diet on Southeast Farallon Island, 1996-2004. Report to USFWS.

Mills, K.L. 2016. Seabirds as part of migratory owl diet on Southeast Farallon Island, California. Marine Ornithology 44: 121–126.

Moleón, M., P. Almaraz, and J. A. Sánchez-Zapata. 2008. An emerging infectious disease triggering large-scale hyperpredation. PLoS ONE 3:e2307.

Morgan, D. R. and G. R. Wright. 1996. Environmental effects of rodent Talon® baiting. Part I: Monitoring for toxic residues. Science for Conservation: 38, New Zealand Department of Conservation, Wellington, NZ.

Morgan, A.P., J.P. Didion, J.J Hughes, J.B. Searle,W.J. Jolley, K.J. Campbell, D. W. Threadgill, and F. Pardo-Manuel de Villena. In review. Genetic characterization of invasive house mouse populations on small islands. bioRxiv; doi: http://dx.doi.org/10.1101/332064

Morriss, G. 2007. Susceptibility of Rangitoto and Motutapu island house mice to 20R brodifacoum baits. Landcare Research Contract report, No. LC0607/155. Landcare Research Ltd., Linconln, New Zealand.

Moskoff, W. and L. R. Bevier. 2002. Mew gull (*Larus canus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/687.

Mowbray, T. B., C. R. Ely, J. S. Sedinger, and R. E. Trost. 2002. Canada goose (*Branta canadensis*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/682.

Mulder, C. and S. Keall. 2001. Burrowing seabirds and reptiles: impacts on seeds, seedlings, and soil in an island forest in New Zealand. Oecologia 127:350-360.

National Marine Fisheries Service (NMFS). 2005. Draft Programmatic Environmental Impact Statement: Toward an ecosystem approach for the Western Pacific Region: from species-based fishery management plans to place-based fishery ecosystem plans. Page 243. National Marine Fisheries Service, Honolulu, HI.

NMFS. 2008. Recovery plan for the Steller sea lion (*Eumetopias jubatus*) (Eastern and western distinct population segments): revision. Department of Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2011. Endangered and Threatened Wildlife and Plants; Final Rulemaking to Designate Critical Habitat for Black Abalone. Federal Register 746(208): 66806-66844. http://www.nmfs.noaa.gov/pr/pdfs/fr/fr76-66806.pdf

National Oceanic Atmospheric Administration (NOAA). 1997. Impacts of California sea lions and Pacific harbor seals on Salmonids and on the coastal ecosystems of Washington, Oregon, and California.*in* U.S. Department of Commerce, editor. NOAA Technical Memorandum NMFS-NWFSC-28.

NOAA. 2008. Gulf of the Farallons National Marine Sanctuary Final Management Plan. Department of Commerce, NOAA, National Ocean Service, National Marine Sanctuaries Program, San Francisco, CA.

NOAA. 2013. Endangered and Threatened Species; Delisting of the Eastern Distinct Population Segment of Steller Sea Lion Under the Endangered Species Act; Amendment to Special Protection Measures for Endangered Marine Mammals. Federal Register 78(213):66140-66199.

NOAA. 2014. Gulf of the Farallones National Marine Sanctuary final management plan. NOAA, NOAA, Gulf of the Farallones National Marine Sanctuary, San Francisco, California. https://farallones.noaa.gov/manage/management_plan.html.

Najera-Hillman, E., P. King, A. Baird, and B. Breen. 2009. Effect of pest-management operations on the abundance and size-frequency distribution of the New Zealand endemic from *Leiopelma hochstetteri*. New Zealand Journal of Zoology 36:389-400.

Nathan, H. 2011. Population dynamics and behavior of a founder population of house mice. M.S. Thesis. Auckland Univeristy, Auckland, New Zealand.

New, M., D. Liverman, H. Schroder, and K. Anderson. 2011. Four degrees and beyond: the potential fora global temperature increase of four degrees and its implications. Philosophical Transactions of the Royal Society A 369:6-9.

Newman, D. 1994. Effects of a mouse, *Mus musculus,* eradication programme and habitat change on a lizard populations on Mana Island, New Zealand with special reference to McGregor's skink, *Cyclodina macgregori*. New Zealand Journal of Zoology 21:443-456.

Newton, K., M. McKown, C. Wolf, H. Gellerman, T. Coonan, D. Richards, A. L. Harvey, N. Holmes, G. Howald, K. Faulkner, B. R. Tershy, and D. A. Croll. 2016. Response of native species 10 years after rat eradication on Anacapa Island, California. Journal of Fish and Wildlife Management 7:72-85; e1944-687X. doi: 10.3996/082015-JFWM-073.

Nomura, N. 1977. Release rate of 14C-Diphacinone from bait to soil under high rainfall condtions. Unpublished reort, Hawaiian Sugar Planters.

North, S., D. Bullock, and M. Dulloo. 1994. Changes in the vegetation and reptile populations on Round Island, Mauritius, following eradication of rabbits. Biological Conservation 67:21-28.

Null, J. 1995. Climate of San Francisco. NOAA Technical Memorandum NWS WR-126. http://www.wrh.noaa.gov/mtr/sfd_sjc_climate/sfd/SFD_CLIMATE3.php.

Nur, N., R. Bradley, L. Salas, and J. Jahncke. 2013a. Modeling the impacts of house mouse eradication on Southeast Farallon Island. Unpublished report to the US Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1880.

Nur, N., A.L. Harvey, S.K. Thomsen, R. Bradley, and J. Jahncke. 2013b. Modeling the Population-level Impacts of Barn Owls on Scripps's Murrelet Population Trends on Santa Barbara Island. Unpublished report to the National Fish and Wildlife Foundation. Point Blue Conservation Science, Petaluma, California. PRBO contribution Number 1969.

Nur, N.,R.W. Bradley, D.E. Lee, P.M. Warzybok, and J. Jahncke. 2013c. Population viability analysis of Western Gulls on the Farallon Islands in relation to potential mortality due to proposed house mouse eradication. Unpublished report, PRBO Conservation Science, Petaluma, California.

Nur, N., R. W. Bradley, L. Salas, and J. Jahncke. 2018. Farallon Ashy Storm-Petrel population status evaluation. Final programmatic report narrative to the National Fish and Wildlife

Foundation, Pacific Seabird Program. Point Blue Conservation Science, Petaluma, California.

Nur, N., R W. Bradley, L. Salas, and J. Jahncke. In review. Evaluating population impacts of predation by owls on storm petrels in relation to proposed island mouse eradication. Submitted to Ecosphere.

O'Connor, C. and L. Booth. 2001. Palatability of rodent baits to wild house mice. Science for Conservation 184.

Ogilvie, S. C., R. J. Pierce, G. R. G. Wright, L. H. Booth, and C. T. Easton. 1997. Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. New Zealand Journal of Ecology 21:195-197.

Olson, S. 1989. Extinction on islands: man as a catastrophe.*in* D. Western and M. Pearl, editors. Conservation for the Twenty-first Century. Oxford University Press, New York.

Orazio, C., M. Tanner, C. Swenson, J. Herod, P. Dunlevy, and R. Gale. 2009. Results of laboratory testing for diphacinone in seawater, fish, invertebrates, and soil following aerial application of rodenticide on Lehua Island, Kauai County, Hawaii, January 2009. Report prepared by the US Geological Survey in cooperation with the US Fish and Wildlife Service, Region 1 Open-File Report 2009-1142.

Ornithological Council. 2010. The Rat Island rat eradication project: critical evaluation of nontarget mortality. Prepared for the USFWS, the Nature Conservancy, and Island Conservation. December 2010.

Pain, D. J., M. d. L. Brooke, J. K. Finnie, and A. Jackson. 2000. Effects of brodifaoum on the land crab of Ascension Island. The Journal of Wildlife Management 64:380-387.

Pank, L. 1976. Effects of seed and backround colors on seed acceptance by birds. Journal of Wildlife Management 40:769-774.

Parkes, J. 1990. Eradication of feral goats on islands and habitat islands. Journal of Royal Society of New Zealand 20:297-304.

Parkes, J., P. Fisher, and G. Forrester. 2011. Diagnosing the cause of failure to eradicate introduced rodents on islands: brodifacoum versus diphacinone and method of bait delivery. Conservation Evidence 8:100-106.

Parkes, J., D. Ramsey, N. Macdonald, K. Walker, S. McKnight, B. Cohen, and S. Morrison. 2010. Rapid eradication of feral pigs (*Sus scrofa*) from Santa Cruz Island, California. Biological Conservation 143:634-641.

Parmar, G., H. Bratt, R. Moore, and P. L. Batten. 1987. Evidence for common binding site in vivo for the retention of anticoagulants in rat liver. Human Toxicology 6:431-432.

Parrish, R. 2005. Pacific rat (*Rattus exulans*) eradication by poison-baiting from the Chicken Islands, New Zealand. Conservation Evidence 2.

Pascal, M., O. Lorvelec, V. Bretagnolle, and J. Culioli. 2008. Improving the breeding success of a colonial seabird: a cost-benefit comparison of the eradication and control of its rat predator. Endangered Species Research 4:267-276.

Pearson, O. 1963. History of two local outbreaks of feral house mice. Ecology 44:540-549.

Penniman, T., M. Coulter, L. Spear, and R. Boekelheide. 1990. Western gull. Pages 219-244 *in* D. Ainley and R. Boekelheide, editors. Seabirds of the Farallon Islands: Ecology, Dynamics, and Structure of an Upwelling-system Community. Stanford University Press, Stanford, CA.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Washington, DC.

Pickard, C. 1984. The population ecology of the house mouse (*Mus musculus*) on Mana Island. Victoria University, Wellington, New Zealand.

Pierotti, R. J. and C. A. Annett. 1995. Western gull (*Larus occidentalis*).*in* A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/174, Ithaca, NY.

Pierotti, R. J. and T. P. Good. 1994. Herring gull (*Larus argentatus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/124.

Pitt, WC, Berentsen AR, Shiels AB, Volker SF, Eisemann JD, Wegmann AS, et al. 2015. Non-target species mortality and the measurement of brodifacoum rodenticide residues after a rat (*Rattus rattus*) eradication on Palmyra Atoll, tropical Pacific. Biological Conservation185: 36-46.

Pitt, W., A. Berentsen, S. Volker, and J. Eisemann. 2012. Palmyra Atoll raiforest restoration project: monitoring results for the application of broadcast of brodifacoum 25W: conservation to eradicate rats. QA-1875 Final Report. USDA, APHIS, W, NWRC. Hilo, HI. 83 pp.

Pitt, W. C., L. C. Driscoll, and R. T. Sugihara. 2011. Efficacy of rodenticide baits for the control of three invasive rodent species in Hawaii. Archives of Environmental Contamination and Toxicology 60:533-542.

Pitt WC, Berentsen AR, Shiels AB, Voker SF, Eisemann JD, Wegmann AS and Howald GR. 2015. Non-target species mortality and the measurement of brodifacoum rodenticide residures after a rat (Rattus rattus) eradication on Palmyra Atoll, tropical Pacific. Biological Conservation. 185: 36 – 46.

Polis, G. and S. Hurd. 1996. Linking marine and terrestrial food webs: allochthonous input from the ocean supports high secondary productivity on small islands and coastal land communities. The American Naturalist 147:396-423.

Ponder, J. and F. Cunninghame. 2011. Proyecto Rabida: hawk mitigation report and future recommendations. Report prepared for Project Rabida rat eradication.

Pott, M. and D. Grout. 2012. Results of a Pilot Gull Hazing Trial on the Farallon Islands National Wildlife Refuge. Island Conservation, Santa Cruz, California, USA.

Preston, C. R. and R. D. Beane. 2009. Red-tailed hawk (*Buteo jamaicensis*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/052.

Primus, T., G. Wright, and P. Fisher. 2005. Accidental discharge of brodifacoum baits in a tidal marine environment: a case study. Bulletin of Environmental Contamination and Toxicology 74:913-919.

Pyle, P. and L. Gilbert. 1996. Occurrence patterns and trends of cetaceans recorded from Southeast Farallon Island, California, 1973 to 1994. Northwest Naturalist 77:1-8.

Pyle, P. and R. Henderson. 1991. The birds of Southeast Farallon Island: occurance and seasonal distribution of migratory species. Western Birds 22:41-48.

Pyle, P., D. Long, J. Schonewald, R. Jones, and J. Roletto. 2001. Historical and recent colonization of the South Farallon Islands, California, by northern fur seals (*Callorhinus ursinus)*. Marine Mammal Science 17:397-402.

Quammen, D. 1996. The Song of the Dodo: Island Biogeography in an Age of Extinctions. Hutchinson, London, UK.

Radvanyi, A., P. Weaver, C. Massari, D. Bird, and E. Broughton. 1988. Effects of chlorophacinone on captive kestrels. Bulletin of Environmental Contaminant Toxicology. 41:441-448.

Rasmussen, J. L., S. G. Sealy, and R. J. Cannings. 2008. Northern saw-whet owl (*Aegolius acadicus*). The Birds of North America Online (A. Poole, Ed.). Ithaca Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/042.

Rattner, B. A., K.E.Horak, S.E.Warner, and J.J.Johnston. 2010. Acute toxicity of diphacinone in Northern bobwhite: effects on survival and blood clotting. Ecotoxicology and Environmental Safety 73:1159-1164.

Rattner BA, Horak KE, Lazarus RS, Eisenrich KM, Meteyer CU, Volker SF, Campton CM, Eisemann JD, and Johnston JJ. 2012. Assessment of toxicity and potential risk of the anticoagulant rodenticide diphacinone using Eastern screech-owls. Ecotoxicology. 21: 832 – 846.

Rattner BA, Horak KE, Warner SE, Day DD, Meteyer CU, Volker SF, Eisemann JD, and Johnston JJ. 2011. Acute toxicity, histopathology, and coagulopathy in American kestrels (Falco sparverius) following adminstrations of the rodenticide diphacinone. Environmental Toxicology and Chemistry. 30(5): 1213 – 1222.

Rattner, BA., K. Horak, R. Lazarus, D. Goldade, and J. Johnston. 2014. Toxicokinetics and coagulopathy threshold of rodenticide diphacinone in Eastern screech-owls (Megascops asio). USDA National Wildlife Research Center, Staff Publication Paper 1406.

Raup, D. 1988. Diversity crises in the geological past. Pages 51-57 *in* E. Wilson, editor. Biodiversity. National Academy Press, Washington D.C.

Reed, A., D. H. Ward, D. V. Derksen, and J. S. Sedinger. 1998. Brant (*Branta bernicla*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/337.

Reilly SB, Corl A, Wake DB. 2015. An integrative approach to phylogeography: investigating the effects of ancient seaways, climate, and historical geology on multi-locus phylogeographic boundaries of the Arboreal Salamander (Aneides lugubris). BMC Evolutionary Biology15(1):241.

Reiter, J., N. L. Stinson, and B. J. L. Boeuf. 1978. Northern elephant seal development: the transition from weaning to nutritional independence. Behavioral Ecology and Sociobiology 3:337-367.

Rennison, B. and M. Hadler. 1975. Field trials of difenacoum against warfarin resistance infestations of *Rattus norvegicus*. Journal of Hygiene 74:449-455.

Richardson, T., P. Pyle, R. Burneff, and P. Capitolo. 2003. The occurence and seasonal distribution of migratory birds on Southeast Farallon Island, 1968-1999. Western Birds 34:58-96.

Richardson, W., J. Greene, C., C. Malme, and D. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA.

Ricketts, T., E. Dinerstein, T. Boucher, T. Brooks, S. Butchart, M. Hoffmann, J. Lamoreux, J. Morrison, M. Parr, J. Pilgrim, A. Rodrigues, W. Sechrest, G. Wallace, K. Berlin, J. Bielby, N. Burgess, D. Church, N. Cox, D. Knox, C. Loucks, G. Luck, L. Master, R. Moore, R. Naidoo, R. Ridgely, G. Schatz, G. Shire, H. Strand, W. Wettengel, and E.

Wikramanayake. 2005. Pinpointing and preventing imminent extinctions. PNAS 120:18497-18501.

Riegerix RC, Tanner M, Gale RW, and Tillitt DE. 2017. Acute toxicity of three anticoagulant rodenticides to various fish species. Poster presentation #312. Society of Environmental Toxicology and Chemistry – North America 38th Annual Meeting, Minneapolis, MN. November 12-16, 2017

Roberts, J. R., & J. R. Reigart. 2013. Recognition and management of pesticide poisonings. 6th Edition. EPA 735K13001, U.S. Environmental Protection Agency, Office of Pesticide Programs, Washington, DC. http://www2.epa.gov/pesticide-worker-safety.

Robertson HA and RM Colbourne. 2001.Survival of little spotted kiwi exposed to the rodenticide brodifacoum. The Journal of Wildlife Management. 65(1): 29-34.

Roemer, G., T. Coonan, D. Garcelon, J. Bascompte, and L. Laughrin. 2001. Feral pigs facilitate hyperpredation by golden eagles and indirectly cause the decline of the island fox. Animal Conservation 4:307-318.

Roletto, J., S. Kimura, N. Consentine-Manning, R. Berger, and R. Bradley. 2014. Status and trends of the rocky intertidal community on the Farallon Islands. Monographs of the Western North American Naturalist. 7:260-275.

Roletto, J., S. Kimura, G. Cox, and J. Steinbeck. 2015. Black abalone survey of the South Farallon Islands: Summary Report. Unpublished reported to NOAA, National Marine Fisheries Service, Office of Protected Resources; U.S. Fish and Wildlife Service; Farallon Islands National Wildlife Refuge; and NOAA, Office of National Marine Sanctuaries, Greater Farallones National Marine Sanctuary, San Francisco, CA.

Rolseth, S. L., C. E. Koehler, and R. M. R. Barclay. 1994. Differences in the diets of juvenile and adult hoary bats, *Lasiurus cinereus*. Journal of Mammalogy 75:394-398.

Ronconi, R. and C. St. Clair. 2006. Efficacy of radar-activated on-demand system for deterring waterfowl from oil sands tailings ponds. Journal of Applied Ecology. 43:111-119.

Ross, D B, N L Roberts, and C Fairley. 1980. "Brodifacoum: The Acute Oral Toxicity (LD50) of Brodifacoum to the Mallard Duck." MRID 415633-03.

Rowe-Rowe, D.T., B. Green, and J. Crafford. 1989. Estimated impact of feral house mice on sub-Antarctic invertebrates at Marion Island (Indian Ocean). Polar Biology 9:457-460.

RTECS. 1980. Registry of toxic effects of chemical substance. National Institute of Health 2:449.

Rueda, D., Campbell, K. J., Fisher, P., Cunninghame, F., & Ponder, J. B. (2016). Biologically significant residual persistence of brodifacoum in reptiles following invasive rodent eradication, Galapagos Islands, Ecuador. Conservation Evidence, 13, 38-38.

Rueda D., Carrion, V., Castaño, P.A., Cunninghame, F., Fisher, P., Hagen, E., Ponder, J.B., Riekena, C.A., Sevilla, C., Shield, H., Will, D., Campbell, K.J. (in press). Preventing extinctions: planning and undertaking invasive rodent eradications from Pinzon Island, Galapagos. In: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) Island Invasives: Scaling up to Meet the Challenge, pp. xx-xx. Gland, Switzerland: IUCN.

Ruscoe, W. 2001. Advances in New Zealand mammology 1990-2000: house mouse. Journal of the Royal Society of New Zealand 31:127-134.

Ruscoe, W. and E. Murphy. 2005. House mice.*in* C. King, editor. The handbook of New Zealand mammals (Second Edition). Oxford University Press, Auckland, New Zealand.

Russell, S. M. 1996. Anna's hummingbird (*Calypte anna*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/226.

Ryder, J. P. 1993. Ring-billed gull (*Larus delawarensis*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/033.

Samaniego, A. 2016. Mouse eradication on Midway Atoll: a review of the record. In Pacific Invasives Initiative (PII).

Samaniego-Herrera, A., J. Russell, D. Choquenot, A. Aguirre-Munoz, and M. Clout. 2014. Invasive rodents of tropical islands: eradication recommendations from Mexico. 26th Vertebrate Pest Conference, at UC Davis, CA.

Schmieder, R. 1992. Notes on a collecion of insects from the Southeast Farallon Island, California. Report to the Point Reyes Bird Observatory.

Scholz, A. and C. Steinback. 2006. Socioeconomic profile of fishing activities and communities associated with the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report to NOAA. Ecotrust, Portland, OR.

Seastedt, T. and D. Crossley. 1984. The influence of arthropods on ecosystems. BioScience 34:157-161.

Shae, E. L., G. Dolcemascolo, C. L. Anderson, A. Barnston, C. P. Guard, M. P. Hamnett, S. T. Kubota, N. Lewis, J. Loschnigg, and G. Meehl. 2001. Preparing for a changing climate: the potential consequences of climate variability and change. East-West Center, Honolulu, HI.

Shaffer, S.A., S. Cockerham, P. Warzybok, R.W. Bradley, J. Jahncke, C. A. Clatterbuck, M. Lucia, J.A. Jelincic, A.L. Cassell, E.C. Kelsey and J. Adams. 2017. Population-level plasticity in foraging behavior of western gulls *(Larus occidentalis*). Movement Ecology 5:27. DOI 10.1186/s40462-017-0118-9.

Sheils, A. 2010. Ecology and impacts of introduced rodents (*Rattus spp.* and *Mus Musculus*) in the Hawaiian Islands. University of Hawaii.

Shiels, A., G. Witmer, C. Sandra, R. Moulton, E. Ruell, J. O'Hare, J. Eisemann, S. Volker, and D. Goldade. 2017. Assessment of bait density, bait availability, and non-target impacts during an aerial application of rodenticide to eliminate invasive rats from Desecheo Island, Puerto Rico. Final Report QA-2588. USDA, APHIS, WS, NWRC, Ft. Collins, CO. 87 pp.

Shields, M. 2002. Brown pelican (*Pelecanus occidentalis*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/609.

Skeel, M. A. and E. P. Mallory. 1996. Whimbrel (*Numenius phaeopus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/219.

Skerratt, L. F., Berger, L., Speare, R. et al. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. EcoHeath: 4:125. DOI 10.1007/s10393-007-0093-5

Smallwood, J. A. and D. M. Bird. 2002. American kestrel (*Falco sparverius*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/602.

Smith, A. and D. Quin. 1996. Patterns and causes of extinction and decline in Australian conilurine rodents. Biological Conservation 77:243-267.

Smith, E. M. and F. H. Pough. 1994. Intergeneric aggression among salamanders. Journal of Herpetology 28:41-45.

Smith, V. R. 2008. Energy flow and nutrient cycling in the Marion Island terrestrial ecosystem: 30 years on. Polar Record 44:211-226.

Soldatini, C., Y. Albores-Barajas, P. Torricelli, and D. Mainardi. 2008. Testing the efficacy of deterring systems in two gull species. Appied Animal Behavior Science. 110:330-340.

Spurr, E. B. 1996. Environmental effects of rodent Talon® baiting. Part II: Impacts on invertebrate populations. Science for Conservation: 38, New Zealand Department of Conservation, Wellington, NZ.

St Clair, J.J.H. 2011. The impacts of invasive rodents on island invertebrates. Biological Conservation 144: 68–81.

Stahmann, M., C. Huebner, and K. Link. 1941. Studies on the hemorrhagic sweet clover disease vs. identification and synthesis of hemorrhagic agent. Journal of Biological Chemistry 138:512-527.

State Water Resources Control Board. 2003. Areas of Special Biological Significance: California's marine state water quality protection areas. Page 37. Division of Water Quality and Office of Legislature and Public Affairs, Sacramento, CA.

Stebbins, R. 1951. Amphibians of Western North America. University of California Press, Berkeley, CA.

Steiner, J. 1989. Temporal and spatial distribution of the camel cricket, *Farallonophilus cavernicola* Rentz (Orthoptera: Gryllacrididae), on Southeast Farallon Island, California. Pan-Pacific Entomologist 65:429-435.

Stevens, G., J. Rogue, R. Weber, and L. Clark. 2000. Evaluation of a radar-activated, demand-performance bird hazing system. International Biodeterioration and Biodegradation. 45:129-137.

Stewart, S., P. Yochem, H. Huber, R. DeLong, R. Jameson, W. Sydeman, S. Allen, and B. Le Boeuf. 1994. History and present status of the northern elephant seal population.*in* B. Le Boeuf and R. Laws, editors. Elephant Seals: Population Ecology, Behavior and Physiology. University of California Press, Berkeley, CA.

Suchanek, T. H., M. C. Lagunas-Solar, O. G. Raabe, R. C. Helm, F. Gielow, N. Peek, and O. Carvacho. 1996. Radionuclides in fishes and mussels from the Farallon Islands Nuclear Waste Dump Site, California. Health Physics 71:167-178.

Swanson, K. A. 2008. The cost of doing business: corporate vicarious criminal liability for the negligent discharge of oil under the Clean Water Act. Washington Law Review 84:555-579.

Swift, C. 1998. Laboratory bioassays with wild-caught roof (Rattus rattus) and Plynesian (R. exulans) rats to determine minium amounts of Ramik Green (0.005% diphacinone) and exposure times for field broadcast applications in Hawaii. University of Hawaii, Manoa, Honolulu, HI.

Sydeman, W. and S. Allen. 1997. Trends an oceanographic correlates of pinniped populations in the Gulf of the Farallones, California. Report to NMF, Southwest Fisheries Science Center. Point Reyes Bird Observatory and NPS (Point Reyes National Seashore), Stinson Beach, CA and Point Reyes, CA.

Sydeman, W., R. Bradley, P. Warzybok, C. Abraham, J. Jahncke, K. Hyrenbach, V. Kousky, J. Hipfner, and M. Ohman. 2006. Planktivorous auklet *Ptychoramphus aleuticus* responses to ocean climate, 2005: unusual atmospheric blocking. Gephysical research letters 33.

Sydeman, W., K. Mills, J. Santora, and L. Thompson. 2009. Seabirds and climate in the California Current; a synthesis of change. In CalCOFI Rep. 50, pp. 82–104. La Jolla, CA: Calif. Coop. Ocean. Fish. Investig.

Sydeman, W. J. and S. G. Allen. 1999. Pinniped population dynamics in central California: correlations with sea surface temperature and upwelling indices. Marine Mammal Science 15:446-461.

Syngenta Crop Protection, I. 2003. Materials Safety Data Sheet for Weatherblock XT (brodifacoum 50 ppm). Greensboro, NC.

Tasheva, M. 1995. Anticoagulant rodenticides. World Health Organization, Geneva.

Taylor, R.H. 1993. The feasibility of rat eradication on Langara Island, British Columbia, Canada. Report to the Canadian Wildlife Service, Ottawa, ON. 30 pp.

Tenera Environmental and Gulf of the Farallones National Marine Sanctuary. 2012. Farallon Islands intertidal characterization. Unpublished report, Tenera Environmental, San Luis Obispo, CA and Gulf of the Farallones National Marine Sanctuary, San Francisco, CA.

Tershy, B. and D. Breese. 1994. Color preference of the island endemic lizard *Uta palmeri* in relation to rat eradication campaigns The Southwest Naturalist 39:295-297.

Tershy, B., D. Breese, M. Angeles, M. Cervantes, M. Mandujano, E. Hernandez, and A. Cordaba. 1992. Natural history and management of Isla San Pedro Martir, Gulf of California, Mexico. Unpublished report to Conservation International.

Tietz, J. 2013a. Bird migration report on Southeast Farallon Island: totals and analyses for the fall season 2012. Unpublished report to the U.S. Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1799.

Tietz, J. 2013b. Pinniped surveys on West End Island. Farallon Islands National Wildlife Refuge 2012. Unpublished Report to the U.S. Fish and Wildlife Service. PRBO Conservation Science, Petaluma, California. PRBO Contribution Number 1923.

Thomas, P. J., Mineau, P., Shore, R. F., Champoux, L., Martin, P. A., Wilson, L. K., & Elliott, J. E. 2011. Second generation anticoagulant rodenticides in predatory birds: probabilistic characterisation of toxic liver concentrations and implications for predatory bird populations in Canada. Environment International, 37(5), 914-920.

Tillmann, P. and D. Siemann. 2011. Climate change effects and adaptation approaches in marine and coastal ecosystems of the North Pacific Landscape Conservation Cooperative Region: a compilation of scientific literature. National Wildlife Federation Phase 1 Draft Final Report, August 2011.

Timm, R. 1994. Norway rats. Pages 105-120 *in* S. Hygnstrom, R. Timm, and G. Larson, editors. Prevention and Control of Wildlife Damage. University of Nebraska, Lincoln, NE.

Tobin, M. and M. Fall. 2005. Pest control: Rodents In: Agricultural Sciences, encyclopedia of Life Support Systems (EOLSS), developed under the auspices of the UNited Nations Educational, Scientific, and Cultural Organization. EOLSS publishers, Oxford, UK, http://www.eolss.net.

Towns, D. 1991. Response of lizard assemblages in the Mercury Islands, New Zealand, to removal of an introducedrodent, the kiore (*Rattus exulans)*. Journal of the Royal Society of New Zealand 21:119-136.

Towns, D. and C. Dougherty. 1994. Patterns of range contractions and extinctions in the New Zealand herpetofauna following human colonisation. New Zealand Journal of Zoology 21:325-339.

Towns, D. R., C. H. Daugherty, and A. Cree. 2001. Raising the prospects for a forgotten fauna: a review of 10 years of conservation effort for New Zealand reptiles. Biological Conservation 99:3-16.

Triggs, G. 1991. The population ecology of house mice *Mus domesticus* on the Isla of May, Scotland. Journal of Zoology 225:449-468.

U.S. Environmental Protection Agency (USEPA). 1998. Reregistration eligibility decision (RED): Rodenticide cluster. Prevention, Pesticide and Toxic Substances (7508W).

USEPA. 2008. Risk mitigation decision for ten rodenticides. U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Washington, DC.

U.S. Fish and Wildlife Service (USFWS). 2005a. Farallon Islands National Wildlife Refuge Annual Narrative Report. U.S. Fish and Wildlife Service, SF Bay NWR Complex, Freemont, CA.

USFWS. 2005b. Regional Seabird Conservation Plan, Pacific Region U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, Portland, OR.

USFWS. 2006. Peregrine Falcon (*Falco peregrinus*): Fact Sheet. US Fish and Wildlife Service, May 2006.

USFWS. 2008. Birds of Conservation Concern 2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp. [Online version available at <http://www.fws.gov/migratorybirds/>]

USFWS. 2009. Farallon Islands National Wildlife Refuge Final Comprehensive Plan. U.S. Fish and Wildlife Service, SF Bay NWR Complex, Newark, CA.

USFWS. 2010. Migratory bird permits for controlling invasive species, FWS/AMB/BMBM/043727. Washington, D.C.

USFWS. 2013. Potential best management practices for rodent eradication projects. Unpublished Report from the USFWS, Alaska Region. April 29, 2013.

USFWS. 2015. Memorandum of Understanding between USFWS and Island Conservation. Signed April 16, 2015.

USFWS. 2017. Final Environmental Assessment for the Lehua Island Ecosystem Restoration Project. 179 pp.

USFWS. 2018. Midway Seabird Protection Project: Draft Environmental Assessment: Sand Island, Midway Atoll, Papahanaumokuakea Marine National Monument. U.S. Fish and Wildlife Service, Papahanaumokuakea Marine National Monument, Honolulu, Hawaii. 198 pp.

U.S. National Park Service (USNPS). 2000. Anacapa Island restoration projects, final Environmental Impact Statement. Ventura, California.

Valdez, E. W. and P. M. Cryan. 2009. Food habits of the hoary bat (*Lasiurus cinerus)* during spring migration through New Mexico. The Southwestern Naturalist 54:195-200.

Valentine, N. 2000. Foundation removal for habitat enhancement, Farallon NWR. Report to USFWS.

Van Denburgh, J. 1905. The reptiles and amphibians of the islans of the Pacific Coast of North America form the Farallones to Cap San Lucas and the Revilla Gigedos. Proceedings of the California Academy of Science IV 1:1-38.

Van den Berg, G and Nauta W. 1975. Effects of anti-inflammatory 2-aryl-1,3,-indandiones on oxidative phosphorylation in rat liver mitochondria. Biochemical Pharmacology. 24: 815 - 821

Vasey, M. 1985. The specific status of *Lasthenia maritima* (Asteraceae), an endemic to seabird-breeding habitats. Madrono 32:131-142.

Veit, R., P. Pyle, and J. McGowan. 1996. Ocean warming and long-term change in pelagic bird abundance within the California Current System. Marine Ecological Progress 139:11-18.

Veitch, C., M. Clout, and D. Towns (eds.). 2011. Island invasives: eradication and management.*in* Proceedings of the International Conference of Island Invasives, Gland, Switzerland: IUCN and Auckland, New Zealand: CBB. xii + 542pp.

Vennum, W., J. Dunning, R. Leu, B. Anderson, and K. Bergk. 1994. Unusual phosphate minerals and diatom-bearing stalactites from the Farallon Islands. California Geology 47:76-83.

Verbeek, N. A. and P. Hendricks. 1994. American pipit (*Anthus rubescens*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/095.

Vredenburg, V. T., R. A. Knapp, T. S. Tunstall, and C. J. Briggs. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences 107:9689-9694.

Wake, D. B. and J. Hanken. 1996. Direct development in the lungless salamanders: what are the consequences for developmental biology, evolution and phylogenesis? International Journal of Developmental Biology 40:859-869.

Wake, T. and A. Graesch. 1999. Surface archaeology of Southeast Farallon Island, California: Preliminary report on the 1998 season. Unpublished report to USFWS.

Walker, A. 2010. Ipipiri Rodent Eradication Operation 2009 Monitoring Report – Post Operational Report. Department of Conservation internal report DOCDM-483696 prepared as a requirement of Resource Consent CON20082006901 issued by Northland Regional Council. 38p.

Wanless, R., A. Angel, R. Cuthbert, G. Hilton, and P. Ryan. 2007. Can predation by invasive mice drive seabird extinctions? Biology Letters 3:241-244.

Wanless, R., P. Fisher, J. Cooper, J. Parkes, P. Ryan, and M. Slabber. 2008a. Bait acceptance by house mice: an island field trial. Wildlife Research 35:806-811.

Wanless, S., M. Harris, S. Lewis, M. Frederiksen, and S. Murray. 2008b. Later breeding in northern gannets in the eastern Atlantic. Marine Ecology Progress Series 370:263-269.

Warkentin, I. G., N. S. Sodhi, R. H. M. Espie, A. F. Poole, L. W. Oliphant, and P. C. James. 2005. Merlin (*Falco columbarius*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/044.

Warzybok, P., R. Bradley, and W. Sydeman. 2003. Population size and reproductive performance of seabirds on Southeast Farallon Island, 2003. Report to the US Fish and Wildlife Service. Farallon Islands National Wildlife Refuge.

Warzybok, P. and R. Bradley. 2011. Status of seabirds on Southeast Farallon Island during the 2011 breeding season. PRBO Conservation Science. Petaluma, CA..

Warzybok, P. and R. Bradley. 2012. Status of seabirds on Southeast Farallon Island during the 2012 breeding season. PRBO Conservation Science. Petaluma, CA.

Warzybok, P., R. Bradley, D. Grout, R. Griffiths, M. Pott, W. Vickers, D. Milsaps, and G. McChesney. 2013. Evaluating the use of non-lethal hazing techniques to minimize

potential exposure of Western Gulls to rodenticide from a proposed rodent eradication on the South Farallon Islands. Unpublished report to the Oiled Wildlife Care Network, Point Blue Conservation Science, Petaluma, California, and Island Conservation, Santa Cruz, California.

Warzybok, P.M., R. Berger, and R.W. Bradley. 2016. Population size and reproductive performance of seabirds on Southeast Farallon Island, 2016. Unpublished report to the U.S. Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California.

Warzybok, P.M., M. Johns, and R.W. Bradley. 2018. Population size and reproductive performance of seabirds on Southeast Farallon Island, 2017. Unpublished report to the U.S. Fish and Wildlife Service. Point Blue Conservation Science, Petaluma, California.

Warzybok, P., R.W. Bradley, D. Grout, T.W. Vickers, R. Griffiths, and G.J. McChesney. Submitted. Hazing effectiveness of a large gull colony during the non-breeding season. Submitted to The Wildlife Society Bulletin.

Webster, K. H., Harr, K. E., Bennett, D. C., Williams, T. D., Cheng, K. M., Maisonneuve, F., & Elliott, J. E. 2015. Assessment of toxicity and coagulopathy of brodifacoum in Japanese quail and testing in wild owls. Ecotoxicology, 24(5), 1087-1101.

Wegmann, A. 2011. Palmyra Atoll restoration project: calibration for aerial broadcast alternatives b and c. Island Conservation, Santa Cruz, California, USA.

Wegmann AS, Flint E, White S, Fox M, Howald G, McClelland P, et al. 2012. Pushing the envelope in paradise: a novel approach to rat eradication at Palmyra Atoll. Proceedings of the 25th Vertebrate Pest Conference; Monterey, California, USA. University of California, Davis. pp. 48–53.

Weldon, G., P. Fisher, and A. Fairweather. 2011. Brodifacoum: a review of current knowledge. Part 6 Department of Conservation pesticide information review series. New Zealand.

Weng, K., A. Boustany, P. Pyle, S. Anderson, A. Brown, and B. Block. 2007. Migration and habitat of white sharks (*Carcharadon carcharia*s) in the eastern Pacific Ocean. Marine Biology 152:877-894.

Whitaker, J. O., Jr. , C. Neefus, and T. H. Kunz. 1996. Dietary variation in the Mexican free-tailed bat (*Tadarida brasiliensis mexicana*). Journal of Mammalogy 77:716-724.

White, C. M., N. J. Clum, T. J. Cade, and W. G. Hunt. 2002. Peregrine falcon (*Falco peregrinus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/660.

White, G. and K. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.

White, P. 1995. The Farallon Islands: Sentinals of the Golden Gate. Scottwall Associates, San Francisco, CA.

Whittaker, R. 1998. Island Biogeography: Ecology, Evolution and Conservation. Oxford University Press, Oxford, New York.

Wiggins, D. A., D. W. Holt, and S. M. Leasure. 2006. Short-eared owl (*Asio flammeus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/062.

Wiles, G., J. Bart, R. B. Jr, and C. Aguon. 2003. Impacts of the brown tree snake: patterns of decline and species persistence in Guam's avifauna. Conservation Biology 17:1350-1360.

Williams, B., R. Szaro, and C. Shapiro. 2009. Adaptive Management: The U.S. Department of Interior technical guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington D.C.

Wilson, D. E. and S. Ruff. 1999. The Smithsonian Book of North American Mammals. Smithsonian Institution Press, Washington, DC.

Winkler, D. W. 1996. California gull (*Larus californicus*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/259.

Witmer, G. 2007. Efficacy of commercially available rodentacide baits for the control of wild house mice. Final Report QA-1304. USDA/APHIS/WS National Wildlife Research Center, Fort Collins, CO.

Witmer, G. 2018. An assessment of the potential hazards of anticoagulant rodenticides to *Plethotontid* salamanders. Final Report QA-2688. USDA/APHIS/WS National Wildlife Research Center, Fort Collins, CO. A Report for the USFWS, Farallon Islands National Wildlife Refuge.

Witmer, G. and S. Jojola. 2006. What's up with house mice? A review.*in* Proceedings of the 22nd Vertabrate Pest Conference, University of California, Davis.

Witmer, G., K. Horak, and R. Moulton. 2014. New rodenticides: an update on recent research trials. Proceedings of the Wildlife Damage Management Conference 15: 79-85.

Wolf, B. O. 1997. Black phoebe (*Sayornis nigricans*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/268.

Wolf CA, Young HS, Zilliacus KM, Wegmann AS, McKown M, Holmes ND, et al. 2018. Invasive rat eradication strongly impacts plant recruitment on a tropicalatoll. PLoS ONE 13(7): e0200743. https://doi.org/10.1371/journal.pone.0200743.

World Conservation Monitoring Centre. 1992. Global Biodiversity: Status of the Earth's Living Resources. Chapman & Hall, London.

World Health Organization. 1995. Anticoagulant Rodenticides. World Health Organization, Geneva.

Wright, A. L., G. D. Hayward, S. M. Matsuoka, and P. H. Hayward. 1998. Townsend's warbler (*Dendroica townsendi*). The Birds of North America Online (A. Poole, Ed.). Ithaca. Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/333.

Yap, T.A., L. Gillespie, S. Ellison, S.V. Flechas, M.S.. Koo, A E. Martinez, and V.T. Vredenburg. 2015. Invasion of the fungal pathogen *Batrachochytrium dendrobatidis* on California Islands. EcoHealth; DOI: 10.1007/s10393-015-1071-y.

7 Index

aerial broadcast, v, viii, xv, xvi, 50, 37, 42, 43, 49, 50, 54, 62, 64, 69, 75, 82, 84, 86, 87, 132, 134, 135, 136, 137, 197, 229, 232, 256, 259, 281, 298
Alternative, v, viii, xii, xiii, xv, xvi, xvii, xix, 4, 21, 30, 31, 41, 49, 50, 52, 64, 70, 72, 82, 84, 86, 87, 131, 132, 133, 134, 135, 136, 137, 138, 142, 161, 162, 163, 165, 167, 197, 200, 229, 232, 233, 234, 235, 236, 238, 253, 255, 256, 257, 258, 259, 260, 262
anticoagulant, vii, xii, 3, 37, 38, 39, 40, 41, 48, 52, 54, 61, 70, 73, 82, 84, 85, 149, 152, 153, 155, 156, 226, 273, 274, 276, 281, 291, 292, 295, 299
anticoagulants, 20, 36, 37, 38, 39, 40, 52, 70, 155, 156, 282, 289
ashy storm-petrel, vi, viii, xviii, 2, 3, 4, 5, 9, 11, 12, 14, 15, 17, 55, 59, 70, 90, 97, 98, 99, 100, 102, 104, 105, 137, 138, 143, 144, 161, 172, 185, 205, 217, 218, 233, 246, 250, 268, 272, 277, 288
Brodifacoum, v, viii, xii, xiii, xv, xvi, xvii, xviii, 30, 31, 32, 37, 38, 39, 40, 41, 42, 43, 44, 48, 49, 50, 52, 54, 61, 64, 70, 72, 82, 86, 84, 87, 131, 132, 134, 135, 136, 137, 146, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 197, 200, 224, 226, 227, 228, 232, 233, 234, 235,236, 237, 256, 272, 275, 278, 280, 281, 283, 285, 286, 287, 289, 290, 292, 295, 298
burrowing owls, vi, 2, 4, 5, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 46, 47, 73, 74, 79, 101, 104, 109, 143, 144, 172, 173, 205, 236, 246
climate change, vi, vii, 5, 14, 56, 90, 91, 99, 242, 243, 248, 250, 251, 252, 253, 254, 256, 257, 258, 259, 260, 261, 262, 276, 280, 283, 284, 287, 295
Comprehensive Conservation Plan
CCP, vii, xix, 3, 4, 25, 32
Control, xii, 24, 33, 34, 44, 46, 94, 110, 132, 133, 249, 265, 273, 274, 276, 277, 278, 279, 294, 295
Diphacinone, v, viii, xiii, xv, xvi, xvii, xviii, 20, 21, 30, 31, 32, 36, 37, 38, 39, 40, 41, 42, 44, 50, 52, 54, 61, 64, 70, 72, 84, 85, 86, 87, 131, 132, 133, 135, 137, 138, 146, 147, 148, 150, 151, 152, 153, 154, 155, 156, 157, 162,165, 166, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 232, 233, 234, 235, 238, 259, 269, 272, 280, 281, 282, 284, 285, 288, 289, 294, 294
EIS, i, v, vii, viii, xi, xx, 3, 4, 18, 19, 21, 22, 23, 24, 31, 32, 43, 44, 77, 136, 264, 267, 268, 269
eradication, v, vi, vii, 3, 5, 7, 8, 14, 15, 18, 19, 20, 21, 24, 25, 26, 27, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 53, 54, 55, 56, 57, 58, 59, 60, 62, 63, 64, 66, 67, 68, 69, 71, 72, 73, 74, 76, 77, 78, 79, 80, 81, 84, 85, 86, 87, 91, 108, 122, 123, 131, 132, 133, 137, 138, 139,140, 141, 145, 146, 147, 148, 150, 151, 152, 153, 156, 157, 162, 163, 165, 166, 168, 169, 170, 171, 172, 173, 186, 189, 190, 191, 192, 193, 194,195, 196,, 201, 202, 203, 204, 205, 218, 222, 223, 224, 225, 226, 227, 228, 232, 233, 234, 252, 255, 256, 261, 262, 263, 267, 268, 275, 276, 277, 278, 279, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 292, 293, 295, 296, 297, 298, 299
Eradication, i, iii, v, xi, xii, xv, xviii, xix, 5, 33, 36, 42, 47, 138, 275, 279, 281, 283, 287, 289, 297
Farallon Islands, v, vi, vii, viii, xi, xviii, 2, 3, 4, 5, 9, 10, 14, 18, 19, 21, 22, 25, 26, 30, 35, 40, 43, 45, 46, 47, 49, 52, 53, 58, 59, 60, 62, 65, 69, 70, 71, 72, 79, 80, 90, 95, 96, 98, 99, 100, 101, 109, 110, 114, 115, 117, 118, 119, 123, 135, 138,139, 140, 142, 144, 153, 156, 159, 160, 161,

162, 165, 166, 167, 185, 186, 200, 217, 218, 232, 233, 234, 239, 242, 243, 244, 251, 252, 253, 254, 255, 256, 258, 259, 261, 262, 281, 282, 284, 288, 290, 294, 295
Farallon Islands National Wildlife Refuge, i, v, vi, vii, xx, 2, 4, 25, 32, 81, 91, 96, 97, 120, 129, 157, 269, 273, 283, 292, 295, 296, 297, 299
FEIS, viii, xix, xx, 3, 4, 19, 21, 35, 42, 47, 52, 138, 141, 142, 149, 150, 157,235,267
house mouse, i, iii, v, vii, xi, xii, xviii, xix, 3, 4, 6, 7,12, 14, 35, 36, 37, 41, 42, 47, 48, 49, 51, 52, 57, 91, 138, 139, 143, 144, 145239, 273, 274, 281, 282, 287, 288, 290, 292
Hyperpredation, xi, 8, 9, 10, 11, 13, 14, 236, 278, 287, 292
Impacts, v, vii, viii, ix, xi, xiii, xv, xvi, xvii, xviii, xix, 2, 4, 5, 7, 9, 10, 12, 13, 14, 15, 16, 18, 19, 20, 21, 26, 27, 28, 30, 32, 33, 34, 40, 41, 44, 45, 46, 47, 53, 55,56, 57, 58, 68, 71, 72, 74, 75, 76, 77, 78, 79, 80, 81, 90, 91, 94, 96, 97, 99, 106, 110,122, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 144, 145, 146, 147, 148, 151, 154, 155, 157, 158, 159, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175,176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 19, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 246, 248, 249, 250, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 266, 268, 269, 273, 278, 280, 284, 287, 288, 289, 293, 294, 298, 299
invasive, i, iii, iv, v, vi, vii, viii, xi, xx, 3, 4, 5, 6, 7, 8, 9, 10 13, 14, 18, 19, 22, 23, 25, 26, 30, 32, 33, 36, 37, 40, 54, 55, 56, 82, 91, 97, 99, 109 ,119, 128, 142, 146, 150, 239, 248, 249, 252, 254, 255, 258, 259, 260, 261, 262, 264, 273, 274, 276, 278, 279, 281, 282, 283, 285, 286, 287, 292, 293, 294, 296, 297, 299
lessons learned, viii, xi, xv, 3, 19, 20, 31,42, 43, 44, 53, 138, 139, 268
NEPA, v, xx, 21, 26, 30, 34, 55, 77, 128, 139, 232, 239, 264, 267
Notice of Intent, vii, 26, 267
Pinnipeds, 25, 27, 28, 50, 53, 58, 59, 60, 64, 66, 71, 74, 75, 80, 90, 97, 111, 116, 118, 119, 121, 135, 136, 137, 144, 148, 161, 162, 163, 188, 189, 190, 198, 221, 222, 230, 233, 237, 238, 244, 247, 251, 252, 276
Point Blue, 4, 12, 14, 19, 28, 59, 79, 81, 90, 91, 92, 93, 97, 98, 101 ,103, 104, 105, 106, 107, 108, 109, 110, 115, 116, 117, 118, 120, 122, 126, 143, 145, 156, 158, 165, 170, 202, 220, 240, 242, 244
POINT BLUE CONSERVATION SCIENCE, POINT BLUE, vi, xxi, 244, 266, 270, 288, 289, 298
Salamanders, vi, viii, xi, xiii, xiv, 3, 5, 13, 18,54, 55, 74, 78, 79, 91, 105, 106, 107, 136, 137, 144, 145, 148, 150, 151, 190, 191, 198, 223, 224, 230, 240, 241, 247, 252, 254, 257, 260, 261, 262, 273, 278, 289, 294, 297, 299
Steller sea lion, xiv, 59, 71, 117, 142, 188, 199, 221, 231, 239, 247, 274, 282, 287, 288
Structured Decision Making, vii, xxi, 32