U.S. Fish & Wildlife Service

Farallon National Wildlife Refuge

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

Photos Courtesy of Island Conservation

United States Department of the Interior

FISH AND WILDLIFE SERVICE
San Francisco Bay National Wildlife Refuge Complex
1 Marshlands Road
Fremont, California 94555

Dear Reader:

The U.S. Fish and Wildlife Service (Service) released a Draft Environmental Impact Statement (DEIS) for the South Farallon Islands Invasive House Mouse Eradication Project, Farallon National Wildlife Refuge, California, on August 16th, 2013, for public review and comment pursuant to the National Environmental Policy Act. During that original 45-day public comment period, ending on September 30th, 2013, the Service decided to issue a Revised Draft Environmental Impact Statement (Revised DEIS) in order to modify language that clarifies our scientific review of possible impacts to seabirds. This Revised DEIS does not modify, add, or delete any alternatives from the former DEIS. As a quick reference, the following sections were edited:

Title Page

- ✓ Changed title to "Revised" DEIS.

Public Comment Period

- ✓ Updated public comment period to October 11-November 25, 2013.

1.2.2.2 Detailed Analysis of House Mouse Impacts on Storm-Petrels

- ✓ Paragraph 1: Clarified language on burrowing owl predation to ashy storm-petrels.

1.2.2.2 Detailed Analysis of House Mouse Impacts on Storm-Petrels

- ✓ Paragraph 3: Corrected estimates from Bradley et al. (2011) of numbers of ashy storm-petrels depredated by BUOW each year and clarified interpretation of burrowing owl impacts to ashy storm-petrels from Nur et al. (2013).

1.2.3 Direct impacts of mice on storm-petrels

- ✓ Paragraph 1: Clarified Ainley et al. (1990d) report of mouse predation and its potential impacts to ashy storm-petrel chicks.

4.2.3.1 Significance Thresholds by Impact topic

- **Biological Resources**
  Plants and Animal Species
  - ✓ Clarified meaning of "population level" to plants and animal species.

4.5.2 Assessing Significance of Impacts to Biological Resources

- ✓ Paragraph 1: Clarified meaning of "population level."
- ✓ Paragraphs 4-5: Clarified how significance determinations were done by examining

potential impacts to both local and range-wide populations.

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

4.5.3.2.1 Impacts to breeding seabirds

- ✓ Paragraph 2: Indicated that for house mouse impacts we are referring to the South Farallon Islands.
- ✓ Paragraph 3: For the significance determination for seabirds under Alternative A, provided more detailed description of Nur et al. (2013) study on impacts of mice and burrowing owls on Farallon ashy storm-petrels. Also we modified the significance finding for the ashy storm-petrel to indicate that the impact of Alternative A would be significant to the South Farallon Islands population, not the range-wide population.

4.5.6.1 Impacts of Alternative B on Biological Resources: Aerial Brodifacoum

*4.5.6.1.1.7 Seabird*s

- **Cassin's Auklet, Ashy Storm-petrel, Leach's Storm-petrel**
- ✓ ***Significance Determination***, paragraph 1: Clarified the reasons for the significance determination for ashy and Leach's storm-petrels under Alternative B.

4.5.6.2 Impacts of Alternative C on Biological Resources: Aerial Diphacinone

*4.5.6.2.1.7 Seabird*s

- **Cassin's Auklet, Ashy Storm-petrel, Leach's Storm-petrel**
- ✓ ***Significance Determination***, paragraph 1: Clarified the reasons for the significance determination for ashy and Leach's storm-petrels under Alternative C.

4.7 Unavoidable Adverse Impacts

4.7.1 Alternative A: No Action

Biological Resources

- Birds
- ✓ Bullet 1: Changed "long-term" impacts to "ongoing" impacts to ashy and Leach's storm-petrel populations.

4.8.7 Summary of Cumulative Impacts Under Alternative A (No Action)

4.8.7.1 Summary of Combined Affects with Alternative A

- ✓ Paragraph 1: Rephrased certain sentences to more simply describe that future impacts of mouse presence on Farallon ashy storm-petrels is unclear but that reducing the numbers of overwintering burrowing owls (which is inflated by mouse presence) on the Farallones will likely have benefits for the Farallon ashy storm-petrel population.

Biological Resources

- Birds
- ✓ Bullet 1: Clarified language regarding potential future projects to benefit seabirds on the South Farallon Islands and on potential cumulative impacts to ashy and Leach's storm-petrels under Alternative A.

4.8.8 Summary of Cumulative Impacts under Alternatives B

4.8.8.1 Summary of Combined Affects with Alternative B

Biological Resources

- Birds
- ✓ Bullet 1, sentence 5: Added language to indicate that under Alternative B, long-term impacts to ashy and Leach's storm-petrels are likely to "partially" offset the "potential" long-term negative effects to these birds from climate change.

4.8.9 Summary of Cumulative Impacts under Alternatives C

4.8.9.1 Summary of Combined Affects with Alternative C

Biological Resources

- Birds
- ✓ Bullet 1, sentence 5: Added language to indicate that under Alternative B, long-term impacts to ashy and Leach's storm-petrels are likely to "partially" offset the "potential" long-term negative effects to these birds from climate change.

4.9 Irreversible and Irretrievable Impacts

4.9.1 <u>Alternative A</u>

- ✓ Clarified language to better reflect the currently known impacts of burrowing owl predation on ashy and Leach's storm-petrels.

Please note that if you previously submitted comments on the former DEIS, you do not need to resubmit them because they have already been incorporated into the public record and will be fully considered during the preparation of the Final EIS.

Revised Draft 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

October 2013

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

August 2013

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 ashy storm-petrels (*Oceanodroma homochroa*), other native species, and the ecosystem of the Farallon National Wildlife Refuge. In accordance with the National Environmental Policy Act (NEPA) and its associated regulations, the Service has prepared this Revised Draft 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: 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 is soliciting comments from the interested public on this Revised Draft EIS. If no substantial issues are identified, and public comments do not warrant major changes in the proposed action, the Service would then issue a Final EIS and a Record of Decision (ROD).

Public Comment Period

Dates:*October 25, 2013 through December 9, 2013*

Comment Submissions: We will accept comments received or postmarked on or before December 9, 2013. Comments submitted electronically using the Federal eRulemaking Portal (see Adresses section, below) must be received by 11:59 p.m. Eastern Time on the closing date.

ADDRESSES:

- Document Availability: You may obtain copies of the documents in the following places:
  - *Internet:*
    - http://www.regulations.gov (Docket Number FWS–R8–NWRS–2013–0036)
  - *In-Person:*
    - San Francisco Bay National Wildlife Refuge Complex Headquarters, 1 Marshlands Road, Fremont, CA 94555.
    - The following library:
      - San Francisco Public Library, 100 Larkin Street, San Francisco, CA 94102.

- Submitting Comments: You may submit written comments by one of the following methods:
  - *Electronically:*
    - Go to the Federal eRulemaking Portal: http://www.regulations.gov. In the Search box, enter FWS–R8–NWRS–2013–0036, which is the docket number for this notice. Then, on the left side of the screen, under the Document Type heading, click on the Notices link to locate this document and submit a comment.
  - *By hard copy:*
    - Submit by U.S. mail or hand-delivery to: Public Comments Processing, Attn: FWS–R8–NWRS–2013–0036; Division of Policy and Directives Management; U.S. Fish and Wildlife Service; 4401 N. Fairfax Drive, MS 2042–PDM; Arlington, VA 22203.

- We request that you send comments only by the methods described above. We will post all information received on http://www.regulations.gov. This generally means that we will post any personal information you provide us.

FOR FURTHER INFORMATION CONTACT:
Gerry McChesney, Refuge Manager
510–792–0222, ext. 222 (phone).

Executive Summary

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

The benefits of house mouse eradication would be greatest to two seabird species that are impacted by the presence of invasive mice, the ashy storm-petrel (*Oceanodroma homochroa*) and the Leach's storm-petrel (*Oceanodroma leucorhoa*). However, other rare native species such as the endemic Farallon arboreal salamander (*Aneides lugubris farallonensis)*, the endemic Farallon camel cricket (*Farallonophilus cavernicolus*), and the maritime goldfield (*Lasthenia maritima)* are also likely to benefit.

The benefit of this conservation action is significant from a regional perspective because the Farallon Islands are an important breeding and resting location for wildlife, especially seabirds and marine mammals. The Refuge comprises the largest seabird breeding colony in the contiguous United States, and supports nearly half of all breeding ashy storm-petrels in the world. In addition, the islands support the world's largest breeding colonies of Brandt's cormorants (*Phalacrocorax penicillatus*) and western gulls (*Larus occidentalis*). Mouse removal would satisfy the Service's goal of invasive species control in the United States. Mouse removal will also benefit wilderness character since mice have noticeably altered the landscape. Additionally, the eradication of house mice at the 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 ecosystem stressor from the Farallones ecosystem (Tillmann and Siemann 2011).

The South Farallon Islands are about 30 miles west of the Golden Gate Bridge and the City of San Francisco, California. The Farallon 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 PRBO Conservation Science (PRBO, now Point Blue Conservation Science) and the U.S. Coast Guard to assist with wildlife monitoring, facilities management, and protection of the Refuge. The waters around the Farallones below the mean high tide line are part of the Gulf of the 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 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. Overfishing and climate change impacts on Pacific sardines (*Sardinops sagax*) in the mid-20th century may have reduced seabird and marine mammal food supplies (Deyle et al. 2013). This, along with extensive mortality from heavy oil pollution in the early to mid-20th century, exacerbated earlier declines. Activities associated with the operation of the U.S. Coast Guard light station further affected island wildlife and habitat. These impacts were reduced upon the full automation of the light station in 1972. Since FWS 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.

The National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), as amended, requires all lands within the National Wildlife Refuge System to be managed in accordance with the purposes for which the refuge was established. For the Farallon National Wildlife Refuge, the eradication of introduced house mice would aid in achieving the following Refuge goals and objectives, which are 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 states a 5 year goal of reducing the impacts of invasive wildlife on the island ecosystem.

The USFWS 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 Draft 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. The potential impacts of a No Action alternative and two action alternatives are fully analyzed in this Revised Draft EIS.

The alternatives are:

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 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.*

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 economic environment
  - Impacts to personnel from operations
  - Impacts to refuge visitors and recreation
  - Impacts to fisheries resources
  - Impacts to historical and cultural resources
- Unavoidable adverse impacts
- Cumulative impacts
- Irreversible or irretrievable commitments of resources
- Relationship of short-term uses to long-term ecological productivity

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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
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 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	Gulf of the 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
PCB	Polychlorinated Biphenyl
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PPE	Personal Protective Equipment
PRBO	Point Reyes Bird Observatory, now Point Blue Conervation 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

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1 Purpose and Need

1.1 Purpose of and Need for the Proposed Action

1.1.1 Introduction

The Farallon 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." The Refuge included the North Farallon Islands, Middle Farallon Island, and Noonday Rock. In 1969 the Refuge was expanded to include the South Farallon Islands. 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.

The Farallon Islands host a unique ecosystem. They house the largest seabird breeding colony in the contiguous United States, with approximately 200,000 to 300,000 birds of 13 species. Populations of five marine mammal species use the islands for resting and breeding. Hundreds of species of migratory birds stop there to rest and feed. Several rare species also occur, including the ashy storm-petrel (*Oceanodroma homochroa*), endemic Farallon arboreal salamander (*Aneides lugubris farallonensis*), endemic Farallon camel cricket (*Farallonophilus cavernicolus*), and threatened Steller sea lion (*Eumatopius jubatus*).

Up until the 19th Century, the Farallon Islands (or Farallones) ecosystem evolved in the absence of terrestrial mammals. Introductions of invasive mammals to the South Farallon Islands have led to long-term ecological damage. Introduced European rabbits (*Oryctolagus cuniculus*) and domestic cats (*Felis catus*) severely impacted vegetation and birds; both cats and rabbits were removed from the islands in the early 1970s (Ainley and Lewis 1974). Invasive house mice are believed to have been first introduced to the islands in the early to mid-19th century.

House mice are the only remaining invasive mammals on the Farallones. They provide a food resource for a migratory population of burrowing owls that also prey upon rare ashy storm-petrels. House mice also consume native invertebrates and the seeds and seedlings of native vegetation, they are a potential vector for disease transmission to pinnipeds, and induce other ecosystem impacts. At their annual peak, invasive house mice on the South Farallones are present at plague-like densities, numbering over 490 per acre (1,200 per hectare) (Appendix C). House mouse densities recorded from the South Farallon Islands are amongst the highest for any island in the world (Pearson 1963, Mackay et al. 2011).

In 2009, the Service prepared a Comprehensive Conservation Plan (CCP) for the Refuge. The CCP concluded that predation by house mice was impacting populations of certain native seabird species on the Refuge. The CCP called for the elimination of invasive house mice from the Farallon Islands to help restore native seabird populations (USFWS 2009). This DEIS is tiered from the policy decision set forth in the CCP.

1.1.2 Purpose Statement

The purpose of this DEIS is to present a range of alternatives to meet the Service's management goal of eradicating invasive house mice from the Farallon National Wildlife Refuge in order to eliminate their negative impacts on seabirds and other native species of the Farallon Islands.

1.1.3 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. The following benefits to the Farallon Islands ecosystem are anticipated as a consequence of eradicating house mice:

1. **Seabirds**: Nesting seabirds are expected to benefit as a consequence of improved survivorship. In particular, eradicating house mice is expected to result in increased populations of at least two seabird species, the ashy storm-petrel (*Oceanodroma homochroa*; Figure 1.1) and Leach's storm-petrel (*Oceanodroma leucorhoa*), by reducing the numbers of overwintering burrowing owls and resulting owl predation on storm-petrels.
2. **Salamanders**: The endemic Farallon arboreal salamander is anticipated to benefit from the removal of a likely competitor for invertebrate prey and a potential predator of salamander eggs and juveniles.
3. **Invertebrates**: Native invertebrates of the South Farallon Islands, including the endemic Farallon camel cricket (*Farallonophilus cavernicolus*), 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**: Native plants stand to benefit as a consequence of reduced seed and seedling predation by mice.
5. **Pinnipeds**: Marine mammals may benefit as a result of removing house mice, which are known vectors of pathogens that affect marine mammals (de Bruyn et al. 2008).
6. **Burrowing owls:** Migrant burrowing owls (*Athene cunicularia*) stop at the islands each autumn. Attracted by the abundance of mice present in autumn, 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 island for breeding activities, owls switch their diet to feed primarily on rare ashy storm-petrels (Chandler and PRBO 2012 unpubl. data and Mills 2006 unpubl. data), impacting storm-petrel populations (Nur et al. 2013). In addition to storm-petrels, terrestrial insects are also consumed. The loss of

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

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 have on storm-petrels.

1.1.4 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.

1.1.5 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 Farallon NWR 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;
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). 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 in 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 (Lowe et al. 2000) by the Invasive Species Specialist Group (ISSG) of the IUCN. 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. In addition, they are known to have dramatic, negative impacts on endemic arthropods (Rowe et al. 1989, Cole et al. 2000). This direct impact on arthropods in turn has 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. 2008). On Marion Island in the southern Indian Ocean, 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. 2008). 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). Mice have also altered the vegetation community on Marion Island, through seed predation, showing a preference for seeds of native plants over introduced ones (Angel et al. 2008).

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, common gecko (*Hoplodactylus maculates*), and an endemic giant cricket (*Deinacrida rugosa*) all 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. 2008). On Gough Island in the southern Atlantic Ocean, introduced house mice prey on chicks of the rare Tristan albatross (*Diomedea dabbenena*), contributing to an unusually low breeding success rate of 27 percent in this declining seabird species (Cuthbert and Hilton 2004). Dramatic video footage has shown mice in the process of killing these large seabirds chicks (up to 10 kg) by burrowing inside the birds and eating their organs while the birds are still alive. The level of predation on the Tristan Albatross population is unsustainable and if it continues would lead to the extinction of this Critically Endangered (IUCN) seabird (Wanless et al. 2007). 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). Similarly, 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. 2008).

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). Hyperpredation is considered to be one of the principal reasons why ashy storm-petrel and potentially Leach's storm-petrel populations on the South Farallones are declining and otherwise kept at levels below their potential. The introduction of house mice on the South Farallones is believed to have led to hyperpredation (increased predation levels) by burrowing owls on ashy storm-petrel and Leach's storm-petrel highlighting the impacts that introduced species can have on an ecosystem. The mechanisms in place on the Farallones are more fully described in Section 1.2.2.

Figure 1.2. A house mouse feeding on a seabird carcass on Gough Island.

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 was experiencing a mortality rate that is considered to be twice as high as the shearwaters mortality 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 steep 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). 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 lead to native population recovery. Similarly, the removal of mice from the South Farallon Islands is expected to reduce or eliminate hyperpredation of ashy and Leach's storm-petrels by burrowing owls (See Section 1.2.2).

1.2.2 House Mice Impacts on Storm-Petrels at the South Farallon Islands

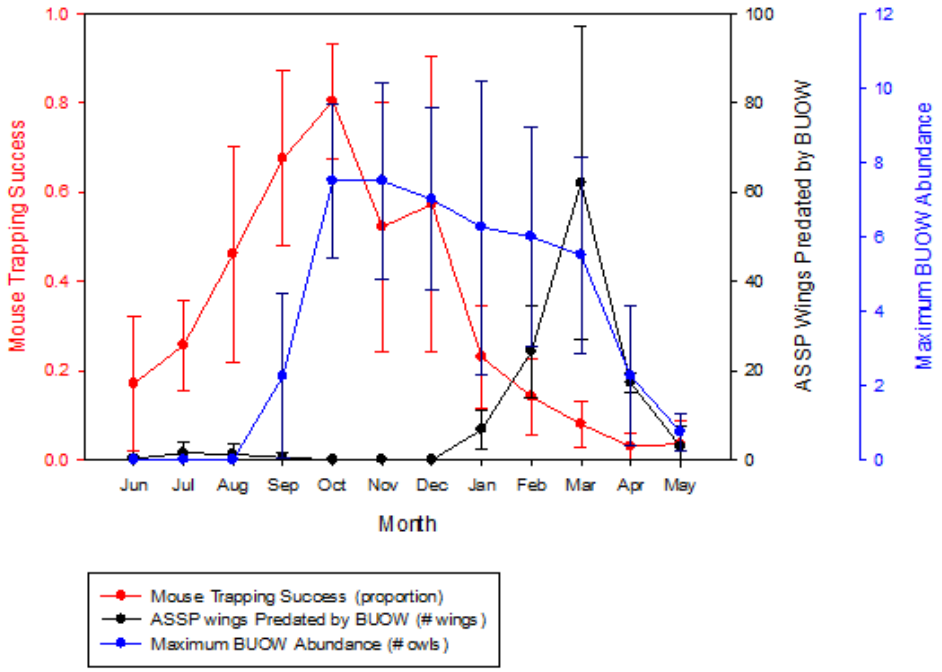
1.2.2.1 *Introduction*

Introduced mice are indirectly and directly negatively impacting the populations of certain seabird species on the South Farallones, particularly storm-petrels, as well as other native, natural resources.

Hyperpredation on the Farallones consists of a transient burrowing owl population subsidized by an invasive mouse population (Mills 2006, Nur et al. 2013). As the mouse population naturally declines in the winter months, the owls begin preying on native species, including storm-petrels and Farallon camel crickets. Over 90 percent of owl pellets (regurgitated boluses that contain indigestible items such as feathers and bones) collected on the South Farallon Islands after

February 1st in recent years contained storm-petrel remains (Chandler and PRBO unpubl. data). If house mice were no longer present on the Farallones, it is anticipated that migrating owls, visiting the islands during the fall months would move on because of a lack of suitable food. Storm-petrels and other small seabirds are either absent or present in very low numbers in the fall and would provide an insufficient prey base to encourage owls to remain on the islands. The terrestrial invertebrate population is also considered insufficiently abundant to sustain owls for long periods of time. Figure 1.3 illustrates the temporal changes in prey availability and burrowing owl abundance on the South Farallones.

Figure 1.3: 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.



1.2.2.2 *Detailed Analysis of House Mouse Impacts on Storm-Petrels*

Researchers have discovered that mice on the South Farallon Islands are indirectly responsible for ongoing and recently increased predation of ashy storm-petrels by burrowing owls. Burrowing owls overwinter on the islands because of the ready availability of mice as a dietary item when owls arrive in the fall (Mills 2006, Bradley et al. 2011, Nur et al. 2013). Physical and behavioral similarities between ashy storm-petrels and Leach's storm-petrels, along with recovered carcasses suggest that the less common Leach's storm-petrels may be experiencing similar impacts (Bradley et al. 2011).

Burrowing owls are not considered island residents, but each fall some migrating burrowing owls stop to rest on the South Farallones (DeSante and Ainley 1980). The arrival of migrating or dispersing landbirds onto the Farallones is actually quite common; over 400 different landbird

species have been recorded on the islands since 1968 (Richardson et al. 2003) (PRBO, unpubl. data).

Most landbirds that arrive on the Farallones depart within a few days of arrival (DeSante and Ainley 1980). However, the majority of burrowing owls arrive in the fall when the house mouse population is near its annual peak. Some burrowing owls then remain on the islands for up to several months, initially subsisting almost solely on a diet of mice (Mills 2006) (Chandler and PRBO, unpubl. data). Between December and January, the mouse population declines rapidly (a natural, cyclical counterpart to its fall peak) reducing food availability to burrowing owls (Irwin 2006). As a result, burrowing owls starve to death, leave the island, or switch to an alternative prey source. Adult storm-petrels, which begin arriving on the islands in mid-winter to establish breeding sites and engage in courtship activity, become a favored alternative prey item for the owls. Vulnerability of storm-petrels to burrowing owl predation is heightened because they come ashore at night when owls are active (Figure 1.4). Native invertebrates, including the endemic Farallon camel cricket, are also consumed in higher numbers following the mouse population crash (S. Chandler and PRBO unpubl. data).

Figure 1.4: Ashy storm-petrel remains beneath burrowing owl roost on Southeast Farallon Island. Photo courtesy of PRBO by R. Wanless and A. Angel

Predation by wintering owls accounts for substantial annual mortality of adult ashy storm-petrels. Bradley et al. (2011) estimated an average of 225-270 ashy storm-petrels preyed upon by burrowing owls, western gulls, and unknown avian predators per year in 2003-2011, based on standardized carcass surveys). They further estimated that 40% of this avian predation was from burrowing owls (Bradley et al. 2011); this equates to 90-108 storm-petrels depredated by burrowing owls per year. However, these totals may underestimate total predation because only easily accessible portions of Southeast Farallon Island were surveyed (Bradley et al. 2011). On a monthly basis, owl predation on storm-petrels was strongly positively related to burrowing owl abundance and strongly 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. This reflects the fact that mice are the primary prey and ashy storm-petrels are the secondary prey (Nur et al. 2013). Burrowing owl abundance and predation on storm-petrels has increased in the last 10 years, with especially high levels of both parameters in the most recent years (Nur et al. 2013), 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. 2013). Annual variation in owl abundance and predation on storm-petrels are highly correlated. A capture-recapture analysis revealed a statistically significant effect of burrowing owl abundance on annual ashy storm-petrel adult survival (Nur et al. 2013); in years when owls were more abundant, storm-petrel survivorship was reduced. Nur et al. (2013) estimated the change in ashy storm-petrel population trend as a result of anticipated reductions in burrowing owl predation on Southeast Farallon Island, using a population-dynamic model. Fewer burrowing owls wintering on the South Farallon Islands will likely result in a reduction of burrowing owl predation on ashy storm-petrels, with significant and positive benefits for the Farallon ashy storm-petrel population (Nur

et al. 2013). Without removal of house mice, predation by burrowing owls will continue at elevated levels.

Two separate studies have been conducted to enumerate owl diet on Southeast Farallon Island. Mills (2006) analyzed regurgitated pellet casts of burrowing, barn, saw-whet (*Aegolius acadicus*), and long-eared (*Asio otus*) owls collected between 1996 and 2004. Mills (2006) found that mice were the most commonly occurring prey item in owl pellets, with 58 percent of pellets containing mice. Other common prey items were birds (44 percent of pellets) and insects (16 percent of pellets). When the year was subdivided into four periods, mice were most common (93 percent of pellets) and birds least common (8 percent of pellets) in the November through February period. In contrast, March to June had the lowest frequency of mice (38 percent) and greatest frequency of birds (62 percent of pellets). The pattern of mouse abundance in a trapping study (Irwin 2006) determined that mouse occurrences in pellets were similar. Storm-petrel remains were found in 10.2 percent of pellets, mainly those from burrowing owls. Mills (2006) surmised that mice were the preferred prey of owls on the Farallones, and that when the mouse population crashed in winter, owls switched to birds as alternate prey.

A burrowing owl diet study was conducted from September 2010 to May 2011 (Chandler and PRBO 2012, unpubl. data). Chandler and PRBO's more intensive study of Farallon burrowing owls included capture, banding, radio tracking, and pellet collection and analyses. During the eight month research study, nine wintering burrowing owls were captured, banded and tracked on Southeast Farallon. Several other owls were also detected but were not captured or tracked. In addition to mapping all known owl roosts, approximately 679 owl pellets (regurgitated casts) were collected and analyzed: 412 pellets from roosts used by banded owls, and 267 pellets from unbanded owls. A total of 1,618 prey items were detected in the pellets: 1,067 invertebrates, 453 mice, 82 storm-petrels and 16 other birds. Although invertebrates made up the majority of the prey items, the majority of the biomass consumed was made up primarily of house mice and storm-petrels. Storm-petrels made up 85 percent of all birds eaten by the burrowing owls.

From October through December 2010 house mice comprised over 60 percent of the items found in the pellets of tracked owls, with predation on mice peaking in November when mice are near peak population size. Birds comprised less than three percent of the diet during the fall, and no storm-petrels or auklets were found in owl pellets during this time. From January to May 2011, however, when mice were less abundant, mouse consumption dropped from 60 percent to nine percent of the diet, and a minimum of 64 storm-petrels were eaten by the nine banded owls. Storm-petrels began to show up in owl pellets in January, with the largest number of petrels eaten by owls during February, March, and April. Owls switched from mice to storm-petrels as the mouse population crashed and storm-petrels began to show up in increasing numbers for pre-breeding season attendance.

Camel crickets and other invertebrates comprised 37 percent of the items found in burrowing owl pellets from September through December, but from January to May the number of invertebrate prey items was nearly twice this rate (78 percent of the total). What is especially revealing is that in January, after the mouse population had crashed and before storm-petrels had arrived back in large numbers, the owls showed a large spike in invertebrate consumption, reaching 85 percent of all prey items. Overall, invertebrates made up 67 percent of the prey items in owl diet over the

entire winter, and over 42 percent of the invertebrates consumed were endemic Farallon camel crickets.

The relative amount of biomass of mice and storm-petrels killed by burrowing owls during the fall and winter periods differs dramatically from the spring period. Using the known average live weights for Farallon house mice (0.5 oz or about 15 g) and ashy storm-petrels (1.3 oz or about 38 g), mice accounted for almost all of the prey biomass during the fall, while storm-petrels provided most of the biomass in the winter-spring (Table 1.1). Although not estimated here because of their extremely small size, biomass of invertebrates would be substantially less than either mice or storm-petrels.

Table 1.1 – Numbers of individuals and estimated biomass of house mice and storm-petrels recorded in burrowing owl pellets from Southeast Farallon Island, collected from September 2010 through May 2011.

Time Period	# Mice	# Petrels	Biomass of Mice	Biomass of Petrels	% Biomass of Mice	% Biomass of Petrels
Oct. 1 – Jan. 1	179	0	2685g	0g	100%	0%
Jan. 1 – May 15	59	74	885g	2432g	27%	73%

1.2.3 Direct impacts of mice on storm-petrels

The inconspicuous rock-crevice nest sites and nocturnal habits of storm-petrels make it difficult to collect evidence of mouse predation and disturbance on the South Farallones without disrupting and destroying nest sites. However, evidence of direct mouse impacts has been recorded. 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 (PRBO, unpublished data). Chicks of storm-petrels and Cassin's auklets (*Ptychoramphus aleuticus*) have been found with toes or feet missing as a result of mouse predation (D. Ainley pers. comm.; P. Pyle pers. comm.). These data, combined with the fact that mice have been documented preying on seabird eggs and chicks on other islands around the world (Cuthbert and Hilton 2004, Wanless et al. 2007, Angel et al. 2008, Jones and Ryan 2010; see Section 4.5.3.2.1), 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 with monitoring storm-petrels in their small crevice nests, it is possible that house mice are imposing a greater impact on Farallon storm-petrels than has been directly observed.

1.2.4 Impacts on invertebrates, plants, and salamanders

Evidence from the South Farallones and other islands (see Sections 1.2.5.4 and 4.5.3.6) suggests that mice may impact native invertebrates (including the endemic Farallon camel cricket), plants, and the endemic Farallon arboreal salamander (*Aneides lugubris farallonensis*) of the Farallon Islands. Analysis of mouse diet on Southeast Farallon Island has shown frequent consumption of native invertebrates and plants, including the endemic Farallon camel cricket and ecologically

important maritime goldfield (*Lasthenia maritima*), a California native daisy species (Jones and Golightly 2006) (S. Chandler and PRBO, unpubl. data). Invertebrates and plants play an important structural role in the ecosystem of the South Farallon Islands and the impact on these organisms may be affecting the balance of the entire island ecosystem. These impacts could reduce the ability of the South Farallon Island ecosystem to withstand future or growing threats. Figure 1.5 demonstrates the house mouse food web on the South Farallon Islands.

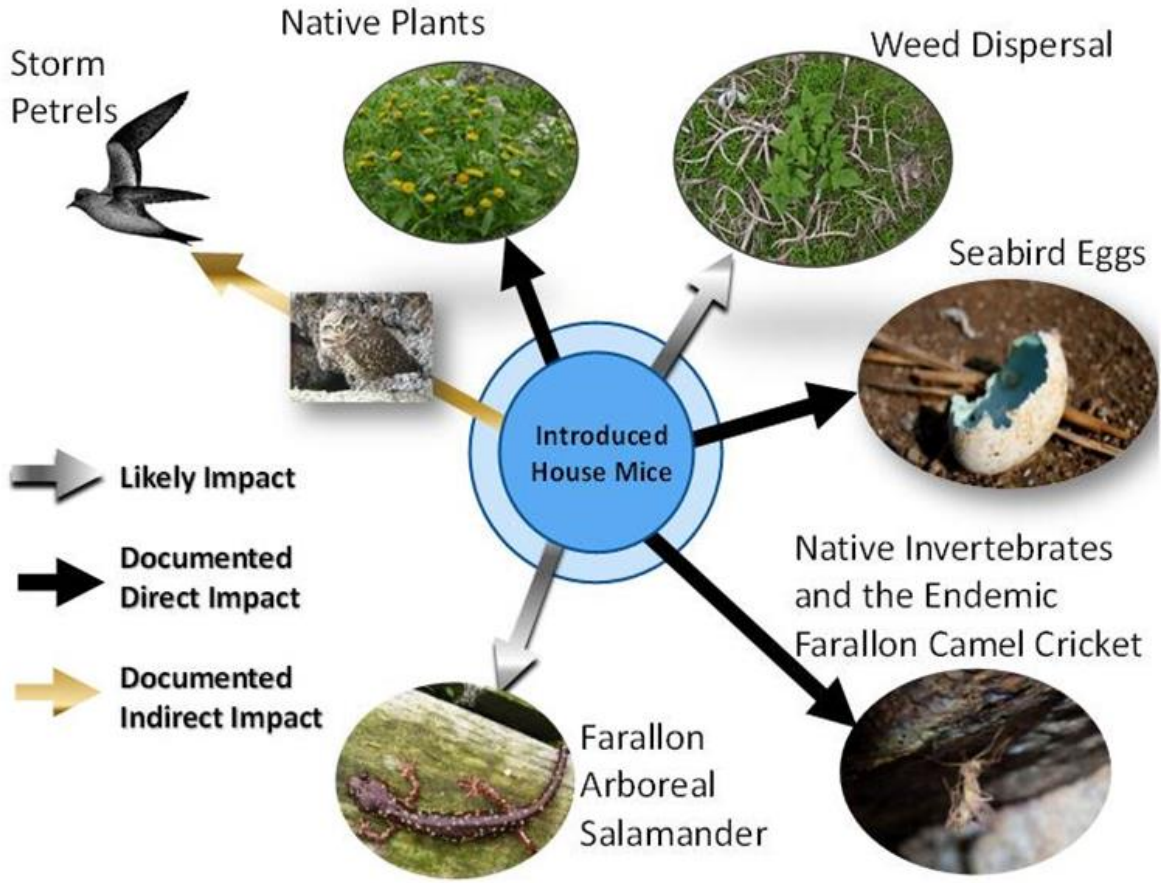


Figure 1.5 – Food web of house mice on the Farallon Islands

1.2.5 Benefits of House Mouse Eradication

The eradication of house mice from the South Farallon Islands would result in significant benefits to the Farallon ecosystem. Reduced predation pressure on native species of conservation concern would allow population recovery. Elimination of house mice would cement more than a century's worth of restoration efforts allowing the South Farallon Islands to flourish as a hub of biodiversity and a globally significant breeding colony for marine birds and mammals.

1.2.5.1 *Reducing the Impact of Burrowing Owls on Ashy and Leach's Storm-Petrels*

The best scientific evidence available to the Service indicates that if mice are removed from the South Farallon Islands, few of the burrowing owls that 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 (Mills 2006) (Chandler and PRBO, unpubl. data). By the time the owls switch from preying on mice to storm-petrels in the winter and spring, most have been on the island for several months (PRBO unpublished data). Additionally, there have been no confirmed accounts, current or historic, of burrowing owls successfully breeding on the islands (PRBO unpubl. data) (DeSante and Ainley 1980), indicating that the Farallones provide an unsuitable environment for burrowing owls to reside.

While ashy storm-petrels are present at least in low numbers year-round, attendance by ashy and Leach's storm-petrels is greatest from February or March until October (Ainley and Lewis 1974, Ainley et al. 1990d). On the other hand, burrowing owls mainly arrive on the South Farallones in the fall and early winter (Richardson et al. 2003, Nur et al. 2013). 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.

Capture-recapture analyses reveal a strong and significant effect of burrowing owl abundance on annual ashy storm-petrel adult survival. Results of a survival analysis indicate that a 50 percent reduction in owl abundance can be expected to increase overall annual ashy storm-petrel survival by 2.64 to 4.92 percent. Nur et al. (2013) estimated the change in population trend as a result of anticipated reductions in burrowing owl predation on SEFI using a population-dynamic model. As the best-fit negative linear population trend of 7.19 percent annual decrease ("Observed Steep Decline" scenario – Scenario A) was not statistically significant, they also assessed the sensitivity of modeling results by considering two other scenarios: a "Moderate Decline" scenario (Scenario B), of 3.36 percent annual decline, and a "Near Stable" scenario (Scenario C), of 0.63 percent annual increase. They then used these scenarios for modeling plausible future population trends. A 50 percent reduction in burrowing owl abundance can be expected to change population growth rates by 2.3-3.9 percent depending on whether one assumes Scenarios A or C, with Scenario B values in between. This corresponds to changing a population that is strongly declining to weakly declining (7.19 percent annual decline to 3.26 percent, Scenario A) or from near-stable to increasing (0.63 percent increase per year to 2.90 percent increase, Scenario C). Under Scenario B, the population trajectory would change from declining at 3.36 percent per year to nearly stable with a 0.22 percent decline per year. With a 71.5 percent reduction in the burrowing owl abundance index, ashy storm-petrel population growth rates change by 3.1-5.3 percent, depending on the scenario. This greater reduction in burrowing owl abundance results in larger population benefits for storm-petrels, resulting in 1.88 percent annual decline under Scenario A and 3.69 percent annual increase under Scenario C.

To summarize, reduction in Burrowing Owl abundance has strong positive population impacts in all scenarios examined. Under Scenario A, the "Observed Steep Decline" scenario, rates of decline are substantially reduced. Under Scenario B, the "Moderate Decline" scenario, the population trends change from moderate decline to stable or slight annual increase. Under Scenario C, the "Near Stable" scenario rates of annual population change from a very weak increase to a strong increase after owl reduction, which is a nearly five-fold increase in the net

population growth rate. A reduction in burrowing owl predation on storm-petrels would have positive population consequences for ashy storm-petrels on the Farallon Islands regardless of the scenario examined (Figure 1.6).

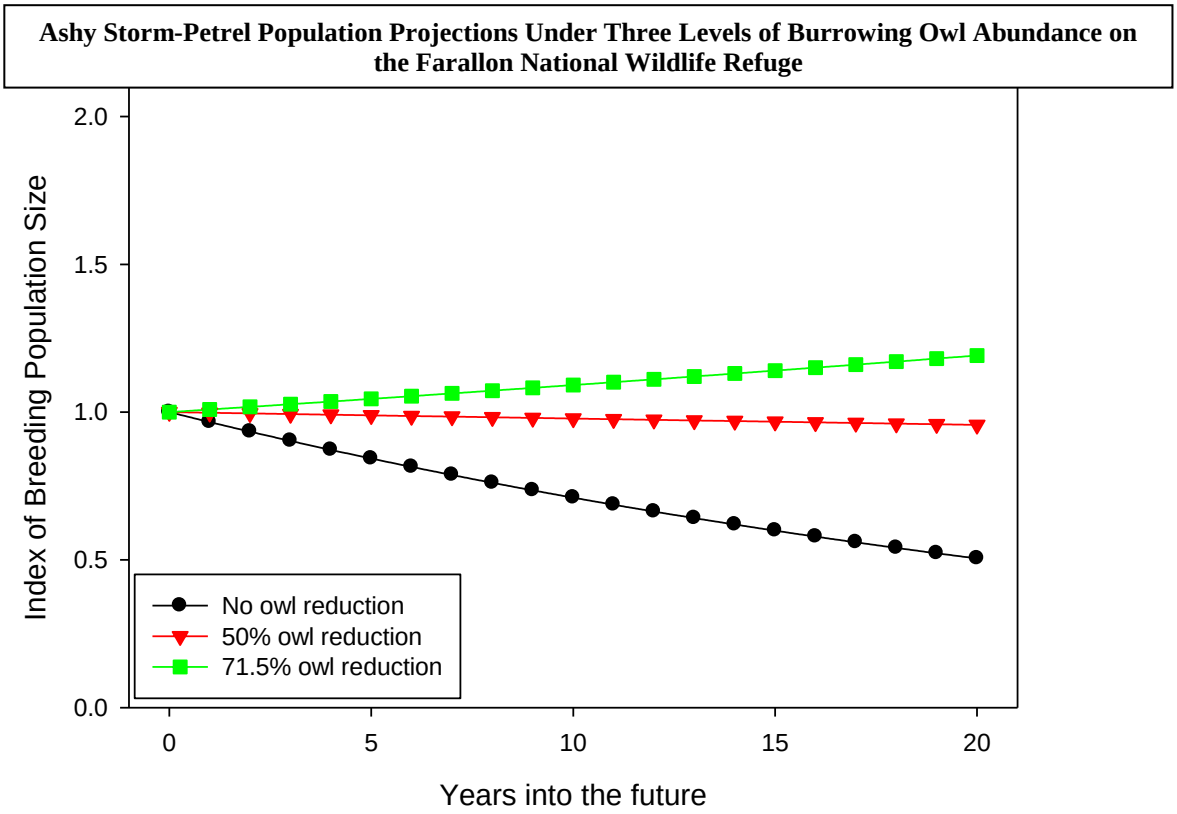


Figure 1.6: Farallon ashy storm-petrel population projections under three levels of reduction in burrowing owl abundance: Zero percent reduction, 50 percent reduction, and 71.5 percent reduction. Depicted are relative ashy storm-petrel breeding population sizes for a 20-year period with year Zero set to 1.0. Year Zero corresponds to most recent conditions and it is during this year that burrowing owl reduction is initiated.

1.2.5.2 *Decreasing the risk of spreading diseases to pinnipeds*

Several incidences of mass marine mammal mortality have been recorded over the past 30 years and disease has been implicated in several of these events (Bruyn et al. 2008). For example the death of approximately 20,000 harbor seals (*Phoca vitulina*) in 1988 in the North Sea was found to be a consequence of phocine distemper virus (PDV), and in 1998 two different bacteria were implicated in the mortality of 1,600 New Zealand sea lions (*Phocarctos hookeri*) (Bruyn et al. 2008). Pathogens can be transmitted between hosts, and mice on the Farallones present a potential reservoir of diseases that could be transmitted to pinnipeds. Mice frequently utilize pinniped haul out and breeding areas (Avenant and Smith 2003) and the urine and excrement they leave behind in these locations create the potential for disease transmission. Eradicating mice on the South Farallon Islands would eliminate the threat of disease transmission between mice and pinnipeds, as well as eliminate a risk that could be exacerbated by changing environmental conditions such as the effects of climate change (Harvell et al. 1999).

1.2.5.3 *Increasing wilderness character*

With the exception of Southeast Farallon Island, the South Farallon Islands are federally designated wilderness under the Wilderness Act of 1964. The effect of mice in the wilderness is widespread and readily noticeable and has degraded wilderness character. 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 4.4.3).

1.2.5.4 *Increasing native invertebrate populations*

Mouse eradication would likely lead to an increase in native and endemic invertebrate abundance on the South Farallones (Newman 1994, Ruscoe 2001). This was the case on Mana Island, New Zealand, where 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 consume large numbers of terrestrial invertebrates on the islands, including the endemic Farallon camel cricket.

1.2.5.5 *Increasing the native salamander population*

The eradication of mice on the South Farallones would likely benefit the island's endemic Farallon arboreal salamander by removing the presumed predation pressure on salamanders from mice, as well as eliminating potential competition between salamanders and mice for small invertebrate prey. 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 these 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. The Farallon arboreal salamander population is expected to increase as a result of increased productivity, juvenile survivorship, and/or adult survivorship in response to complete mouse removal.

1.2.5.6 *Decreasing impacts to native vegetation*

The native plants of the Farallones evolved without grazing pressure from rodents, 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 endemic maritime goldfields, which are a common food item for mice on the South Farallones (Jones and Golightly 2006). Many of the invasive plants that have been introduced to the South Farallones originally evolved under grazing pressure from small mammals such as rodents on the mainland, so mice are likely to have less of a negative impact on them. Additionally, during the fall mice on the Farallones commonly consume the seeds of the invasive hare barley and spread the seeds in their droppings. Hare barley has spread to new areas on the islands in recent years (Coulter and Irwin 2005). The presence of mice on the Farallones increases the likelihood that introduced plants dispersed by rodents would successfully establish and spread on the islands outcompeting with native plant communities. The eradication of mice should have significant positive benefits to vegetation on the Farallones. Their removal should decrease grazing on native plants and their seeds, while

also decreasing the spread of invasive plants on the islands (see sections 4.5.3.7, 4.5.6.1.6, and 4.5.6.2.6).

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

It has been suggested that many burrowing owls that attempt to overwinter 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 labor-intensive. Several weeks of effort each year were required to capture owls and many were not captured. Several owls appeared to be present in inaccessible areas and were rarely seen (PRBO unpubl. data). To safeguard the captured owls, they were held and cared for on island before transporting them to the mainland for release in suitable habitat. To limit on-island hold times, owls had to be captured just prior to scheduled supply boats, which occur only approximately once every two weeks. This situation was exacerbated when scheduled transportation was postponed or cancelled due to inclement weather.

After transport to the mainland, owls were released into ground squirrel burrows in known burrowing owl habitat on National Wildlife Refuge lands. Following release, each owl was supplied with dead mice for several days to help them acclimate to their new environment and was monitored in an attempt to ascertain if translocation was successful. While some owls were able to be monitored, tracking owls to ascertain success proved difficult without the use of radio telemetry. It is also uncertain if owl translocation improved owl survivorship. More intensive studies in recent years have shown that many owls survive the winter on the Farallones, and some individuals have returned to overwinter in subsequent years (PBBO, unpubl. data).

1.3 Authority and Responsibility to Act

The eradication of invasive house mice from the South Farallon Islands is consistent with several federal laws and policies mandating land managers to conserve and restore native wildlife and their habitats under their jurisdiction.

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 threat that introduced species pose to habitat and native wildlife makes addressing their impacts one of the Service's top management priorities. Lessening or eliminating the impacts of introduced species on the Farallones is essential to the Service's management strategy for the islands.

The Farallon National Wildlife Refuge was established under Executive Order 1043 in 1909 as a "…preserve and breeding ground for marine birds." The refuge is managed with the principal goal of protecting the native breeding birds of the Farallon Islands.

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 National Wildlife Refuge System Administration Act of 1966 (as amended) (16 USC 668dd) established the unifying mission of the National Wildlife Refuge System "to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." Among other mandates, the Refuge Administration Act requires the Service to provide for the conservation of fish, wildlife, plants, and their habitats within the System; and to ensure that the biological integrity, diversity, and environmental health of the System are maintained.

The National Wildlife Refuge System Improvement Act of 1997, which amended the Refuge Administration Act, serves as an "Organic Act" for the Refuge System and provides comprehensive legislation on how the Refuge System should be managed and used by the public. The Act clearly establishes that wildlife conservation is the singular Refuge System mission, provides guidance to the Secretary of the Interior for management of the System, provides a mechanism for refuge planning, and gives refuge managers uniform direction and procedures for making decisions regarding wildlife conservation and uses of the System.

The USFWS policy for maintaining biological integrity and diversity and environmental health (601 FW 3, 2001), directs Refuges to "prevent the introduction of invasive species, detect and control populations of invasive species, and provide for restoration of native species and habitat conditions in invaded ecosystems." Furthermore, 601 FW 3 directs refuge managers to "develop integrated pest management strategies that incorporate the most effective combination of mechanical, chemical, biological, and cultural controls while considering the effects on environmental health."

The Wilderness Act of 1964 (16 U.S. C. 1131-1136) established a National Wilderness Preservation System composed of federally owned areas designated by Congress as "wilderness areas." An area designated as wilderness is to be "…protected and managed so as to preserve its natural conditions ..." All of the Farallon Islands except for Southeast Farallon Island are designated under this system as the Farallon Wilderness.

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 National Wildlife Refuge. As mandated by the NWRSIA, 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.

Presidential Executive Order 13112 on Invasive Species (February 3, 1999): Section 2(a)(2), on Federal agency duties, states: "Each Federal agency whose actions may affect the status of

invasive species shall, to the extent practicable and permitted by law, subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (vi) promote public education on invasive species and the means to address them."

Executive Order 13112 defines "invasive species" as "an alien species [a species that is not native with respect to a particular ecosystem] whose introduction does or is likely to cause economic or environmental harm or harm to human health."

The USFWS Coordination Act of 1965 (16 USC 661-666c), as amended: Section 661 states that: For the purpose of recognizing the vital contribution of our wildlife resources to the Nation, the increasing public interest and significance thereof due to expansion of our national economy and other factors, and to provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through the effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation for the purposes of sections 661 to 666c of this title in the United States, its Territories and possessions, the Secretary of the Interior is authorized (1) to provide assistance to, and cooperate with, Federal, State, and public or private agencies and organizations in the development, protection, rearing, and stocking of all species of wildlife, resources thereof, and their habitat, in controlling losses of the same from disease or other causes, in minimizing damages from overabundant species, in providing public shooting and fishing areas, including easements across public lands for access there to, and in carrying out other measures necessary to effectuate the purposes of said sections; (2) to make surveys and investigations of the wildlife of the public domain, including lands and waters or interests therein acquired or controlled by any agency of the United States; and (3) to accept donations of land and contributions of funds in furtherance of the purposes of said sections.

The Central California Coast Biosphere Reserve includes the Farallon 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."

1.4 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.

1.4.1 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 1.5 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.

1.5 Environmental Issues (Impact Topics) Identified

1.5.1 Impact Topic: Physical Resources

1.5.1.1 *Sub-topic: Impacts to water resources*

Because the proposed action may 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.

1.5.1.2 *Sub-topic: Impacts to geology and soils*

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

1.5.1.3 *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.

1.5.2 Impact Topic: Biological Resources

1.5.2.1 *Sub-topic: Non-target impacts from toxicant use*

Mouse eradication may 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.

1.5.2.2 *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 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.

1.5.3 Impact Topic: Social and Economic Environment

1.5.3.1 *Sub-topic: Impacts to Personnel Safety*

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

1.5.3.2 *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 PRBO Conservation Science (PRBO) personnel, contractors, and visiting researchers utilize the island year-round.

1.5.3.3 *Sub-topic: Impacts to fishing resources*

The waters near the Farallones are important recreational and commercial fishing grounds 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).

1.5.3.4 *Sub-topic: Impacts to social 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.

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 (Alternatives B and 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. 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' storm-petrels and other native and endemic species.*

- *Alternative B: 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.*

- *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.*

A number of additional alternatives were initially considered but removed from full consideration after completion of scoping and the 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 Sections 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 rodent bait, the many features common to both alternatives were grouped into Section 2.10.

DOI regulations, 43 CFR 46.425(a), state that a Draft EIS, "should identify the bureau's preferred alternative or alternatives, if one or more exists." At this time, there is not a preferred alternative. Full and objective input from the public is encouraged on all of the alternatives analyzed in the Draft EIS. All public comments received on the Draft EIS will be evaluated and considered in the development of the preferred alternative, which will be identified in the Final EIS.

2.1.1 Integrated Pest Management (IPM)

Service policy, as reflected in the Departmental Manual , 517 DM 1, and the FWS Manual 569 FW 1 and best management practices established by Alaska FWS (USFWS 2013), calls for the use of an integrated pest management (IPM) approach, as the decision making tool for making pest management decisions on Refuge lands. Integrated Pest Management is a science-based decision making process that incorporates management goals, consensus building, pest biology, monitoring, environmental factors, and a 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. Integrated Pest Management considers various methods to achieve desired outcomes based upon human safety, environmental integrity, effectiveness, and cost. Pesticides may be used where physical, cultural, and biological methods or combinations thereof are impractical or incapable of providing adequate control, eradication, or containment. If a pesticide would be needed on Refuge lands, the most specific (selective) chemical available for the target species would be used unless considerations of persistence of other environmental and/or biotic hazards would preclude its use. In accordance with 517 DM 1, pesticide usage would be further restricted because only pesticides registered with the U.S. Environmental Protection Agency (USEPA or EPA) and as provided in regulations, orders, or permits issued by EPA may be applied on lands and waters under Refuge jurisdiction.

Environmental harm by pest species refers to a biologically substantial decrease in environmental quality as indicated by a variety of potential factors including declines in native species populations or communities, degraded habitat quality or long-term habitat loss, and/or altered ecological processes. Environmental harm may be a result of direct effects of pests on native species including preying and feeding on them; causing or vectoring diseases; preventing them from reproducing successfully by preying on eggs or young; outcompeting them for food, nutrients, light, nest sites, or other vital resources; or hybridizing with them so frequently that within a few generations, few if any truly native individuals remain. Environmental harm can also be the result of an indirect effect of pest species. For example, decreased waterfowl use may result from invasive plant infestations reducing the availability and/or abundance of native wetland plants that provide forage during the winter.

Environmental harm may involve detrimental changes in ecological processes. For example, extirpation of seabird populations on islands by introduced rodents reduces the rate of nutrient flow in the form of guano from the pelagic zone to the island and surrounding reefs. This change in nutrient regime in turn, favors different coral reef species and modifies communities.

Environmental harm may also cause or be associated with economic losses and damage to human, plant, and animal health. For example, invasions by fire-promoting grasses that alter entire plant and animal species can also greatly increase fire-fighting costs (Beck et al. 2008).

Here, the Service's management goal is the complete removal of non-native mice from the Farallon Islands. Given that eradication rather than control or containment is the purpose of this project, the Service undertook a comprehensive evaluation of biological, physical and chemical approaches to eradicating mice. The evaluation process sought to identify the best available technologies to eradicate mice while minimizing effects to non-target species and ensuring human safety. This process is described below.

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 Draft 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 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 Service management and policy guidelines of the National Wildlife Refuge System, including:
    a. Mission of the Farallon National Wildlife Refuge
    b. Farallon Comprehensive Conservation Plan
    c. U.S. Department of 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 was 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 draft EIS. The two action alternatives selected for analysis in the DEIS 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: A 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 482 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.

	Eradication on Islands	Control on Mainland
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 occur.
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. The latter two principles are being explored as part of the NEPA process and the preparation of this EIS. All of the principles would be resolved prior to the implementation of an eradication operation on the Farallon Islands. 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 this DEIS, house mice had been successfully eradicated from 50 islands, with six more either pending confirmation or in progress, and four whose success is unknown (Keitt et al. 2011). 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 acre (1 ha) and can be as large as 27.2 acre (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 accentuates 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 (15g to 25g). Of 250 mice captured on SEFI the average weight recorded was 0.5 oz (15g). 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 toxin, 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 1970's (Howald et al. 2007), rodent eradication have been attempted 796 times and rodents have now been removed from nearly 571 islands in more than 50 countries around the world including the U.S. (Keitt et al. 2011). These successes have invariably resulted in species and ecosystem recovery and almost certainly saved some species from extinction (Bellingham et al. 2010). For example the eradication of black rats (*Rattus rattus*) on Anacapa Island (California, Channel Islands) resulted in increased abundance of the Scripps murrelet (*Synthliboramphus scrippsi*) (http://www.nps.gov/chis/naturescience/restoring-anacapa-island-sea-bird-habitat.htm). 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). Apart from three very small (less than 14ha) islands where trapping was utilized, all of the successful rodent eradications were completed with one or more rodenticide (MacKay et al. 2007).

Of the 796 rodent eradications, 82 targeted house mice and 50 were successful (Keitt et al. 2011). Success rates have improved over time and since 2007, ten of the eleven mouse eradications undertaken have been confirmed as successful (MacKay et al. 2007). 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 60 mouse eradication attempts on 48 islands. Hand broadcasting was used in two attempts, and aerial broadcast was used in 25 attempts.

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 (MacKay et al. 2007). 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. The following table summarizes the results of attempted mouse eradications and corresponding success rates.

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

Toxicant used		Eradication attempts	Successful	Failed
1st Generation anticoagulant rodenticides	Diphacinone	1**	0	1
	Pindone	1	0	1
	Warfarin	1	1	0
2nd Generation anticoagulant rodenticides	Brodifacoum	50	35	15
	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		66	47***	19

*Only eradication attempts with known methods and known results were included in this table.
**Buck Island project in USVI successfully eradicated rats, but failed to remove house mice, although mice were not the targeted species (Witmer 2007).
***47 successful mouse eradications were conducted; however, four have subsequently been reinvaded.

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. 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 First-generation Anticoagulants

First-generation anticoagulants generally have shorter half-lives, require higher concentrations, and require consecutive intake over several days in order to accumulate in the liver to cause death. They are also less toxic to the target species than second-generation anticoagulants (Eason and Ogilvie 2009). The lower toxicity of first-generation anticoagulants relative to second-generation anticoagulants can be attributed to their poorer binding affinity to sites in the liver (Parmar et al. 1987). First-generation anticoagulants effectively block the vitamin K cycle, but only for relatively short periods of time.

First-generation anticoagulants, including diphacinone, appear to be most effective at achieving mortality in rodents when consumed over several consecutive days (Buckle and Smith 1994,

Swift 1998). In some cases a single high dose may cause mortality (Eason and Ogilvie 2009). Reflected in these results is the inherent variability of susceptibility within a population (Eason and Ogilvie 2009). To achieve successful eradication, enough bait must be available so that each individual within the population can consume diphacinone repeatedly over several consecutive days (Swift 1998).

2.6.2 Second-generation Anticoagulants

Second-generation anticoagulant rodenticides are more potent than first-generation anticoagulants and were synthesized in response to growing resistance within rodent populations to first-generation anticoagulants (Hadler and Shadbolt 1975, Marsh et al. 1980, Eason and Ogilvie 2009). Second-generation anticoagulants have a greater binding affinity to sites in the liver than first-generation anticoagulants (Parmar et al. 1987), and depending on the amount consumed, can commonly cause death after a single dose or single 24 hour feeding event (Hone and Mulligan 1982). As with first generation anticoagulants, symptoms of toxicosis are delayed and rodents will continue to feed and behave normally for some time after a lethal dose has been ingested. Second-generation rodenticides are generally applied in lower concentrations than first-generation compounds (usually between 0.002 and 0.005 percent), and are effective against populations of rodents resistant to first-generation anticoagulants.

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

Currently, three rodenticide based products are registered 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)

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.

2.6.4 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 340.4µ. It is practically insoluble in cold water (Fisher and Broome 2010).

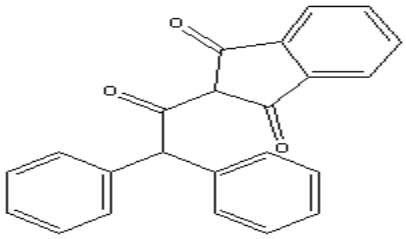


Figure 2.1. Chemical structure of diphacinone

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 10 days or until feeding has stopped" 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), although recent research suggests that the toxicity of diphacinone to some birds may be higher than previously thought (Eisemann and Swift 2006, Rattner et al. 2010). See Chapter 4 for a discussion of the potential impacts of diphacinone on the Farallon environment.

2.6.5 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 523.4µ. 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.

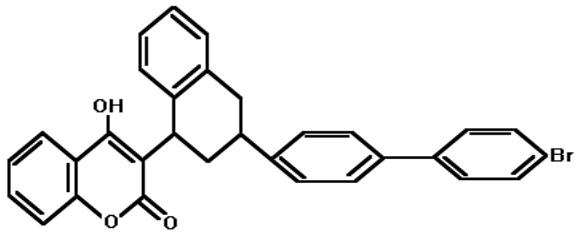


Figure 2.2. Chemical structure of brodifacoum

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, Keitt et al. 2011).

The LD_{50} value for brodifacoum for house mice is 0.52 ppm, with house mice needing to eat 0.43- 0.65g of bait containing 20 ppm brodifacoum to ingest a median lethal dose (Fisher 2005). The acute oral toxicity (LD_{50}) for brodifacoum for house mice is 0.4 ppm (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 25ppm. House mice eat up to 20 percent of their body weight daily (Berry 1970). The time to death for 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, from one to 20 micrograms per kilogram of bodyweight (Wanless et al. 2008b).

2.6.6 Rationale for Proposing the Rodent Bait Products and Toxins

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 as the South Farallones. Brodifacoum was the toxicant used in more than 71 percent of rodent eradication campaigns and in 91 percent of the total area treated (Howald et al. 2007). Of the 50 confirmed successful island mouse eradications, all but one used brodifacoum or a closely related second-generation anticoagulant (Table 2.2 in Section 2.5). 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 four islands and was recently used successfully in 2012 to remove mice from Allen Cay in the Bahamas. 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 developed for use in dry California coastal island environments such as 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), including one aerial application on Mokapu Island, Hawaii (4 ha). However, no house mouse eradications have been successfully conducted using diphacinone as the primary toxicant (Parkes et al. 2010, Parkes et al. 2011). The one project (Buck Island-USVI) utilized diphacinone on an island where mice were present, successfully removed ship rats but did not remove 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. However, waiting for a new product to be developed is not being considered at this time since it will take a minimum of three years before a new product will be ready for island use, and any novel products would be considered experimental. An action alternative relying on diphacinone as the primary eradication tool is being considered because:

- Diphacinone-50 Conservation is EPA-approved, is legally available 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.

2.7 Alternatives Considered and Dismissed from Further Consideration

The Council on Environmental Quality (CEQ) has defined reasonable alternatives as those that meet project objectives to a large degree, are technically feasible, and meet the purpose and need for the proposed action. Alternatives that cannot be implemented, that do not resolve the need for action, or will not fulfill the stated purpose to a large degree should be eliminated from further analysis.

Forty-nine alternatives were considered and analyzed in the Alternatives Selection Report (Appendix C) including the use of a range of different rodenticides with three different delivery methods, as well as several non-rodenticide alternatives. The following is a brief explanation of why all but two action alternatives were dismissed from full analysis. Alternatives were dismissed from detailed consideration if they did not meet most project objectives, did not meet safety and logistical requirements, or were not feasible to implement at this time.

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 (cholecalciferol, chlorophacinone, difethialone, bromadiolone, wafarin, zinc phosphide, bromethaline, and strychnine) or are not registered with EPA for any purpose (pindone, 1080, 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) use of acute toxicants could have led to bait shyness in the targeted mouse population which in an eradication operation would result in operational failure; 3) there was potential for mice to develop resistance; 4) the product lacked an effective antidote (in case of human exposure); 5) 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 6) the product had never been tested in a rodent eradication.

2.7.2 Control as the Primary Method

On the 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, 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. Consequently, this alternative would not meet the project objective to eradicate mice from the 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 principal reasons that bait stations as the primary method are not being considered is due to the following: 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); 2) assuming access to all parts of the South Farallon Islands would be possible, bait stations would need to be deployed on a 20 m x 20 m grid and more than 1,200 bait stations would be required. Installing and maintaining more than 1,200 bait stations across the entire island for several months would require extensive effort and a considerable number of personnel. For a bait station operation to be effective, stations should be maintained for at least one month after the last evidence of rodent bait take is observed. Maintaining such a large number of bait stations would likely cause large-scale, unacceptable impacts to nesting seabirds and their habitat, breeding and resting marine mammals, other sensitive species, 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 island's 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.

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 island's 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). 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 (likely more than five years) required to trial and register the technology disqualified the use of fertility control from detailed consideration.

2.7.9 Burrowing Owl Translocation

The capture and translocation of wintering burrowing owls from the Farallon Islands was considered as a method to reduce owl predation on ashy storm-petrels. In the absence of mouse eradication, the relocation of burrowing owls would be expected to benefit ashy storm-petrels and other seabirds on the South Farallon Islands. To translocate burrowing owls, depredation permits would be required from both the USFWS Office of Migratory Birds and the CDFW. However, at this time the USFWS Office of Migratory Birds is not issuing depredation permits to take or translocate native wildlife (including burrowing owls) except in certain cases to protect endangered or threatened wildlife. Thus, because ashy storm-petrels are not listed on the Endangered Species list, obtaining such a permit would not be possible at this time. Also, obtaining translocation permits from CDFW are difficult to obtain because the burrowing owl is listed as a state Species of Special Concern.

Regardless of the permitting process, significant further investment would be required if burrowing owl translocation was used as the primary method of reducing owl impacts to storm-petrels. This alternative would need to be conducted on an ongoing basis in perpetuity to achieve desired benefits. Several owls per year would need to be captured and translocated, proper captive management facilities would need to be built, staff would need training on proper care and transport of captured owls, and appropriate release and monitoring procedures implemented to assure successful translocation. Additionally, removing owls would not address the direct

threats that mice potentially pose to other aspects of the South Farallon Islands ecosystem, such as those to the endemic Farallon camel cricket and the endemic Farallon arboreal salamander. For these reasons, the burrowing owl relocation alternative was dismissed from further consideration.

2.8 Pre-Eradication Trial Studies Conducted on the Farallones

To advise the development of alternatives for this DEIS, 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 Sections 2.8.1 to 2.8.11.

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 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 of Mouse Abundance 2010-2012 (Trap Success Rate)

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 the Farallones with 0.035 oz (1g) non-toxic Brodifacoum-25D Conservation containing the fluorescent dye biomarker, pyranine. Ten mice from the Farallones were presented with an eight day standard two-choice test in a lab environment (Grote and Brown 1971) 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 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 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, the combination of gull hazing and the use of bait station 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 is likely sufficient to provide four nights of exposure for all mice. 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 would 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 violating safety guidelines on the Farallones. Mapping of these areas was important to identify which areas would be 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.

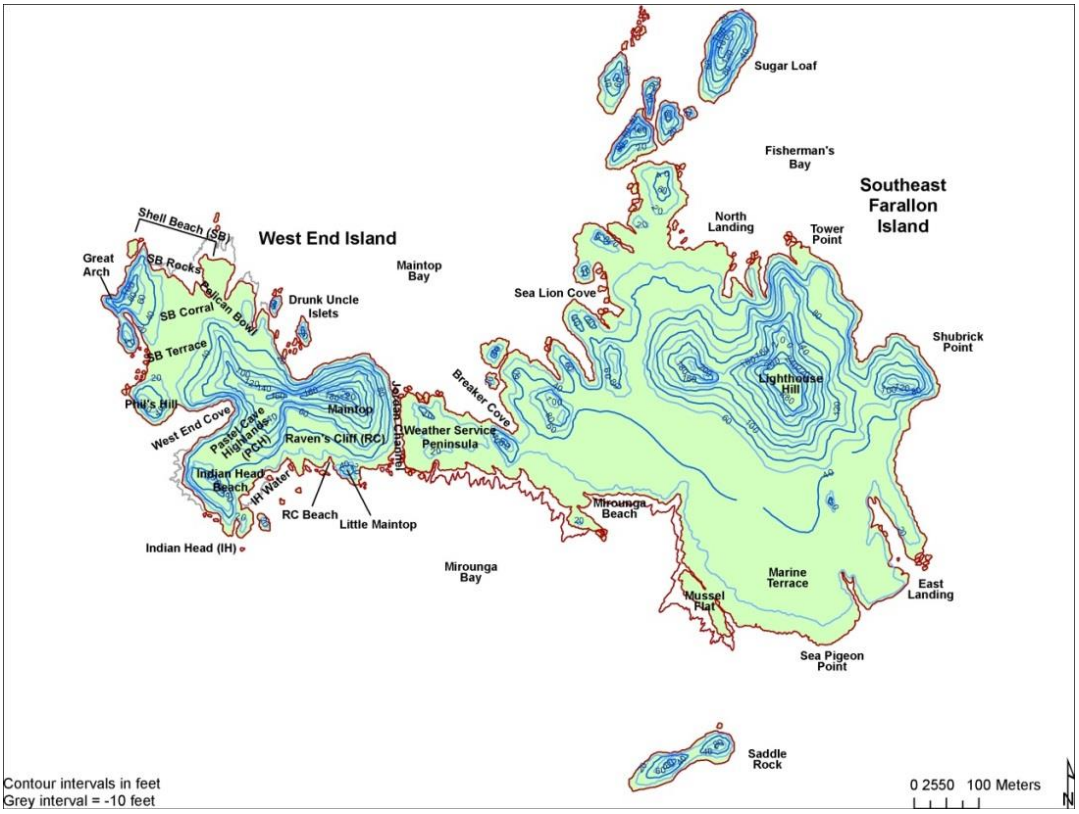


Figure 2.3. Steep Terrain on the South Farallon Islands

2.8.8 Commensal Habitat Assessment

Because bait containing rodenticide cannot legally be applied by helicopter in and immediately surrounding areas of human habitation, the two residences and other man-made structures on Southeast Farallon were surveyed 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 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).

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).

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 they 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 a record-setting 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 up to five weeks after the last bait application. Diphacinone-50 Conservation (Alternative C) may be available and palatable to non-target wildlife for 15 weeks or longer 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 in January 2011 and the second in November and December 2012. In 2011 numerous hazing techniques were tested over the course of three days of 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 making contact with 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).

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 minimal 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).

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. 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 on the mice. Efforts to reduce the likelihood of new rodent introductions also would continue.

The Service currently attempts to manage invasive plants through manual control and the selective application of herbicides. Native plant seeds are also distributed to improve native plant populations and encourage the suppression of non-natives. Vegetation on the islands is closely 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 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 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 be seen. Native plant species including the maritime goldfield would continue to be affected. House mice also represent an ongoing potential vector of disease that could affect the islands' marine mammals (de Bruyn et al. 2008). Mice would continue to degrade the natural quality of the Farallon wilderness.

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 National Wildlife Refuge. Eradicating invasive house mice via the two proposed action alternatives depends on meeting all of the principles for eradication success as specified above in Section 2.4. 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 Farallon National Wildlife Refuge mouse eradication. Hand baiting and bait stations are proposed to be used as a secondary means of bait delivery in some selected areas that would be identified in the final implementation work plan as well as through adaptive management during project implementation.

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 recently published DOI Adaptive Management Technical Guide 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 spread 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.

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 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 of house mice from the South Farallon Islands. These were the annual reproductive and population cycle for house mice, weather, 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 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 is 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 four 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 toxicants 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 (Tietz 2013a). 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 (PRBO unpubl. data).

Specific timing considerations for pinnipeds include the following:

- Pinniped breeding seasons on the South Farallones vary dramatically between species but rang 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 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 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 and/or bait stations. The operational area totals approximately 121 acres (about 49 ha).

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 .02 to .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 EPA-approved pesticide label instructions, 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.

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 this rate would exceed the limit of the EPA-approved pesticide label then a supplementary label would be sought. 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 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 FIFRA. 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 (see below). 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.

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.

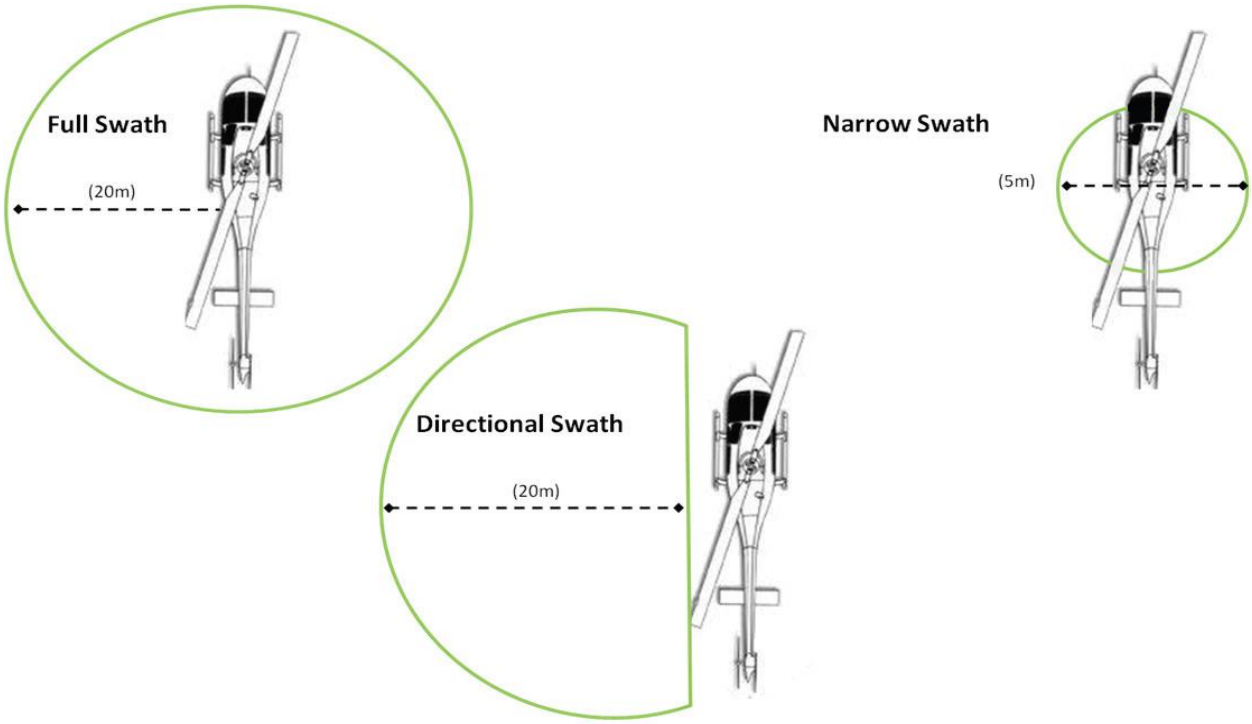


Figure 2.6: Aerial bait applications types *(Swath widths shown are not specific to this project).*

To ensure complete and uniform application of rodenticide:

Figure 2.7: GPS navigation bar

- 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.

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 at the same application rate to ensure eradication success. An aerial application strategy similar to that proposed was employed successfully during a recent rat eradication operation on Palmyra Atoll National Wildlife Refuge that resulted in the complete removal of black rats from the atoll (Wegmann 2012).

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 12 hours of flight time would be required to complete the two to three bait applications required, or up to four hours for each application. For Alternative C, involving the broadcast of Diphacinone-50 Conservation, an estimated total of up to 30 hours of helicopter time would likely be required, or 10 hours for each of the three applications. If a fourth application is required then the total helicopter time would be up to 40 hours. Additional hours of flight time and helicopter costs would be involved in transporting the helicopter, personnel and equipment.

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 and pinnipeds, 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.

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.

Figure 2.8 – Helicopter with bait spreading bucket

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 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 would include sites of human habitation and any shoreline areas where the risk of bait drift into the marine environment is considered excessively high. The only inhabited area on the South Farallon Islands is the site containing the two island residences. An exclusion zone around these buildings would be established during the aerial bait application. The power house and other outbuildings are not considered to be areas of human habitation and bait would be applied aerially over these buildings. Bait would also be applied aerially over the concrete water catchment, but this site would be protected as described in Section 2.10.6 to prevent contamination of the island's waters 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 provides 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 10 bait stations per acre (25 bait stations per hectare) 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.

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 Southeast Farallon Island, 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, it 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 four applications of bait across the islands would be required, 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.

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 EPA and GFNMS. If rodent bait is shipped to the island 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 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 Coordinator will be notified immediately and the Refuge's Spill Prevention and Response Plan would be followed.

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 USFWS. 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. However, waters outside of the state marine protected areas 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 NWR would be closed to all non-essential access during the eradication period and for about two months following operations. 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 bait pellets are no longer found on the islands.

The air space over the waters within one nautical mile of the islands are already restricted by the Gulf of the Farallones National Marine Sanctuary below an altitude of 1,000 feet above ground level, but additional temporary closures might be needed to ensure the safety of the pilots and personnel during and for three months after the implementation.

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.

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 island 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, resident and migrant raptors, and common ravens present on the island 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) 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 that is intended for house mice.

2.10.7.1 *Gull hazing*

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 just 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 recently conducted successfully during a mouse eradication on Allen Cay, Bahamas (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).

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), rodent bait could pose a risk for up to 105 days after the last application of bait. 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. If a normal rainfall pattern ensues, bait is expected to pose a risk to gulls for between eight weeks (Alternative B) and 18 weeks (Alternative C) (Appendix D) after its application. Carcasses are expected to fully degrade within a five week period. Monitoring of bait and mouse carcass degradation and disappearance would be undertaken and used as a guide to determine when to cease hazing efforts.

A team of up to 10 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 if needed. A small reciprocating engine (piston) helicopter, most likely 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 would be affected at any one time.

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). Of those, there were 22 which disturbed roosting cormorants, ten events which disturbed common murres, six events which disturbed roosting brown pelicans and six events which flushed shorebirds from intertidal roosts. 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. Pre-trial counts for all species were statistically similar (two tailed tests - northern elephant seal: $t = 1.686$, $p = 0.106$, $df = 22$, harbor seal: $t = 0.347$, $p = 0.732$, $df = 22$, California sea lion: $t = 1.068$, $p = 0.297$, $df = 22$) or higher (Steller sea lion: $t=3.751$, $p=0.001$, $df=22$, northern fur seal: $t = 4.125$ $p < 0.001$, $df=22$) to 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 ($t = 1.198$, $p = 0.270$, $df = 7$), Steller sea lions ($t = 1.306$, $p = 0.233$,$df=7$), and California sea lions ($t = 1.096$, $p = 0.309$, $df = 7$). The other two species showed declines in their populations: northern elephant seals ($t = 6.328$, $p < 0.001$, $df = 7$) and northern fur seals ($t = 3.721$, $p = 0.008$, $df=7$). However, these declines are consistent with regularly observed seasonal declines as juvenile elephant seals and most fur seals depart the island 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 past five years (northern elephant seals: $t = 0.193$, $p = 0.849$, $df = 24$, northern fur seal: $t = 1.136$, $p = 0.267$, $df = 24$). Thus, we conclude that there were no major impacts to pinniped abundance from the trial.

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, which is, in line with the best management practices established by the Alaska FWS (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. 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 would 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. Unless non-target risk is determined

to be unacceptably high, 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 and Corvid Capture, Captive Management and Release*

To minimize risk to raptors and common ravens (*Corvus corax*), attempts would be made to capture raptors and ravens 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) and resources are available. Resident peregrine falcons would be held off island in a captive facility until it is determined safe to return them to the islands. Migrant species including burrowing owls and common ravens would be transported off the island and held for a period in a soft release (large open pen) before being released into suitable habitat on the mainland. Such techniques have been utilized effectively for island rodent eradications throughout the world such as Anacapa (Howald et al. 2010) and Rabida and Bartolome islands in the Galapagos (Ponder and Cunninghame 2011).

2.10.7.5 *Captive Management of Salamanders*

Although (Appendix A) the risk to salamanders from both action alternatives appears to be low, endemic salamander individuals would be collected prior to bait application on Southeast Farallon Island and held in terrariums 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. Up to 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 residential 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 areas 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. (2012), 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. (2012) 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 (Appendix G), the Service would:

- Minimize travel into the wilderness and only allow activities absolutely necessary to ensure the project's success, including conducting the minimum necessary for bait application, non-target mitigation actions, and monitoring.
- Minimize the use of mechanized equipment within the wilderness area.

2.10.9 Protecting Cultural Resources

All known sites with important cultural resources would be clearly marked 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 operational planning in consultation 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. 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 by the Alaska FWS (USFWS 2013).

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 ecosystem monitoring described below. Operational monitoring would encompass tracking a range of parameters necessary to

ensure project success, which is the complete removal of all house mice from the 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*

Mitigation monitoring including an island wide censuses of wildlife 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 raptors and corvids requiring capture and translocation) and gauge the effectiveness of mitigation techniques. 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, daily surveys and searches would be conducted for 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) and the Endangered Species Act (ESA). As evidenced by the gull hazing trial completed in 2012 disturbance to native wildlife on the South Farallon Islands as a result of the action alternatives is expected to be no more than minor (a full analysis of the potential impacts to all of the Farallon Island resources can be found in Chapter 4) .

2.10.10.3 *Monitoring of Non-target Mortality*

Within one week of the start of project implementation, all easily 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. Three days after the rodent bait is first applied, daily carcass searches and removal would be conducted for assessments of non-target 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. 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 Gulf of the 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 applications would be made.

2.10.10.4 *Monitoring of Ecosystem Restoration Objectives*

The eradication of house mice is expected to result in an increase in the abundance of many native species on the Farallones, primarily seabird species including ashy and Leach's storm-petrels. Benefits are likely to occur for other species such as the endemic Farallon arboreal salamander, Farallon camel cricket, other island invertebrates, and native plants.

Monitoring with the intention of documenting these changes 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 biodiversity and ecosystem function. Biological monitoring on the South Farallon Islands has been an integral part of the management of the islands for over 43 years. Current monitoring efforts include a wide array of activities that 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, and white sharks (http://www.prbo.org/cms/157; See Section 4.8.3 for a summary of current monitoring and research activities). In addition, the Gulf of the Farallones National Marine Sanctuary conducts annual monitoring of intertidal algae and invertebrates.

2.10.10.4.1 Bird Monitoring

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 counts of breeding birds, estimates of productivity, storm-petrel mist-netting to assess population trends and other techniques will be used to monitor the impact of mouse eradication on seabird species. These actions would be carried out by the Service, PRBO Conservation Science, and other contracted or partnering individuals or organizations. The Service, PRBO 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 to detect and track any changes to the island plant community.

2.10.10.4.4 Intertidal Monitoring

Intertidal monitoring would include monitoring of near-shore fish and intertidal invertebrate communities before and after implementation of the project. NOAA has established long-term intertidal study plots around the periphery of Southeast Farallon Island that have been monitored annually by GFNMS since 1993. It is expected that this monitoring program would detect any long-term impacts of the eradication on the relative abundance and diversity of intertidal invertebrates.

If greater than negligible bait drift into the marine environment is detected, additional monitoring of intertidal areas would be conducted after bait application. Samples of fish and marine invertebrates from the intertidal zone would be collected within 48 hours of bait application and submitted for assay to determine if residues exist. If residues are detected then monitoring of the same species would be conducted on a monthly basis thereafter until no further residues are detected. Similar studies have been conducted during and after other rodent eradications (e.g. Howald et al. 2001, Fisher et al. 2011, Pitt et al. 2012). Species to be sampled would be determined in consultation with NOAA.

2.10.11 Biosecurity Measures

In order to mitigate the risk of future rodent reinvasion on the Farallon National Wildlife Refuge, the Farallon Biosecurity Plan (Appendix B) would be implemented by USFWS and PRBO Conservation Science prior to the proposed mouse eradication to prevent and detect future rodent incursions. Southeast Farallon Island hosts a biological research station that is operated year-round by the Service, PRBO, 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 quarantine measures might include the 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 outside agencies of quarantine measures, it is critical that informational briefings, contract and Special Use Permit language, and public outreach 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 including treating the area with rodenticide applied by bait stations, live trapping, snap trapping, sticky pads, or by a combination of these methods. The biosecurity measures that are outlined in the plan must be continued and refined as needed by all staff, volunteers, cooperators, contractors, and other visitors, in perpetuity, and should include appropriate staff training.

Biosecurity measures include post-application rodent detection, rodent reintroduction prevention, and rodent response actions. The conservation and socioeconomic benefits of eradicating mice

from the Farallones would only be fully realized if it is successful, and rodent reinvasion is prevented. Mouse detection response and pest reinvasion mitigation or biosecurity plans are critical components of successful eradication campaigns. The Farallon Biosecurity Plan describes these measures. Detection stations placed in the housing areas and buildings would be monitored and serviced on an ongoing basis according to a set schedule. 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 mouse sighting due to a re-invasion.

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

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. 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 near the specified rates on the current EPA bait label (Reg. No. 56228-37). 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 to increase the application rate in these areas during each application. Applying more bait to steeper areas is appropriate as these areas increase the island's surface area. As above, near label application rates would also be used for any areas where bait is applied by hand. These areas may include caves, and other areas excluded from aerial bait application. Hand baiting may also be used to fill gaps in aerial bait application if deemed appropriate. 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 a maximum of 20 m x 20 m apart to ensure that bait is available to all mice. Exact application rates of Brodifacoum-25D Conservation that will be used would be determined during the development of the detailed operational plan and adaptively managed as necessary during the operation.

Brodifacoum-25D Conservation bait would be applied in two to three applications, each separated by an interval of 10 to 21 days. A third application would be completed if bait was severely degraded by rainfall. 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, the total amount of bait needed would be between 2,917 lb (1,323 kg) and 3,889 lb (1,760 kg). This amount of rodent bait contains between 1.16 oz (33g) and 1.54 oz (44g) 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 two hours of helicopter flight time over the islands. The second applications would be completed with just two bucket loads and require less helicopter flight time. 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. If a third application is deemed necessary through adaptive management, the same protocol for the second application would be used.

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 to three applications, each separated by an interval of 10 to 21 days. A third application would be completed if bait was

severely degraded by rainfall. 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 and other factors outside of the control of the project may delay operations and require deviation from the operational window to maximize the project's likelihood of success or reduce non-target impacts. If weather conditions interfere with scheduled applications, some back-baiting (baiting of areas previously baited) may be required to prevent potential gaps in coverage. Any delays or changes in the schedule of bait application will utilize adaptive management to determine the most appropriate measures to take.

2.11.4 Alternative B: Summary

The operational details for Alternative B are described in Section 2.11.2. 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.

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 0.07 oz (1-2g) pellets with an added fish flavor. The bait contains 50 ppm or 0.005 percent diphacinone. 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. 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) found that an uninterrupted supply of rodent bait containing diphacinone must be provided for at least 10 days for mortality to ensue in rats (using 'Ramik Green' compressed cereal baits with 0.05g/kg 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 should be applied three to four times over the course of an eradication attempt (3-4 weeks) at a rate of at least 43 lb/acre (48 kg/ha) in each application. 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 128 lb/acre (144 kg/ha) or approximately 15,860 lb (7,200 kg) in total. The total amount of diphacinone that would be applied would be between 12.7 oz (360 g) and 16.9 oz (480 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. If there is substantial reduction in the time that bait is available, a fourth application could be required.

To ensure uniformity in the application rate across the islands, steep areas may be flown a second time to increase the application rate in these areas during each application. Applying more bait to steeper areas is appropriate as these areas increase the island's surface area. The same application rates as specified above would also be used for any areas where bait is applied by hand. These areas may include caves and other areas excluded from aerial bait application. Hand baiting may also be used to fill gaps in aerial bait application if deemed appropriate. 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 maximum spacing of 20m x 20m. The exact number of applications and the rate at which Diphacinone-50 Conservation would be applied would be determined in the development of an operational plan and adaptively managed during the operation as necessary.

Approximately 5,286 lb (2,400 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 10 helicopter trips and approximately 3.5 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 rates exceed current EPA label (Registration Number 56228-35) rates. Consequently, a supplemental label would be required. Consultation with USDA and EPA would be necessary to secure a supplemental label that would 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. Weather and operational considerations may delay operations and require deviation to the operational window to maximize efficacy and reduce non-target impacts. If weather conditions interfere with the scheduled applications, some back-baiting (baiting of areas previously baited) may be required to prevent the possibility of gaps in coverage. Adaptive management would be used to determine the most appropriate response to any gaps in coverage.

The bait application strategy for Alternative C would involve broadcasting a proportion of the total amount of bait required during three or four applications, each separated by a time interval

of approximately seven days. A fourth treatment would be conducted if bait was severely degraded by rainfall. More closely spaced applications are planned for Alternative C 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).

2.12.4 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. Over 5 times the amount of rodenticide would be required compared to Alternative B.

2.13 Comparative Summary of Actions by Alternative

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

Action Attribute	Alternative B	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	3-4
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)	128 lb/acre (43 lb/acre x 3) 144 kg/ha (48 kg/ha x 3)
Anticipated total amount of rodent bait that would be applied	2,917 lb (1,323 kg)	15,560 lb (7,056 kg)
Concentration of rodenticide within rodent bait	0.0025%	0.005%

Action Attribute	Alternative B	Alternative C
Anticipated total amount of rodenticide to be applied	33g	353g
Anticipated hours of flight time required for aerial bait application actions	Up to 8 hours (4 hours x 2)	Up to 30 hours (10 hours x 3)
Total helicopter time over island for bait application	Up to 3 hours (~1.5 hours per application)	Up to 10 hours (~3.3 hours per application)
Bait application duration	Up to 21 days (2 drops 21 days apart)	At least 21 days (3-4 drops, each 1 week 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, carcass removal, use of bait stations	Timing of operation, gull hazing, raptor 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

3 Affected Environment

3.1 Introduction

The Farallon 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 PRBO Conservation Science (PRBO) 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 Gulf of the Farallones National Marine Sanctuary. This 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, which together contains almost 7,000 square miles of ocean from Cambria to Bodega Bay 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), North Farallon Islands State Marine Reserve, Southeast Farallon Island State Marine Reserve, and Southeast Farallon Island State Marine Conservation Area. 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, 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 Services/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 several 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. Introduced European rabbits were present on the islands from the late 1800's until 1975 when they were removed by FWS and PRBO (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 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 FWS and PRBO in 1972 (Campbell et al. 2011). In addition, PRBO and FWS continue 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, 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, 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"). Several offshore islets immediately surround the main islands, including Saddle (or "Seal") Rock, Sugarloaf, Arch Rock, Aulon Islet, Sea Lion Rock, and Chocolate Chip.

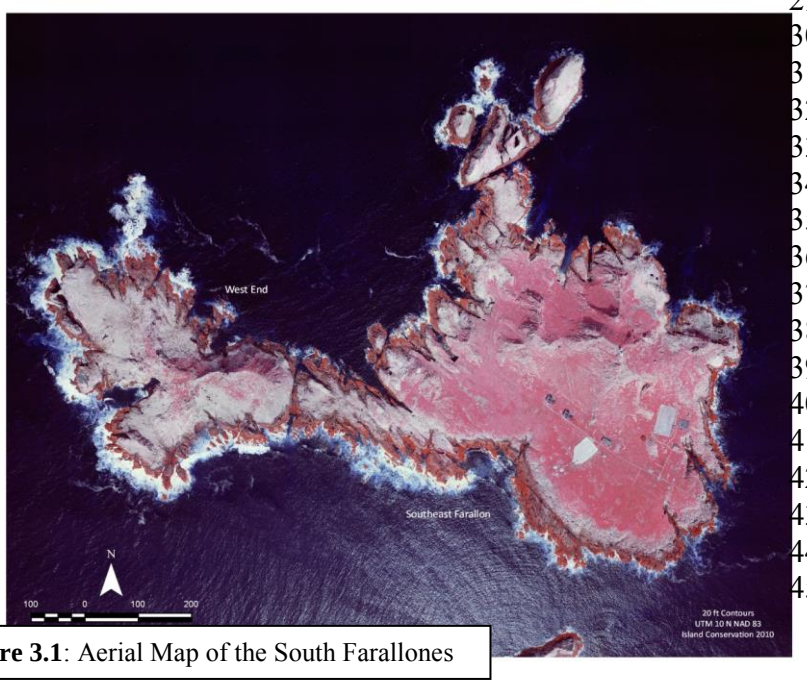


Figure 3.1: Aerial Map of the South Farallones

The Farallon Island group and the Farallon 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.

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; PRBO, 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 (PRBO, 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 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 in (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).

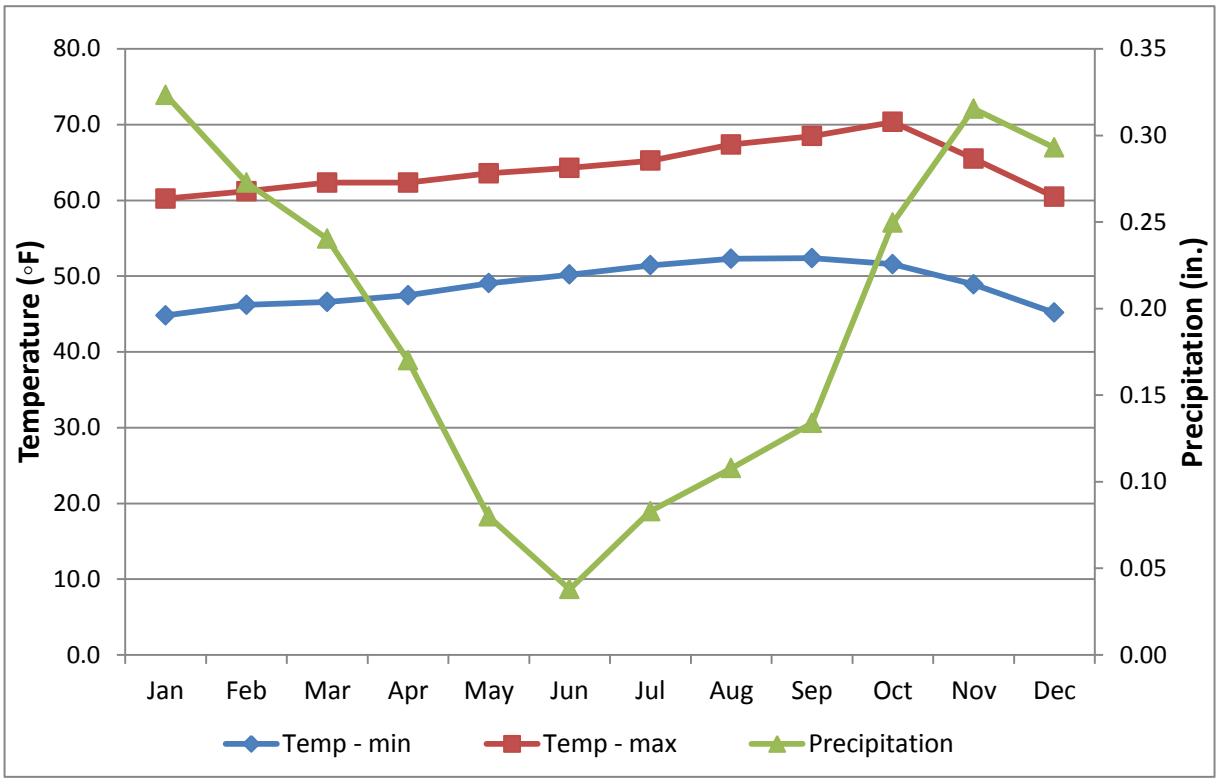


Figure 3.2: Mean temperature and precipitation on the Southeast Farallon Islands between 1971 – 2010 (PRBO, unpubl. data).

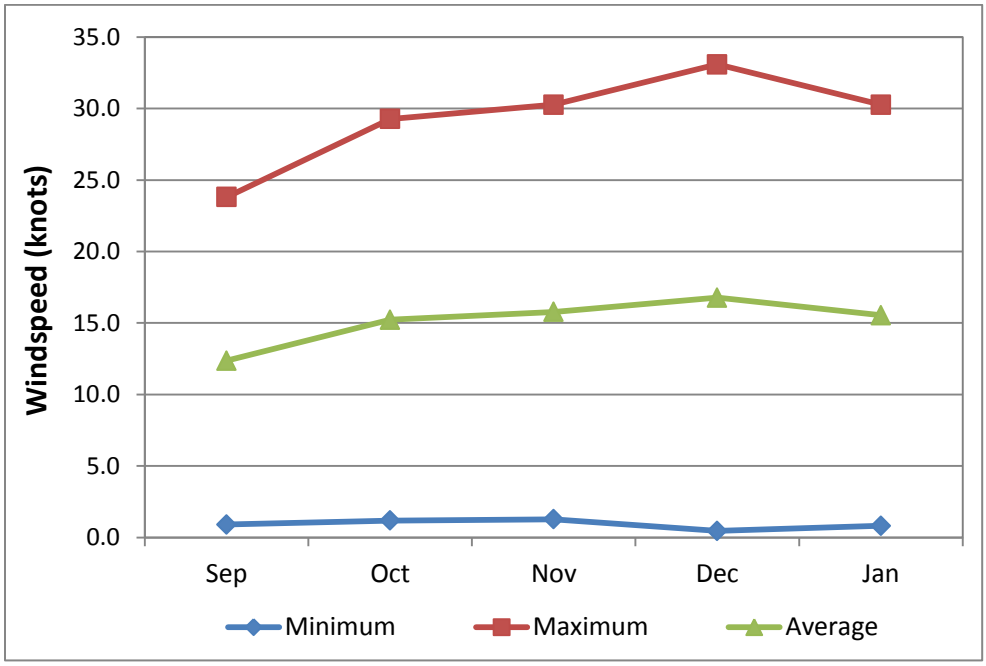


Figure 3.3: Windspeeds on the Southeast Farallon Islands between 2000 – 2010 (PRBO, unpubl. data).

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 three to four times a year 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 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 Gulf of the Farallones National Marine Sanctuary 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 winds, currents, and sea conditions, which could easily overcome protection efforts. Discharges from sunken

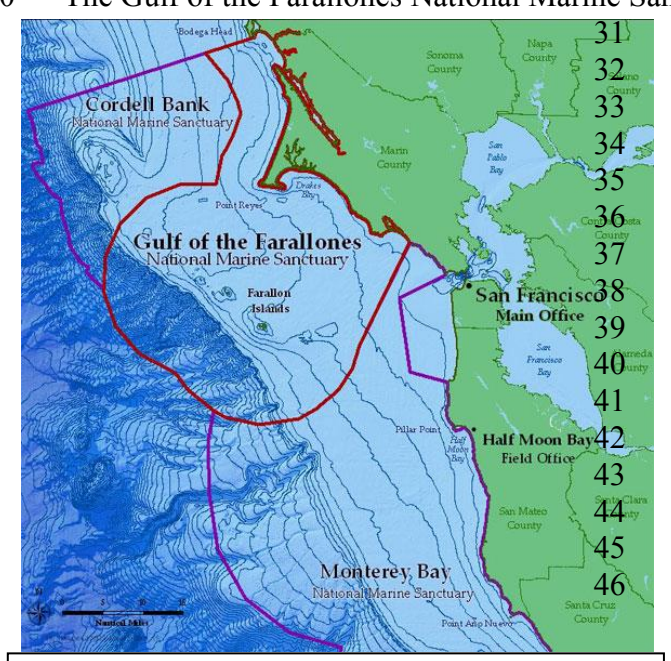


Figure 3.4: Gulf of the Farallones National Marine Sanctuary

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 Island seabird and marine mammals (Jarman et al. 1996).

The Gulf of the Farallones NMS 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 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 (1996) 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 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 National Wildlife Refuge host the largest seabird breeding colony in the contiguous United States. Twenty-five percent of California's breeding marine birds, with more than 200,000 to 300,000 individuals of 13 species, can be found there. About fifty percent of the world's population of the rare ashy storm-petrel (listed as a Species of Management Concern by the U.S. Fish and Wildlife Service and Endangered by the International Union for Conservation of Nature) breeds on the Farallon National Wildlife 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 4.8.7 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 island's ecosystem as a consequence of the removal of house mice (See Section 4.8 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

PRBO has conducted standardized daily monitoring of migrant birds on Southeast Farallon Island since 1968. Over 421 avian species have been recorded on the island, arrive while migrating or traveling through the area (Richardson et al. 2003) (PRBO unpubl. data). The Farallon Islands supports the largest seabird breeding colony in the continental U.S. south of Alaska, with over 200,000 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, black oystercatcher, 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 (Warzybok et al. 2003, Warzybok and Bradley 2011). In addition, during recent years three new or previously extirpated species have bred on the island including common raven, peregrine falcon, and Canada goose (*Branta canadensis*) (Warzybok and Bradley 2011).

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*), Heerman's gull (*Larus heermanni*), and glaucous-winged gull (*L. glaucescens*). Additionally, an average of nine species and 125 individual landbirds are recorded daily 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 and nesting areas.

3.4.2.1 ***Seabirds***

3.4.2.1.1 *Breeding seabirds*

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 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 host 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.

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 (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 aclid 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).

Table 3.1: Marine bird breeding population estimates (numbers of breeding birds) on the South Farallon Islands (PRBO, unpubl. data). Most estimates are based on 2002-2011 averages. X indicates present but no recent estimate.

Species	No. Breeding Birds
Leach's Storm-Petrel	X
Ashy Storm-Petrel	5,768[1]
Double-crested Cormorant	340
Brandt's Cormorant	10,179
Pelagic Cormorant	274
Black Oystercatcher	35
California Gull	333
Western Gull	17,122
Common Murre	198,569
Pigeon Guillemot	2,614
Cassin's Auklet	18,253[2]
Rhinoceros Auklet	3,192[3]
Tufted Puffin	150

[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. 2013).
[2] Does not include West End Island, where 2,243 breeding birds were estimated in 2009.
[3] Estimate is from 2009.

3.4.2.1.2 <u>*Non-breeding seabirds*</u>

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, Canada goose, 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 species including other loons, grebes, albatrosses, gulls, shearwaters, petrels, ducks, and geese visit the islands on a less frequent annual basis and are summarized in Richardson et al. (2003). Finally, many other species of freshwater and estuarine waterbirds have been sighted on the Farallones during migration, and some occasionally overwinter on the islands. The community makeup of these additional waterbirds 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, and willets. 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 (*Tringa semipalmata*), wandering tattler, whimbrel (*Numenius phaeopus*), 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 (PRBO unpubl. data)

3.4.2.3 *Raptors*

For the past several decades there were no year-round resident raptors on the Farallon Islands. However, a pair of peregrine falcons has been resident since 2008 with confirmed breeding in 2009 (PRBO, unpubl. data). In addition to this breeding pair, researchers have observed an average of four to six individual peregrines on the islands during the winter from 1990-1999 and numerous other migrants (Pyle and Henderson 1991, Earnheart-Gold and Pyle 2001), a number that increased during the 2000's (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 SEFI including seabirds, shorebirds and landbirds that are captured either over the island or offshore (USFWS 2009). Several other non-breeding raptors visit the island 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 island during spring and fall migrations (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, PRBO 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. Since the spring of 2009, presumably the same a pair of common ravens has been present off and on and breeding was confirmed in 2010, the first such occurrences in several decades. Canada geese also 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*

3.4.2.5.1 *Seabirds:*

3.4.2.5.1.1 *Breeding Seabirds*

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 three 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, and murres begin to return for periodic non-breeding season visits in late October or early November. 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 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. They reach peak numbers in February, remaining high through 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, 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.

3.4.2.5.1.2 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). 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.

3.4.2.5.2 <u>Shorebirds:</u>

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 (PRBO unpubl. data).

3.4.2.5.3 <u>Raptors:</u>

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 island, 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 overwinter, supported by a diet of house mice in the fall and storm-petrels in the winter and spring. All birds generally depart the islands by early May (PRBO, unpubl. data).

3.4.2.5.4 *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 mid-November and mid-December (PRBO, unpubl. data), which is within the target window for implementation of either action alternative.

3.4.2.6 ***Special status bird species***

All the native birds that visit or reside on the South Farallones are protected from harm 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 Endangered Species Act (ESA). However, the formerly listed American peregrine falcon (*P.f. anatum*) was delisted in 1999 (USFWS 2006) due to recovery (Comrack and Logsdon 2008), and the California brown pelican was delisted in 2010. Most American peregrines are migrants, and up to 56 individuals were recorded on SEFI between 1990-1999, up to three individuals annually winter each year, and a resident pair since 2008 is of this subspecies (Earnheart-Gold and Pyle 2001). Brown pelicans are common migrants and often roost on the islands (see above). The ashy storm-petrel is listed as endangered

by the IUCN but this provides no special legal protection (Birdlife International 2012). However, this species is being considered for listing under the ESA (Birdlife International 2012).

Several bird species that breed on or visit the Farallon islands are listed as California Bird Species of Special Concern and include: tufted puffin, ashy storm-petrel, Cassin's auklet, burrowing owl, brant, harlequin duck **(***Histrionicus histrionicus*), olive-sided flycatcher (*Contopus cooperi*), loggerhead shrike (*Lanius ludovicianus*), purple martin (*Progne subis*), yellow warbler (*Setophaga petechia*), and grasshopper sparrow (*Ammodramus savannarum*) (Richardson et al. 2003, California Dept. of Fish and Game 2011).

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). 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

Photo by Derek Lee, PRBO

Arboreal salamanders are primarily nocturnal and forage on the ground or, 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) 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 PRBO surveys on Southeast Farallon Island indicate population size appears stable and salamanders are largely sedentary. 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-mark-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.

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 island. 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, PRBO 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).

PRBO biologists have recorded the presence of hoary bats on the island since 1965, 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 *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 have been conducted on the Farallones. 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. It is expected that the removal of house mice would result in increases in invertebrate populations. A unique island form of the flightless intertidal beetle (*Endeodes collaris)* has also been described (Giuliani 1982).

Possibly the most abundant terrestrial invertebrate on the Farallones is the kelp fly (*Fucellia thinobia*). Kelp 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 and burrowing owls consume invertebrates throughout the migratory season and rely on their high protein content to refuel at migratory stopover sites such as the Farallon Islands.

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. Although it is not clear 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 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 (PRBO, 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

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).

Sanctuary Ecosystem Assessment Surveys (SEAS), a Gulf of the Farallones National Marine Sanctuary (GFNMS) program, have been ongoing since 1993 to monitor rocky intertidal algal (seaweed) and invertebrate species abundances on 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 are considered to provide a reliable baseline of species abundance and trends upon which potential impacts of action alternatives can be measured against.

Over 190 algal species/taxa, at least one seagrass, over 230 invertebrate, and 10 intertidal fish species/taxa on the islands have so far been documented in the program. The list is from the sampling, shore walk observations, and collections since 1993.

3.4.4.1 *Intertidal Invertebrates*

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 Blow Hole 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, similar to what can occur as a consequence of human foot traffic on the mainland. 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.

Standardized surveys for intertidal black abalone (*Haliotis cracherodii*), a species recently listed as Federally endangered, were initiated in 2009. Recent surveys suggest this species is present at extremely low abundance on the Farallon Islands; the most recent survey found just one individual. Unfortunately, historical data are limited or lacking from locations for comparison purposes.

3.4.4.2 *Nearshore Fish*

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). 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. The highest rockfish diversity found off the coast of California includes 56 species. 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. Its range is from Kodiak Island, Alaska to central Baja California. It can reach a total size of 10 in (25 cm) and has seven vertical dark bands. 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 North-eastern Pacific Ocean. The range of depths in which this fish is found extends from zero to 3,000 feet (0 to 910 m) below sea level. Further north the spotted ratfish lives close to the shore. On the southern end of their range, they live in deeper waters. 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. The spotted ratfish swims slowly above the seafloor in search for food. Locating food is done by smell. Their usual hunting period is at nighttime, when they move to shallow water to feed. 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 is monotypic within the genus *Anarrhichthys*. This superficially eel-like fish feeds on crustaceans, sea urchins, mussels, clams and some fishes crushing them with its strong jaws. 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). They are much smaller than the larger and more northern-ranging Pacific halibut that can reach 300 pounds (140 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. The eyespots on the skates' wings are believed to serve as decoys to confuse predators. Juvenile northern elephant seals are known to consume the egg cases of the big skate (Fishbase. 2013).

The Pacific sanddab is a species of sanddab; it 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. The cabezon is a scaleless fish with a broad bony support extending from the eye across the cheek just under the skin. Cabezon 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). The red brotula is the only known member of its genus. 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).

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 surrounding waters year-round, with peak numbers from May through August (Ainley and Allen 1992, PRBO unpubl. data); however peaks of more than 10,000 animals have been observed in recent years (PRBO, 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 a major breeding site for California sea lions, yet several dozen pups have been born annually in recent years (PRBO, 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 over the past 6 years (Berger 2012a). In 2012, a total of 90 cows were counted on the South Farallones, and 60 pups were weaned (Berger 2012a). PRBO's average monthly counts from 2000-2009 ranged from 20 individuals in July to nearly 500 individuals in November (PRBO unpubl. data).

Northern elephant seals are present on the islands and in the waters 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

Immatures return to the rookery 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). Between less than ten pups are born on the South Farallones each year (PRBO 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 (PRBO 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 (PRBO 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 small but increasing numbers on West End during the summer; 521 animals were observed in 2012 (Tietz 2013b). 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 far 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 and previously bred at the 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 has 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). 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). Regardless, the status of Steller sea lions on the South Farallones is precarious.

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, is listed as Threatened under the Endangered Species Act (ESA). The South Farallon rookery and waters around the island are designated Critical Habitat under the ESA (50 CFR 226.202). In addition to the island, the Critical Habitat designation includes the waters and air space within a radius of 3,000 feet of the rookery (NMFS 2008). The Steller sea lion was listed as Federally Threatened under the ESA in 1990 due to an 80 percent decline in the U.S. population between the 1950s and 1990. In 1997, after new genetic information revealed the existence of significant stratification between regional populations, management of Steller sea lions under the ESA was split amongst two distinct population segments (DPS), the western DPS and the eastern DPS. The western DPS, which is primarily composed of Steller sea lions in the Aleutian Islands, was up-listed to Endangered at that time. The eastern DPS, which includes Steller sea lions on the South Farallones, remained listed as Threatened, although there is an active petition to delist this DPS.

Over the past 20 years, the eastern DPS overall population has been increasing, but most of this increase has occurred in southeast Alaska and British Columbia with population counts in California remaining stagnant or decreasing (NMFS 2008). The reasons for ongoing population declines in central California are unclear, but competition with increasing numbers of, California sea lions, disease, and changing oceanic conditions may be contributing factors (NMFS 2008).

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). The rarity with which these species occur precludes them from detailed analysis in this document.

There are also a number of cetacean species that 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 unlikely to be affected by any of the actions described and analyzed in this document because project activities are restricted to the islands themselves and will not be undertaken in the surrounding marine environment.

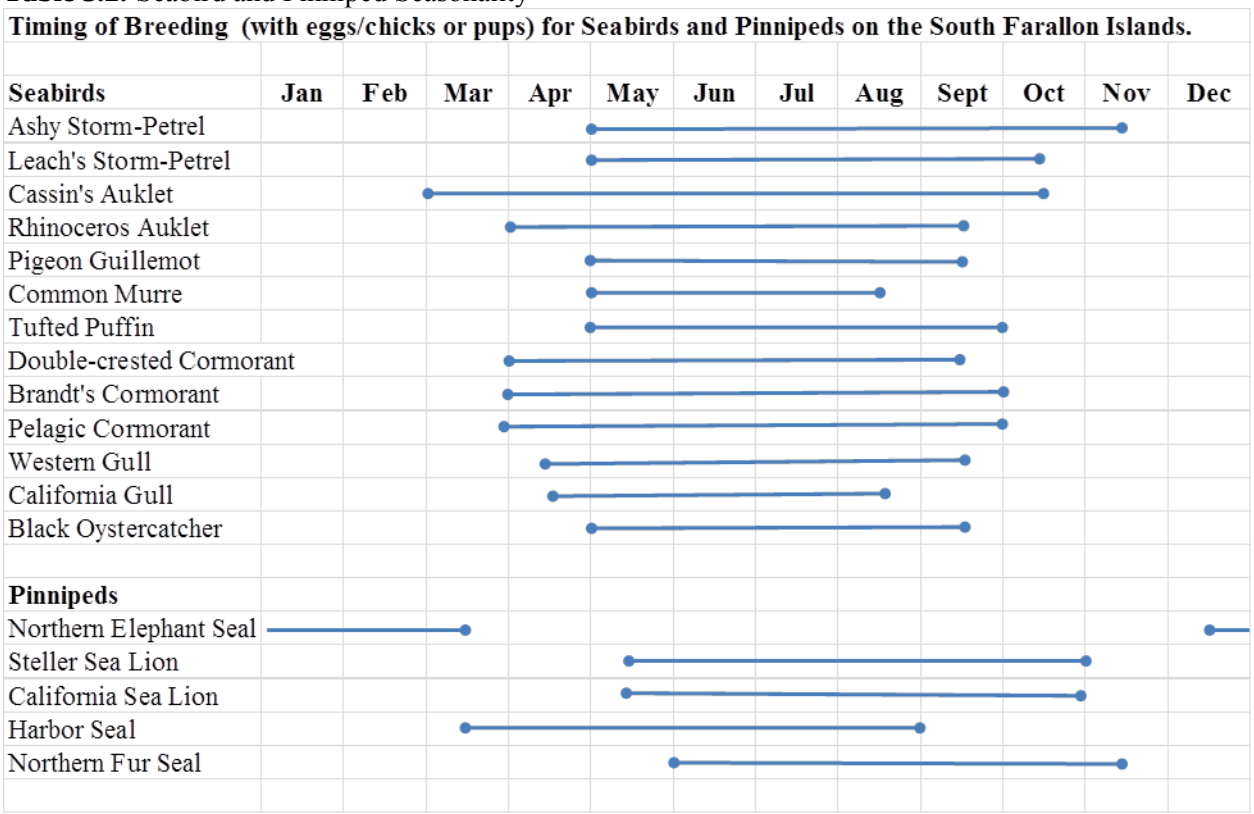
3.4.5.7 *Special legal protection for marine mammals*

All of the marine mammals at the South Farallones are protected from harm under the Marine Mammal Protection Act (MMPA). The Steller sea lion is listed threatened under the ESA.

3.4.6 Breedgin 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 (Figure 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 (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 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 buck's horn 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.

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). 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 buck's horn 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 led by the Service, conducted from late summer to early spring, 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 (*Cupressus 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 (*Lavatera 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 Economic Environment

3.5.1 Ownership/Management/Major Stakeholders

The South Farallon Islands are managed as part of the Farallon 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 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 Gulf of the 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 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).

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 PRBO Conservation Science 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 island 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).

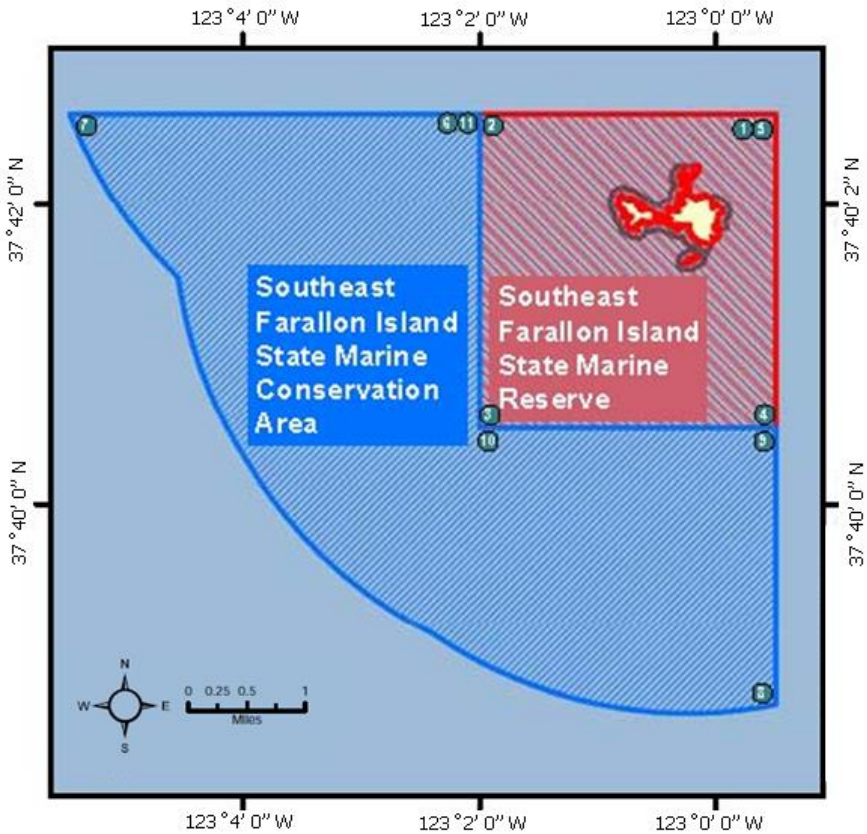


Figure 3.6: Southeast Farallon Island State Marine Reserve and Southeast Farallon Island State Marine Conservation Area (adapted from California Dept. of Fish and Game 2010).

3.5.2 Recreational and Aesthetic Uses

There are currently no on island recreation opportunities available to the public on the Farallon NWR due to the presence of sensitive wildlife and habitats, as well as safety considerations. 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 (weather permitting) out 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, surfperchers, 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.

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 past 23 years, the proportion of revenues derived from commercial fisheries' landings in study-area ports has increased, from five percent of the state total in 1981 to several times that number in recent years.

3.5.4 Historical & Cultural Resources

The South Farallones have had extensive human activity 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 have 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 3.3).

Table 3.3: 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
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: SEFI houses

The two existing residences (Figure 3.7) where built to accommodate lighthouse crews originally 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 PRBO 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 amount 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 *highly controversial*. The courts have since elaborated on this consideration, stating that controversy would be in the form of "substantial dispute" as to "the size, nature or effect of the major Federal action rather than to the existence of opposition to a use [e.g., eradication of mice], the effect of which is relatively undisputed" (*Hanly v. Kleindienst,* 471 F.2d 823, 830 [2d Cir. 1972]).
- 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 economic environment
  - Impacts to personnel safety
  - Impacts to refuge visitors and recreation
  - Impacts to fishing resources
  - Impacts to cultural and historical 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 1.5.

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 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. We considered both the local (i.e., Farallon Islands region) and range-wide population levels.

- **Social and Historical 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.
    - Cultural 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 DEIS. 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 and few occur near the islands during the proposed implementation period. Thus, 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 maximum effort would be taken to prevent bait drift into the marine environment, permitting for aerial pesticide use around the littoral zone would be sought in compliance with EPA's new 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, house mice on the South Farallones are not currently 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 quality conditions would remain unchanged.

4.4.1.3 Alternative B: Aerial Broadcast of Brodifacoum

Some bait pellets may drift into near-shore marine waters during bait application operations. However, the proposed bait application techniques include mitigation measures that would minimize such bait drift. In addition, the Service would acquire all necessary permits from the GFNMS, Cal 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. The low water solubility and strong chemical affinity of brodifacoum to the grain matrix of the bait pellets is an effective inhibitor preventing the rodenticide from contaminating aquatic environments. Hypothetically, even if brodifacoum was highly water soluble and bait was broadcast at the rate of 16 lb/ac (18 kg/ha) into water only 3.3 ft (1 m) deep, the resultant concentration of brodifacoum in the water (about 0.04 parts per billion) would still be nearly 1000 times less than the measured LC_{50} (lethal concentration where 50 percent of the population will experience a lethal impact) value for trout (0.04 parts per million) (Syngenta Crop Protection 2003). 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) (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.

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, Island Conservation unpubl. data). Furthermore, post-application sampling in the Anacapa Island rat eradication did not detect any brodifacoum residue in any of the intertidal invertebrates tested (Buckelew et al. 2005), which would suggest water contamination.

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. Therefore, the significance determination for this alternative is expected to be negligible.

4.4.1.4 Alternative C: Aerial Broadcast of Diphacinone

Some bait pellets may drift into near-shore marine waters during bait application operations. However, 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. In addition, the Service would acquire all necessary permits from the GFNMS and Cal 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 very 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 prevents the rodenticide from entering aquatic environments via run-off. Hypothetically, even if diphacinone was highly water soluble, and bait was broadcast at the rate of 16 lb/ac (18 kg/ha) into water only 3.3 ft (1 m) deep, the resultant diphacinone concentration in the water – about 2.8 parts per billion – would still be nearly 1000 times less than the measured LC_{50} value for trout (2.8 parts per million) (Extoxnet. 1996). Additionally, the Farallones are characterized by their steep rocky coastline, high wave action and strong currents, which would likely breakdown 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. Laboratory tests failed to detect diphacinone in any samples taken after bait application (Gale et al. 2008, Orazio et al. 2009). 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. Therefore, 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, 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 noticeable impact on soil erosion, rock formations, or soil contamination. The installation and maintenance of bait stations in limited circumstances may have highly localized impacts 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 would not lead to long-term soil contamination (World Health Organization 1995). Brodifacoum is strongly bound to soil particles, and 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.

Monitoring data from projects that have used brodifacoum indicate either no soil contamination or insignificant levels of contamination. 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 had just 1.2 ppm of brodifacoum. After 153 days the highest residue level measured from soil extracted from underneath Pestoff 20R baits used on Hauturu Island in 2004 was 0.07 ppm (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 brodifacoum residues of 0.0016 ppm. Soil samples were collected from the Bay of Islands 58 days post baiting and contained brodifacoum residues of approximately 0.002 ppm. 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 ppm) in topsoil analysis on Palmyra Atoll during monitoring efforts conducted 50 days after bait application.

Monitoring of marine sediments following the aforementioned brodifacoum spill 18 tons at Kaikoura 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 ppm). Furthermore, samples taken nine days after the spill were below the level of detection (0.02 ppm) (Primus et al. 2005).

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

4.4.2.4 Alternative C: Aerial Broadcast of Diphacinone

The activities in Alternative C would not have a noticeable impact on soil erosion, rock formations, or soil contamination. The installation and maintenance of bait stations in limited circumstances may have highly localized impacts 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 expected to reach at most the soil surface. 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 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 two ppm 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 13mm 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.

4.4.3 Wilderness

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. This analysis addresses the effects of the alternatives on wilderness character. 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
- Outstanding opportunities for solitude or a primitive and unconfined type of recreation (Landress et al. 2008).

The Service has prepared a draft Minimum Requirements Analysis (MRA) in compliance with the Wilderness Act to determine the minimum necessary actions in the wilderness (Appendix G). The MRA compares the positive and negative effects of seven alternatives to each of the four characters of wilderness quality. The MRA will be finalized prior to finalizing this EIS and the MRA's selected alternative incorporated into the Record of Decision.

4.4.3.2 Alternative A: No action

This effect has degraded the natural wilderness character. 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. 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 some the complete removal of mice their negative effects would continue in perpetuity.

4.4.3.3 Alternative B: Aerial Broadcast of Brodifacoum

The aircraft and personnel activity required under Alternative B would have a short-term adverse impact on the following attributes of wilderness character. The eradication effort would require the temporary manipulation and disturbance of the existing ecological processes in an effort to restore a natural system that has been disrupted through the introduction of an invasive species. These impacts would be limited in duration but noticeable during that time.

Bait application would be undertaken over two to three separate days during the fall, most likely during the month of November. The broadcast of bait over the entirety of the islands, including the wilderness areas, by non-mechanized means has been excluded from consideration largely because of safety considerations (Section 2.7). Thus, completion of the mouse eradication operation would require the use of a turboprop (jet engine) helicopter to apply rodent bait across the islands. Aerial bait broadcast would require multiple low-altitude flights by helicopter above most areas of the wilderness. Portions of the wilderness requiring hand-baiting may be inaccessible on foot and require access to the shoreline by boat. While non-motorized boat access may be possible, strong currents, rough surf, and the large numbers of white sharks in the Farallon nearshore waters would likely make the use of non-motorized boats such as kayaks extremely unsafe. Helicopter transport of personnel to certain portions of the wilderness may also be necessary to support bait broadcast or gull hazing efforts in cases when safe access is otherwise prohibited or disturbance to pinnipeds outweighs the untrammeled impacts from helicopters.

Rodent bait may be present within wilderness areas for several months before being consumed or degraded by rainfall and other factors. Up to 100 bait stations may also be established in these areas to protect bait from consumption from non-target species such as gulls. Bait stations may be established at least six weeks prior to the aerial application of rodent bait and would likely remain in place for one month after the last evidence of mouse consumption of bait is observed. All bait stations and other equipment used during the operation would be removed from wilderness areas at the completion of the operation.

Access to the wilderness to broadcast bait and conduct gull hazing activities will result in the disturbance of thousands of pinnipeds, including California and Steller sea lions, Northern fur seals, northern elephant seals, and possibly harbor seals, as well as roosting seabirds and shorebirds. Disturbance to pinnipeds is expected to be greatest during bait broadcast when multiple passes of each area will be conducted, while disturbance to birds may be greatest during hazing activities. Pinnipeds will also be flushed during gull hazing operations, both from human approach to access wilderness areas and from loud noises associated with hazing. However, duration of disturbances will be short-term and minimized to the extent possible. A gull hazing trial in December 2012 found that pinnipeds were disturbed much less than expected from both hazing activities and from the Robinson R22 helicopter used to support hazing activities (Appendix E).

In summary, impacts to the untrammeled character of the Farallon Wilderness from the use of mechanized equipment will be only short-term and thus not significant. Impacts to the undeveloped character of wilderness from the placement of bait stations will be short-term and thus not significant. Impacts to the natural character of wilderness will have short-term, not significant negative impacts to disturbed pinnipeds and birds. However, long-term, significant positive impacts will occur from the eradication of house mice because it will remove their negative impacts on the natural Farallon ecosystem. Thus, overall, implementation of Alternative B would result in significant beneficial impacts to wilderness character.

4.4.3.4 Alternative C: Aerial Broadcast of Diphacinone

The aircraft and personnel activity required under Alternative C would have a short-term adverse impact on the following attributes of wilderness character. The eradication effort would require the temporary manipulation and disturbance of the existing ecological processes in an effort to restore a natural system that has been disrupted through the introduction of an invasive species. These impacts would be limited in duration but noticeable during that time. Since the islands are closed to visitors, there would be no effects to opportunities for solitude and unconfined recreation.

Bait application would be undertaken over two to three separate days during the fall, most likely during the month of November. The broadcast of bait over the entirety of the islands, including the wilderness areas, by non-mechanized means has been excluded from consideration largely because of safety considerations (Section 2.7). Thus, completion of the mouse eradication operation would require the use of a turboprop (jet engine) helicopter to apply rodent bait across the islands. Aerial bait broadcast would require multiple low-altitude flights by helicopter above most areas of the wilderness. Portions of the wilderness requiring hand-baiting may be inaccessible on foot and require access to the shoreline by boat. While non-motorized boat access may be possible, strong currents, rough surf, and the large numbers of white sharks in the Farallon nearshore waters would likely make the use of non-motorized boats such as kayaks extremely unsafe. Helicopter transport of personnel to certain portions of the wilderness may also be necessary to support bait broadcast or gull hazing efforts in cases when safe access is otherwise prohibited or disturbance to pinnipeds outweighs the untrammeled impacts from helicopters.

Rodent bait may be present within wilderness areas for several months before being consumed or degraded by rainfall and other factors. Up to 100 bait stations may also be established in these areas to protect bait from consumption from non-target species such as gulls. Bait stations may be established at least six weeks prior to the aerial application of rodent bait and would likely remain in place for one month after the last evidence of mouse consumption of bait is observed. All bait stations and other equipment used during the operation would be removed from wilderness areas at the completion of the operation.

Access to the wilderness to broadcast bait and conduct gull hazing activities will result in the disturbance of thousands of pinnipeds, including California and Steller sea lions, northern fur seals, Northern elephant seals, and possibly harbor seals, as well as roosting seabirds and shorebirds. Disturbance to pinnipeds is expected to be greatest during bait broadcast when

multiple passes of each area will be conducted, while disturbance to birds may be greatest during hazing activities. Pinnipeds will also be flushed during gull hazing operations, both from human approach to access wilderness areas and from loud noises associated with hazing. However, duration of disturbances will be short-term and minimized to the extent possible. A gull hazing trial in December 2012 found that pinnipeds were disturbed much less than expected from both hazing activities and from the Robinson R22 helicopter used to support hazing activities (Appendix E).

In summary, impacts to the untrammeled character of the Farallon Wilderness from the use of mechanized equipment will be only short-term and thus not significant. Impacts to the undeveloped character of wilderness from the placement of bait stations will be short-term and thus not significant. Impacts to the natural character of wilderness will have short-term, not significant negative impacts to disturbed pinnipeds and birds. However, long-term, significant positive impacts will occur from the eradication of house mice because it will remove their negative impacts on the natural Farallon ecosystem. Thus, overall, implementation of Alternative C would result in significant beneficial impacts to 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.

4.5.2 Assessing Significance of Impacts to Biological Resources

As described in Section 4.1, 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 that vary for each taxon.

In general, impacts to the individual, however major, are not considered significant (unless impacts to individuals also impact the population). Significance is instead considered in the context of population-level impacts to species utilizing the South Farallones. As an example, species that have large populations, a wide range, and 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 affects 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. In the analysis below, data from other island rodent eradications were reviewed and, where appropriate, combined with known information of Farallon Islands biological resources used 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:

- Is there a high likelihood that the species' population would incur change that is measurable at the local level, including at the South Farallon Islands, Gulf of the Farallones or central California region?; and
- Is there a high likelihood that the species' population would incur change that is 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 with either the National Marine Fisheries Service (NMFS) or the FWS (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.

Two ESA listed species occur at the Farallon Islands: the eastern distinct population segment (DPS) of the Steller sea lion, listed as Threatened, and the black abalone (*Haliotis cracherodii*), listed as Endangered. Additionally, SEFI is designated Critical Habitat for Steller sea lions. Listing under the ESA provides a context for impacts analysis which lowers the level of acceptable short-term risk for that species. In the short-term, a lower acceptable level of impact for listed species would require the FWS to take additional precautions to minimize the impacts to listed species. For short-term analysis, the impacts to any listed individual should be kept below the listed threshold:

- For Steller sea lions, the acceptable short-term impact should not cause mortality to an individual animal or severely degrade designated critical habitat.

- For black abalone, the acceptable short-term impact should not cause mortality to an individual animal.

4.5.2.2 Special considerations for MMPA-listed species

Listing under the Marine Mammal Protection Act (MMPA) of 1972 provides a context for impacts analysis which lowers the acceptable level of short-term impacts to marine mammals. 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. This analysis would identify the potential for impacts to marine mammals that would likely require additional permits under MMPA.

In the short-term, a lower acceptable level of impact for listed species would require the FWS to take additional precautions to minimize the impacts to listed species. For short-term analysis, the impacts to any listed individual should be kept below the listed threshold:

- For Steller sea lion, the acceptable short-term impact should not cause a Level A Harassment, which is 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)).

- For California sea lion, the acceptable short-term impact should not cause a Level A Harassment, which is 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)).

- For harbor seal, the acceptable short-term impact should not cause a Level A Harassment,

which is 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)).

- For northern elephant seal, the acceptable short-term impact should not cause a Level A Harassment, which is 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)).

- For northern fur seal, the acceptable short-term impact should not cause a Level A Harassment, which is 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)).

4.5.2.3 Special considerations for MBTA-listed species

Listing under the Migratory Bird Treaty Act (MBTA) of 1918 provides a context for impacts analysis that lowers acceptable short-term risk than non-listed species. Take under the MBTA includes the unlawful pursuit, hunt, take, capture, or kill of any migratory bird, nest, or egg of any such bird. All of the bird species found on the Farallones are listed for protection under the MBTA except for the introduced house sparrow, European starling, rock pigeon, and Eurasian collared dove (16 USC 703b).

Under certain circumstances where the goal is eradicating or controlling invasive species, the FWS can provide practitioners with a Special Purpose Permit under the MBTA that allows for the take of listed individuals for "projects where the applicant demonstrates expected benefits to migratory birds. These projects support the Service's bird conservation mandate and mission and are consistent with the Administration's emphasis on control of invasive species" (USFWS 2010). The Service would comply fully with all MBTA requirements prior to the implementation of either of the action alternatives.

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 PRBO 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 other islands where mice were introduced (Angel et al. 2008).

4.5.3.2 Birds

4.5.3.2.1 Impacts to breeding seabirds

Invasive house mice are negatively affecting populations of small seabirds on the South Farallones, particularly ashy storm-petrels and Leach's storm-petrels (see Appendix M for a full

report). Ashy storm-petrels are a species of special concern in California 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 to a lesser extent the Leach's storm-petrel, by supporting a population of burrowing owls that in turn prey on these species. See Section 1.2 for a summary of house mouse impacts on the Farallones and other island ecosystems.

If house mice remain on the South Farallon Islands, there will likely continue to be elevated rates of burrowing owl predation on ashy 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. 2013). In order to evaluate the effects of mouse removal on the South Farallon Islands burrowing owls and ashy storm-petrels, Nur et al. (2013) conducted a study using available data. They used models to estimate the effect of house mouse removal on future ashy storm-petrel populations, compared to no removal. Because of model uncertainty, as well as uncertainty about future conditions and trends, they considered several scenarios for future ashy storm-petrel population trends, based on storm-petrel abundance indices for 2007-2012 from the islands (Nur et al. 2013). These included a steep population decline scenario of about 7 percent per year, a moderate decline scenario of about 3.5 percent annual decline, and a near-stable scenario of about 0.5 percent annual population increase (Nur et al. 2013). Their models indicated that regardless of the future scenario, under No Action, the net effect of house mice and burrowing owls would be to negatively impact the South Farallon Islands ashy storm-petrel population. Thus, the significance determination for ashy storm-petrel is significant to the Farallon population. Because the similar Leach's storm-petrel is less numerous on the South Farallon Islands 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 Farallon population. For all other seabird species, the significance determination is not significant.

4.5.3.3 Mammals

4.5.3.3.1 Impacts to Steller sea lions

Mice are not currently known to impact Steller sea lions. Steller sea lions on and around the South Farallones likely would not be affected if the No Action alternative is adopted and mice are allowed to remain. However, mice have the potential to act as a vector for diseases that could negatively impact sea lions (de Bruyn et al. 2008). Steller sea lions are expected to remain healthy on the Farallones unless a pathogen for which mice could be a vector is transmitted to the islands. In addition, ESA and MMPA significance triggers would not be reached if the No Action alternative were implemented. The significance determination for Steller sea lions is negligible.

4.5.3.3.2 Impacts to other pinnipeds

Mice are not currently known to impact other pinniped species on the South Farallones. Pinnipeds would not be affected if the No Action alternative is adopted and mice are allowed to

remain. However, mice have the potential to act as a vector for diseases that could negatively impact sea lions (de Bruyn et al. 2008). Based on current information, ESA and MMPA significance triggers would not be reached if the No Action alternative were implemented. The significance determination for other pinnipeds is negligible.

4.5.3.4 Amphibians

4.5.3.4.1 Impacts to 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). It is possible 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 juvenile salamanders. Competition for prey and/or predation of 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. However, information are lacking on the severity of these potential impacts. For this reason, the significance determination for mouse impacts to salamanders is not significant.

4.5.3.5 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 Invertebrates

4.5.3.6.1 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. Comparisons to other islands with introduced house mouse populations (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. 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 Straight 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 impacts would continue if mice are allowed to remain. Thus, the significance determination for insects, spiders, and other terrestrial invertebrates is significant.

4.5.3.6.2 *Intertidal and Marine Invertebrates*

Intertidal and marine invertebrates, including the ESA listed black abalone, are not known to be a major portion of the house mouse diet and no other impacts from mice to these invertebrates are suspected. Thus, the significance determination to all intertidal and marine invertebrates is negligible.

4.5.3.7 Vegetation

The native plants 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). Many of the invasive plants that have been introduced to the South Farallones originally evolved under grazing pressure from small mammals such as rodents on the mainland, so mice are likely to have less of a negative impact on them. Moreover, during the fall mice on the Farallones consume the seeds of the invasive hare barley and may spread the seeds in their droppings. Hare barley has spread to new areas on the islands in recent years (Coulter and Irwin 2005). 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 introduced plants dispersed by rodents would successfully establish and spread on the islands, outcompeting native plant communities. However, because the extent to which mice impact the vegetation community of the Farallones is uncertain, the significance determination for both native and invasive plants is not 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 toxicity of the compound and the extent of exposure (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 Toxicity

4.5.4.2.1 *Toxicity to birds and mammals*

The 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 per kilogram of body weight (ppm). 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 toxicants. However, it is reasonable to infer

LD_{50} information from tests performed on analogous species. For the purposes of this assessment, the risk to many island species was inferred from the most analogous species.

The EPA has determined the toxicity of brodifacoum to birds and most mammals to be high, 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 regards 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. In general, animals with a larger body mass must ingest more of the toxicant to pass the LD_{50} threshold and die; for example a 2,000 lb animal may need to consume approximately 200 lb of Brodifacoum-25D Conservation bait in order to reach an LD_{50} value (G. Howald pers. comm.). However, other factors also come into play including age, gender, history of previous exposure, behavior, and the presence of anticoagulant resistance.

Predators and scavengers can also be exposed through secondary or tertiary pathways by consuming individuals previously exposed to the toxicant. It is difficult to predict the level of toxicant that might be present in prey animals and the amount of toxic tissue or rodent bait that an individual could consume. Because of the challenges associated with estimating how much a particular predator or scavenger would need to consume to ingest a lethal dose and because this information has not been determined for the majority of species on the Farallones, the risk analysis outlined within this DEIS is conservative and estimated based on the risk pathways and potential for exposure rather than toxicity data.

An example of secondary poisoning in a rodent eradication comes from Rat Island, Alaska. In 2009, an unexpected number of glaucous-winged gull (more than 300) and bald eagle (46) carcasses were encountered along the coastline and around freshwater lakes of Rat Island nearly one year after a rat eradication was implemented with an aerial broadcast of Brodifacoum-25W Conservation. Tissues from a sample of the carcasses tested positive for brodifacoum, suggesting that gulls died from anti-coagulant exposure. However, no population level impact to glaucous-winged gulls is believed to have occurred and it is anticipated that in the long-term gulls on Rat Island will benefit from the rat eradication. Given the increase in gull numbers seen both in beach transects and in observations in the gull colonies in 2010, it appears that populations may be recovering from both the short-term impacts of the bait and long-term impacts of rats (Buckelew et al. 2009).

4.5.4.2.2 Toxicity to amphibians

There are no published or known unpublished studies on the toxicity of brodifacoum or diphacinone to amphibians (D. Towns, pers. comm.). Widely used references listing the LD_{50} values for anti-coagulants (Timm 1994, Tasheva 1995) typically do not list any values for amphibians. Anti-coagulants like brodifacoum and diphacinone inhibit Vitamin K-dependent

pathways in mammals and birds. Because amphibians are poikilothermic (cold-blooded), their blood chemistry and physiology is 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). Amphibians appear less at risk from anticoagulant poisoning than other vertebrate species based on data and observations from invasive species eradication and control projects that have used these compounds. In several cases, the removal of invasive rodents from the ecosystem led to a stabilized population or in some cases large increases in native amphibian populations (Table 4.1) (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, Croll and Newton 2012). Thus, minimal negative impacts are expected to occur to amphibians from the implementation of either action alternative. However, since there is still a level of uncertainty associated with the toxicant effect of brodifacoum and diphacinone to amphibians. To mitigate for this uncertainty, up to 40 individual salamanders would be captured and held for the duration of toxicant risk.

Table 4.1: Bait consumption and impacts to amphibian species from anti-coagulants.

Island or Region	Species	Impact/Bait	Results	Reference
Anacapa Island, California, USA	Slender salamanders (*Batrachoseps attenuatas*)	No consumption noted of Brodifacoum 25D bait.	No recorded mortality. Post-eradication monitoring indicated that the population was still present in 2003. The effects of the rat eradication were not significant with no long-term impacts.	(Croll and Newton 2012) (D. Croll and B. Sinervo, pers. comm.)
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)
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 is equal to that outside of the control area. Juvenile abundance and recruitment was similar inside and outside of control area, as	(Najera-Hillman et al. 2009)

	well.

4.5.4.2.3 *Toxicity to fish*

There is little data on the toxicity of brodifacoum or diphacinone to marine fish. However, several freshwater fish species have been analyzed with diphacinone, and based on that information diphacinone is considered to be moderately toxic to fish species. The 96-hour LC_{50} for technical diphacinone in channel catfish (*Ictalurus punctatus*) is 2.1 mg/L, in bluegill sunfish (*Lepomis macrochirus*) is 7.6 mg/L, and in rainbow trout (*Oncorhynchus mykiss*) is 2.8 mg/L (Extoxnet. 1996). The 48-hour LC50 in Daphnia, a small freshwater crustacean, is 1.8 mg/L (Extoxnet. 1996). Brodifacoum is considered to be very 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).

The USDA 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 2010. Brodifacoum residues were detected in all fish found dead after bait application. Two species of mullet were found, “kanda” (*Moolgarda engeli*) or “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. The only other fish species recovered was a puffer fish and analysis showed brodifacoum residues of 0.44 mg/L (Pitt et al. 2012). It should be noted that bait application rates used on this project were 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 – 0.005ppm) were found in four black snapper (*Macolor niger*) and one papio (*Caranx melampygus*) (Island Conservation, unpubl. data).

Three types of New Zealand marine fish, spotty (*Notolabrus celidotus*), banded wrasse (*Pseudolabrus fucicola*), and triplefins (*Forsterygion varium*), were observed feeding on non-toxic bait pellets dropped into the marine environment (Empson and Miskelly 1999). Additionally, marine fish surveys on Kapiti Island in New Zealand were conducted at three sites before and 1 to 2 months after the aerial application of brodifacoum bait. No change was found in the density of spotty’s during observation, 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 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 Farallon mouse eradication. Additionally, marine fish surveys on Kapiti

Island in New Zealand were conducted at three sites before and 1 to 2 months after the aerial application of brodifacoum bait. Empson and Miskelly (1999) found no change in the density of spotties during observation, and divers did not find any dead or moribund organisms.

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).

4.5.4.2.4 <u>*Toxicity to invertebrates*</u>

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). 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 (reported in Booth et al. 2001). Toxicity in land crabs (*Gecarcinus lagostoma*) was investigated by Pain et al. (2000) who found that crabs readily consumed brodifacoum bait with no lethal effects. Several 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).

Recent 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 in mussels peaked at 0.41 mg/L one day after the spill, and averaged just above detectable concentrations by day 29. Mean concentrations in abalone gut and muscle tissues were the highest on day 29, and at day 191 there was a mean of 0.003 mg/L brodifacoum for gut and of 0.0015 mg/L 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 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 orally. Animals can either ingest the toxicant by consuming bait pellets (known as "primary exposure"), or by preying or scavenging on other animals that previously consumed bait pellets (known as "secondary exposure"). Brodifacoum and diphacinone adhere strongly to the bait pellet matrix and because of their insolubility are not leached away because of moisture and precipitation. Once the pellets disintegrate into particles too small for most foraging vertebrates to consume, the toxicant becomes unavailable within the environment. Eventually, even the sub-measurable 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).

4.5.4.3.1 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.

4.5.4.3.2 Secondary exposure

Secondary exposure is the consumption of prey items that previously consumed rodent bait pellets. 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).

At the Farallones, several species are at risk of exposure to toxicants 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. Shorebirds, landbirds and salamanders may be at risk of secondary exposure to rodenticide

through the consumption of invertebrates that have previously consumed bait. Gulls, common ravens 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.

4.5.4.3.3 *Sublethal exposure*

Adverse effects as a result of possible sub-lethal exposure are unknown for brodifacoum or diphacinone (Weldon et al. 2011). No effect was found on ground weta (Hemiandrus spp) and cave weta held in captivity and allowed to feed freely for 47 days on Talon 50WB® wax baits containing 0.05 ppm brodifacoum; weta are insects closely related to the Farallones camel cricket. Mortality observed over the study period was not significantly different between treatment and non-treatment groups. The mean weight of surviving weta in both groups declined over the period but the difference in weight loss between groups was not significant (Bowie and Ross 2006). Reproduction studies for each species or surrogate are needed to establish a 'no-observable-adverse-effects concentration' (i.e., "toxicity threshold") for each rodenticide in order to accurately assess the sub-lethal risk to species in question (Erickson and Urban 2004). With the exception of mice, this has not been done for any of the species on the Farallones. Consequently, the amount of uncertainty regarding sub-lethal effects of anticoagulant rodenticides precludes its assessment in this document (40 CFR Sec. 1502.22).

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 (PRBO, unpub. data). Annual numbers of western gulls typically are lowest in early to mid-fall months, 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, scavenge carrion and refuse on land, forage and scavenge at sea, in intertidal areas, along beaches, and at landfills.

In addition to western gulls, several other gulls species that visit the Farallones during the non-breeding season may be present during the proposed operational period. Based on long-term monitoring studies (PRBO, unpubl. data), expected numbers of these species during the operational time period are: three Ring-billed gulls (*Larus delawarensis*); 500-1,000 California gulls; 150-400 glaucous-winged gulls, 2-35 mew gulls (*Larus canus*); 100-350 herring gulls, 12-18 Heermann's gulls, and 10-50 Thayer's gulls (*Larus thayeri*). These gull species are all 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 in shoreline roost sites where little foraging occurs. 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 fate of brodifacoum and diphacinone following bait application, there are two major routes of exposure to gulls: ingestion of rodenticide pellets (primary uptake), and 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.

This quantitative risk assessment 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. The toxicological risk is impossible to precisely quantify because of the lack of species-specific toxicity data for western gulls.

4.5.4.4.1.3 Gull Population Viability Analysis

Trials undertaken on the Farallon 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 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 (Appendix N). Western gulls are the only species considered in the modeling exercise as they 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 PRBO'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: 1) 'optimistic' with high gull productivity; 2) 'realistic', with average gull productivity; and 3) 'pessimistic', with greater incidence of low productivity as was observed from 2009 to 2011.

Future population trends for Farallon western gulls, in the absence of any eradication-related mortality, would depend on the likelihood of reoccurrence of years with especially low reproductive success, as was observed from 2009 to 2011, and which was likely driven by environmental conditions. Under "optimistic" environmental conditions, the model predicts that this western gull population would grow by 10.6 percent after 20 years (median or middle value result; 25 percent range on either side of the median +41 percent to -14 percent). Alternatively, under "pessimistic" conditions, the model predicts that the population would decline by 27 percent after 20 years (median or middle value result; 25 percent range on either side of the median -4 percent to -45 percent). Under "realistic" environmental conditions, the model predicts that the population would decline by 8.7 percent after 20 years (median or middle value result; 25 percent range on either side of the median +18 percent to -29 percent). While unforeseen extreme conditions may fall outside the boundaries of what was assessed, the range of scenarios addressed here is broad and inclusive of likely outcomes for this population of western gulls over the next 20 years. Variable reproduction rates were taken into account, based on 30 years of continuous data for this species at this site.

Under the "realistic" scenario with eradication-related gull mortality, it was found that the loss of up to 1,700 gulls as a consequence of non-target mouse eradication mortality produced 20-year population trends that were indistinguishable from the trend where no mouse eradication-related mortality occurred, with over 95 percent overlap in expected outcomes when comparing mortality and no-mortality scenarios. Under "realistic" conditions, the mortality of 1,700 gulls would cause the current declining population trend to change only slightly from 8.7 percent to 12.7 percent after 20 years, relative to initial conditions (median result, quartile range +4 percent to -47 percent).

The report concludes that 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 (Appendix E), the results of a gull risk assessment (Appendix F), 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 very 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 estimates 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 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 SFI 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 are randomly chosen (i.e., sex, body weight, life stage). At the same time, the model determines whether the gull will 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 gulls will not be present if initial application occurs in early to mid-November. Thus, for each gull, a starting date for its appearance on the island is determined by the model. Once a gull appears on the islands, it remains in the area until at least mid-February though only unhazed gulls are 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 SFI 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 changes over time in the Western Gull Risk Model. Subsequent time steps account 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 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 assumes 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 is 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 searches 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 is 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 exceeds the randomly chosen effects dose, the bird is considered dead. Otherwise, the bird is assumed to have survived the rodenticide applications. The model then proceeds to simulate the next gull. The process repeats for the number of model simulations selected by the user.

The net result over many simulations is that the entire dose-response curve is sampled capturing the expected range of sensitivities in the gull population at SEFI. 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. (2012) for western gulls on the South Farallones indicated that a one-time mortality event of 1,700 individual gulls would not result in an ecologically distinguishable change in the population

trend of the western gull on the Farallones over a 20 year period, assuming long term trends in gull productivity. Model predictions were compared to this benchmark.

It is clear from modeling analyses that Alternative B 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 Appendix N. 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, an early start date, and other measures 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, no breeding animals 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 are expected to either land on the water nearby or return to the island 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.

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 might entail two to four applications, there would likely be fewer than three to five 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 (Appendix E). If a helicopter was used for gull hazing it may be used for a period of up to 8 weeks for Alternative B and 18 weeks for Alternative C. Alternative A 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 coast 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 will 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 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), or traveling in small boats in the nearshore waters. Personnel dedicated to mouse eradication would be based at the 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, short-term impacts on western and other gulls by causing them to depart island roost sites. Gulls will either land on the nearby waters surrounding the island or depart for 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 is likely to span a period of at least five weeks or more depending on how long unconsumed bait remains available.

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. Neither alerting, moving, nor flushing is considered to be a Level A Harassment under the MMPA, and would therefore, not violate the Incidental Harassment Authorization (IHA) that the Service would obtain from NOAA prior to implementation. 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).

4.5.6 Impact Indices

The following impact indices were utilized to determine the level of risk to individual species from the perspective of:

1. Duration of risk/Duration of Toxicant Risk – the duration of toxicant risk is based on the amount of time rodenticide would be available through either primary or secondary exposure pathways,
2. Toxicant Sensitivity – the susceptibility of different species to the toxicant based LD_{50} data for analogous species,
3. Toxicant Exposure Risk Level – the number of exposure pathways available to individual species based on feeding ecology and toxicant fate,
4. Overall Toxicant Risk – toxicant risk to individual 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 may be exposed to during operations,
6. Duration of Disturbance Risk – the period of time that individuals would be exposed to disturbance risks,
7. Overall Disturbance Risk – the disturbance risk to individual species from a combination of disturbance risks from rodent bait application, personnel activities, hazing, and other mitigation operations.
8. Scale of the Negative Risk to the Population – the number of individuals that may be affected from toxicant or disturbance and the affect that they would have to the regional breeding population.
9. Significance Determination – the expected level of significance to a species from the given alternative.

The following breakdown of the affects 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 1 – 30 days
    - Medium: Bait or animal tissue available for 31– 90 days
    - Long: Toxicant available anywhere in the environment for more than 90 days
- Toxicant Sensitivity
    - None: Negligible 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 1– 30 days
    - Medium: Impacts for 31– 90 days
    - Long: Impacts for more than 90 days
- Overall Disturbance Risk
    - None: Negligible overall disturbance risk
    - Low: Low overall sensitivity to disturbance
    - Medium: Moderate overall sensitivity to disturbance
    - High: Major overall sensitivity to disturbance
- Scale of Toxicant/Disturbance Risk within a Population
    - Individuals: Few individuals affected
    - Island population: Many individuals affected with no effect to the global or regional breeding population
    - Regional population: Many individuals affected with impacts to the regional breeding population
- Significance Determination
    - Negligible: No long-term impact is expected from eradication operations
    - Not Significant: Some affects are expected from eradication operations; however the effects are not expected to be significant to the population
    - Significant: Long-term effects are expected for the species in question 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. Migrant bird species were included if there are records of more than 10 prior observations on the islands within the proposed operational window. Additional consideration was given to Endangered and Threatened species (i.e., Steller sea lion, black abalone). The number of individuals expected to be on the Farallon Islands during the operational window is listed for each bird species, based on

long-term monitoring data. 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 14 black phoebes on the islands during the operation. However, the Service does not expect any impacts to black phoebe and the Scale of the Impact is considered negligible.

4.5.6.1 Impacts of Alternative B on Biological Resources: Aerial Brodifacoum

4.5.6.1.1 Impacts on Birds

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 exposure (either primary or secondary) to susceptible species (granivorous species, many predators and scavengers, and omnivores) would begin to decline rapidly within 30 days of the final bait application as the mouse population declines and, bait pellets are consumed or disintegrated. The risk of exposure to these high-risk bird species would generally be low within 30 days of the final bait application and negligible within a few months thereafter.

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 secondary exposure due to the low likelihood that these classes of invertebrates would act as reservoirs for brodifacoum; this risk would steadily decline to negligible within a few months. The likelihood of exposure in intertidal specialists would decline even more rapidly, becoming negligible within 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 low likelihood of occurring during the implementation of Alternative B on the South Farallon Islands (Figure 4.2). Additionally, we quantified the number of individuals of each of species that may occur during project implementation, based on numbers of arrivals recorded in past years during similar time periods as that proposed for the implementation of Alternative B (DeSante and Ainley 1980, Pyle and Henderson 1991, Richardson et al. 2003). This assumes that may any individuals that may be present on the island during the eradication operations to be vulnerable to adverse impacts from this action alternative; however, this number does not indicate that all species occurring on the island are likely to be effected by implementing this alternative. The Scale of the Impact provides an estimate of the projected impact to the population.

4.5.6.1.1.1 Raptors:

- **<u>Ferruginous Hawk</u>**

Toxicant risk
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 mice or other species that have been exposed to the toxicant. Generally, ferruginous hawks primarily consume small-to medium-sized mammals (Bechard and Schmutz 1995). Based on their feeding habits, the duration of risk to ferruginous hawks would be for the medium-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 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 could be present at this time on the island.

Disturbance risk
Ferruginous hawks could be exposed to disturbances from both ground and air operations, which would likely cause them to leave 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
The estimated number of individuals likely to occur on the islands during project operations is between zero and three. The significance determination for ferruginous hawks is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Rough-legged hawk and Cooper's Hawk</u>**

Toxicant risk
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, rough-legged hawks consume small-to medium-sized mammals and a variety of birds (Bechard and Swem 2002). Cooper's hawks consume primarily medium-sized birds and some small mammals (Curtis et al. 2006). Based on their feeding habits the duration of risk for these hawks would be for the medium-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
Rough-legged and Cooper's hawks 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

The estimated number of rough-legged and Cooper's hawks that are likely to occur on the islands during project operations are between zero and three for both species. The significance determination for rough-legged and Cooper's hawks is not significant since no long-term negative or positive impacts to the population are expected.

- **Northern Harrier and Red-tailed Hawk**

Toxicant risk

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 and red-tailed hawks consume small- to medium-sized mammals, small birds, reptiles, and amphibians (Macwhirter and Bildstein 1996, Preston and Beane 2009). Based on their feeding habits the duration of risk for these hawks would be for the medium-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 and red-tailed hawks 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 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three red-tailed hawks and five to ten northern harriers. The significance determination for red-tailed hawk and northern harrier is not significant since no long-term negative or positive impacts to the population are expected.

- **Sharp-shinned Hawk and American Kestrel**

Toxicant risk

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 hawks would be for the medium-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 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

The estimated number of individuals likely to be occur on the islands during operations is one to three sharp-shinned hawks and one to five American kestrel. The significance determination for sharp-shinned hawks and American kestrel is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Merlin</u>**

Toxicant risk

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 species would be for the medium-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 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

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 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

The estimated number of individual merlins likely to occur on the islands during operations is between zero and three. The significance determination for merlins is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Short-eared Owl and Long-eared Owl</u>**

Toxicant risk

Short-eared (*Asio flammeus*) and long-eared (*Asio otus*) owls occasionally visit the Farallones. 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 species would be for the medium-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 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three for both short-eared and long-eared owls. The significance determination for short and long-eared owls is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Barn Owl</u>**

Toxicant risk

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 barn owls would be for the medium-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 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three barn owls. The significance determination for barn owls is not significant since no long-term negative or positive impacts to the population are expected.

- **Northern Saw-whet Owl and White-tailed Kite**

Toxicant risk

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. Northern saw-whet owls and white-tailed kites consume primarily small mammals (Dunk 1995, Rasmussen et al. 2008). Based on their feeding habits the duration of risk for these owls would be for the medium-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 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

Northern saw-whet owls and white-tailed kites 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three northern saw-whets and white-tailed kites. The significance determination for northern saw-whet owls and white-tailed kites is not significant since no long-term negative or positive impacts to the population are expected.

- **Burrowing Owls**

Toxicant risk

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 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, invertebrates, and small birds such as ashy storm-petrels (Mills 2006) (PRBO, unpubl. data). Based on their feeding habits the duration of risk for the remaining owls would be for the medium-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 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, transported, and held during operations. The scale of impact would be to the 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

The estimated number of individuals likely to occur on the islands during operations is between five and 20 burrowing owls. The significance determination for burrowing owls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Peregrine Falcon</u>**

Toxicant risk

A pair of Peregrine falcons resides on the Farallones and several non-breeding birds have been known to visit the Farallones regularly during the fall period. 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 brodifacoum 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 the falcons would be for the medium-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 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 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, 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 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
The estimated number of individuals likely to occur on the islands during operations is between 25 and 30 peregrine falcons. The significance determination for peregrine falcon is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.2 Passerines Omnivores:

- **Common Raven**

Toxicant risk
In recent years, one to two common ravens have visited the islands sporadically, occasionally staying for extended periods. If present during eradication implementation, efforts would be made to capture and hold all individuals. Individuals not captured could be exposed to brodifacoum through both primary and secondary exposure pathways by consuming bait pellets, mice or other species that have been exposed to the toxicant. Ravens are generalist omnivores and eat birds, mammals, eggs, insects, grains, fruit, garbage, and carrion (Boarman and Heinrich 1999). Based on their feeding habits the duration of risk for ravens would be for the medium-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
Common ravens 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 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, ravens 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 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
The estimated number of individuals likely to occur on the islands during operations is between one and two common ravens. The significance determination for common ravens is not significant since no long-term negative or positive impacts to the population are expected.

- **Hermit Thrush, Varied Thrush, Cedar Waxwing, and American Robin**

Toxicant risk
Hermit thrushes, varied thrushes, cedar waxwings, and American robins could be exposed to brodifacoum through secondary exposure pathways. These species consume fruit, insects, and invertebrates. Based on their feeding habits the duration of risk for these birds would be for the medium-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

Hermit thrushes, varied thrushes, cedar waxwings, and American robins 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

The estimated number of individuals likely to occur on the islands during operations is: one to five hermit thrushes, four to 16 varied thrushes, two to seven cedar waxwings, and five to 17 American robins. The significance determination for hermit thrush, varied thrush, cedar waxwing, and American robin is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>European Starling</u>**

Toxicant risk

Non-native European starlings could be exposed to brodifacoum 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 medium-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 island. The impacts associated with disturbance sensitivity 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 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 individuals. The significance determination for European starling is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>American Pipit</u>**

Toxicant risk
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 songbirds would be for the medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the range of 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
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 island. The impacts associated with disturbance sensitivity 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 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 20 and 34 American pipits. The significance determination for American pipit is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.3 Passerine Insectivores:

- **<u>Black Phoebe and Townsend's Warbler</u>**

Toxicant risk
Black phoebes and Townsend's warblers could be exposed to brodifacoum through secondary exposure pathways. Both species are primarily insectivorous, catching flying insects and other arthropods (Wolf 1997, Wright et al. 1998). Based on their feeding habits the duration of risk for these songbirds would be for the medium-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
Black phoebe and Townsend's warbler 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 are 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
The estimated number of individuals likely to occur on the islands during operations is: between 12 and 15 black phoebe and three and nine Townsend's warblers. The significance determination for black phoebe and Townsend's warbler is negligible since no long-term negative or positive impacts to the population are expected.

- **Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler and Palm Warbler**

Toxicant risk

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. Based on their feeding habits the duration of risk for these insectivores would be for the medium-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

Golden-crowned kinglets, ruby-crowned kinglets, yellow-rumped warblers and palm warblers 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 are 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

The estimated number of individuals likely to occur on the islands during operations is between zero and five golden-crowned kinglets, four and five ruby-crowned kinglets, seven and 15 Audubon's yellow-rumped warblers, and 19 and 25 yellow-rumped warblers. The significance determination for these species is negligible since no long-term negative or positive impacts to the population are expected.

- **Violet-green Swallow**

Toxicant risk

Violet-green swallows could be exposed to brodifacoum through secondary exposure pathways by consuming insects that have been exposed to the toxicant. Violet-green swallows feed exclusively on flying insects (Brown et al. 1992). Based on their feeding habits the duration of risk for these swallows 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 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

Violet-green swallows 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
The estimated number of individuals likely to occur on the islands during operations is between zero and two violet-green swallows. The significance determination for violet-green swallow is negligible since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.4 Nectivores/Insectivores:

- **Anna's Hummingbird**

Toxicant risk
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 hummingbirds 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 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
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 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
The estimated number of individuals likely to occur on the islands during operations is between 14 and 21 individuals. The significance determination for Anna's hummingbird is negligible since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.5 Passerine Granivores:

- **Fox Sparrow, White-crowned Sparrow, Golden-crowned Sparrow, Dark-eyed Junco, Western Meadowlark, Chipping Sparrow, Spotted Towhee, Savannah Sparrow, White-throated Sparrow, Red-winged Blackbird, Brewer's Blackbird, Purple Finch, Pine Siskin, Lesser Goldfinch**

Toxicant risk
Fox sparrows, white-crowned sparrows, golden-crowned sparrows, dark-eyed juncos, Western meadowlarks, chipping sparrows, spotted towhees, savannah sparrows, white-throated sparrows, red-winged blackbird, brewer's blackbirds, purple finches, pine siskins, and lesser goldfinches 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 birds would be for the medium-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 island. The impacts associated with disturbance sensitivity 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 on the Farallones.

Significance Determination
The estimated number of individuals likely to be present on the islands during operations is between two and 11 fox sparrows, two and 8 white-crowned sparrows, two and 30 golden-crowned sparrows, four and eight "Oregon" dark-eyed juncos, zero and three "slate-colored" dark-eyed juncos, two and 13 western meadowlarks, zero and three chipping sparrows, two and four savannah sparrows, zero and six white-throated sparrows, one and 23 red-winged blackbirds, one and three Brewer's blackbirds, zero and four purple finches, two and eight pine siskins, and one and four lesser goldfinches. The significance determination for these species is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.6 Shorebirds:

- **<u>Wandering Tattler and Black Turnstone</u>**

Toxicant risk
Wandering tattlers and black turnstones could be exposed to brodifacoum 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. Tattlers and turnstones 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 shorebirds would be for the medium-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
Wandering tattlers and black turnstones 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 are short, 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
The estimated number of individuals likely to occur on the islands during operations is between two and five wandering tattlers and 80 and 115 black turnstones. The significance determination

for wandering tattler and black turnstone is not significant since no long-term negative or positive impacts to the population are expected.

- **Black Oystercatcher**

Toxicant risk

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 a few individuals occasionally forage for terrestrial invertebrates in upland habitats. Based on their feeding habits the duration of risk for these shorebirds would be for the medium-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 island population.

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 island. 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.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 30 and 60 black oystercatchers. The significance determination for black oystercatcher is not significant since no long-term negative or positive impacts to the population are expected.

- **Whimbrel**

Toxicant risk

Whimbrels could be exposed to brodifacoum 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. Whimbrels consume marine invertebrates, including 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 shorebirds would be for the medium-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

Whimbrels 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 are medium, 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

The estimated number of individuals likely to occur on the islands during operations is between nine and eleven whimbrels. The significance determination for whimbrel is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.7 Seabirds:

- **<u>Western Gull</u>**

Toxicant risk

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 medium-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 impact would be to the regional population.

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 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 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 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. Because of their long life span, population level impacts were considered to be long-term if impacts were detectable after 20 years (Appendix N). The significance determination for western gulls is not significant since hazing activities are expected to keep non-target mortality below the threshold of 1,700 western gulls; thus, no long-term negative or positive impacts to the population are expected (Appendix N).

- **<u>Ring-Billed Gull</u>**

Toxicant risk

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 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 gulls would be for the medium-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 entire Farallones Island population.

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 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 medium-term, and the scale of impact would be to the entire Farallon Island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between zero and three ring-billed gulls. The significance determination for ring-billed gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>California Gull</u>**

Toxicant risk

All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, California gulls 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 medium-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 impact would be to the entire Farallon Islands population.

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 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 medium-term, and the scale of impact would be to the Farallon Islands population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 500 and 1,000 California gulls. The significance determination for California gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Glaucous-winged Gull</u>**

Toxicant risk
All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, glaucous-winged gulls 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 medium-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 impact would be to the Farallones Island population.

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 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 medium-term, and the extent of the impact would be to the Farallones Island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 150 and 400 glaucous-wing gulls. The significance determination for glaucous-wing gulls is not

significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **Mew Gull**

Toxicant risk

All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, mew gulls 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 gulls would be for the medium-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 impact would be to the entire Farallones Island 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 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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between two and 35 mew gulls. The significance determination for mew gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **Herring Gull**

Toxicant risk

All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, herring gulls 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 medium-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 impact would be to the entire Farallones Island population.

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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 100 and 350 herring gulls. The significance determination for herring gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Heermann's Gull and Thayer's Gull</u>**

Toxicant risk
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 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, 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 medium-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 impact would be to the entire Farallones Island population.

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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 12 and 18 Heerman's gulls and 10 and 50 Thayer's gulls. The significance determination for

Heermann's and Thayer's gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Cassin's Auklet, Ashy Storm-petrel, Leach's Storm-petrel</u>**

Toxicant risk

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; 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 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 sensitivity to the toxicant and the remote nature of a possible exposure pathway. The scale of the impact would be to the few individuals that are on the island during the operational window.

Disturbance risk

These species could be exposed to disturbances from ground and air operations. However, except for a small number of remaining ashy storm-petrel chicks early in the operational period, these species would most likely only be present at night and not susceptible to ground or air operations. The impacts associated with disturbance sensitivity for this alternative are low because the majority of seabirds would not be present during operations. The duration of the disturbance would be for the short-term, and the scale of impact would be entire island population.

Significance Determination

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 250 Leach's storm-petrel. 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 would experience disturbance from ground and air operations and from hazing for the duration of the project (up to 90 days). The significance determination for Cassin's auklet is not significant since no long-term negative or positive impacts to the population are expected. Nur et al. (2013) showed that the removal of house mice and associated burrowing owl predation on ashy storm-petrels would likely result in an increased Farallon ashy storm-petrel population (see Sections 1.2.2.2 and 4.5.3.2). Because the similar Leach's storm-petrel also likely experiences impacts from burrowing owl predation, we assume that Leach's storm-petrels also would benefit from mouse removal and reduction in owl predation. Thus, 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.

- **<u>Common Murre</u>**

Toxicant risk

Common murres on the South Farallones are not likely to be exposed to brodifacoum 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 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 sensitivity to the toxicant and the remote nature of a possible exposure pathway. The scale of the impact would be to the individuals that are on the island during the operational window.

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 short-term, and the scale of impact would be entire island population.

Significance Determination

The estimated number of common murres likely to occur on the islands during operations is expected to be up to 200,000 individuals. The significance determination for common murre is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Brown Pelican, Brandt's Cormorant, Pelagic Cormorant, Double-crested Cormorant</u>**

Toxicant risk

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 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 or away from the island. The impacts associated with disturbance sensitivity for this alternative are medium, the duration of the disturbance would be for the short-term, and the scale of impact would be to the few individuals that are seen at this time on the island.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is expected to be up to 1,000 brown pelicans, 2,000 Brandt's cormorants, 100 double-crested cormorants, and 200 pelagic cormorants. The significance determination for these species is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.1.8 Waterfowl:

- **Cackling Goose**

Toxicant risk

Cackling geese 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). On the Farallones, cackling 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 medium-term, the toxicant sensitivity would be high, and the toxicant exposure risk is medium 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 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 are 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

The estimated number of individuals likely to occur on the islands during operations is between one and 700 cackling geese. The significance determination for cackling geese is negligible since no long-term negative or positive impacts to the population are expected.

- **Brant**

Toxicant risk

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 medium-term, the toxicant sensitivity would be medium, and the toxicant exposure risk is medium 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 island. The impacts associated with disturbance sensitivity 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 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 one and 850 brant. The significance determination for brant is negligible 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 *Non-breeding Pinnipeds:*

- **Steller Sea Lion**

Toxicant risk
Steller sea lions breed on the Farallones but will not be breeding during the proposed implementation of this alternative. Steller sea lions could be exposed to brodifacoum through primary and secondary exposure pathways. Pinnipeds primarily consume marine fish and invertebrates, while pups have been known to suckle on rocks. On the Farallones, these species are found along the immediate shoreline. 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 source, pelagic fish, 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 fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the entire Farallones Island population.

Disturbance risk
Steller sea lions are typically sensitive to nearby human activities and would be exposed to disturbance from ground, air, and gull hazing operations. The impacts of these 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 island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 145 and 300 Steller sea lions. 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. Ground, air and hazing operations would disturb individual Steller sea lions for up to 90 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no long-term negative or positive impacts to the population are expected.

- **California Sea Lion, Northern Fur Seal, and Pacific Harbor Seal**

Toxicant risk

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 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 source, pelagic fish, 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 fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the entire Farallones Island population.

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. The impacts of these 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 island populations.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 70 and 140 Pacific harbor seals, 11,000 and 21,500 California sea lions, and 34 and 125 northern fur seals. 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 pinnipeds would be harmed as a result of direct or indirect toxicant consumption. Ground, air and hazing operations would disturb individual pinnipeds for up to 90 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.1.2.2 Breeding Pinnipeds:

- **<u>Northern Elephant Seal</u>**

Toxicant risk

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 found along the immediate shoreline. 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 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 entire Farallon Islands population.

Disturbance risk

Northern elephant seals do not often react to nearby human activities. They would be exposed to disturbance from ground, air, and gull hazing operations. 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. However, every effort will be made to minimize disturbance risk to these 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 island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 65 and 135 northern elephant seals. 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. Ground, air and hazing operations would disturb individual elephant seals for up to 90 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no 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 medium-term, the toxicant sensitivity is considered to 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 entire population of this subspecies of arboreal salamander as they are endemic to the South Farallon Islands. Also, in an effort to mitigate potential unforeseen impacts to salamanders, up to 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 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 short-term, and the scale of impact would be to the entire population of this subspecies of arboreal salamanders since they are endemic to the South Farallon Islands.

Significance Determination
There is enough anecdotal evidence to support the assertion that mice are at minimum competing with salamanders on the Farallon Islands, but the level of uncertainty is too great to determine if mouse eradication will significantly benefit salamanders (40CFR 1502.22). Also, potential negative impacts from eradication operations are considered to be not significant. For these reasons, the significance determination for arboreal salamanders is not significant.

4.5.6.1.4 *Impacts on Fish*

- **Marine Fish**

Toxicant risk
Marine fish could be exposed to brodifacoum through both primary and secondary exposure pathways by consuming bait pellets, invertebrates, or other fish that have been exposed to the toxicant. Based on their feeding habits, the duration of risk for these fish would be for the short-term since bait pellets would dissolve within a few hours, the toxicant sensitivity would be high, and the toxicant exposure risk is high due to the existence of both primary and secondary toxicant exposure pathways. However, most fish species near the Farallones are either predators or planktivores that are unlikely to come in contact with or consume a bait pellet. However, measures will be taken to minimize bait drift into the marine environment; see Section 2.10.7.7 for details. The overall toxicant risk is medium due to the short duration of potential exposure, sensitivity to the toxicant, and the number of 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 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.

4.5.6.1.5 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. However, 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) therefore, the toxicant sensitivity would be negligible. Based on their feeding habits the duration of risk for camel crickets would be for the medium-term and the toxicant exposure risk low due to the primary exposure pathway. The overall toxicant risk is low due to the low sensitivity of insects to the toxicant. The scale of impact would be to the total 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 short-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 since with 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 disturbance from ground operations during project implementation.

- **Other Terrestrial Invertebrates**

Toxicant risk

Invertebrates such as kelp 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. However, brodifacoum consumption by invertebrates generally does not cause mortality. Based on their feeding habits the duration of risk for terrestrial invertebrates would be for the medium-term. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The toxicant sensitivity would be negligible, and the toxicant exposure risk is low due to the primary exposure pathway. The scale of impact would be to a few individuals.

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 a few individuals.

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 ground operations during project implementation.

Intertidal Invertebrates

- **Black Abalone**

Toxicant risk

Black abalones are intertidal gastropod mollusks that feed on marine algae such as kelp. Abalone could be exposed to brodifacoum through a primary exposure pathway. Some 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 is not known to cause mortality (Primus et al. 2005). Based on their feeding habits, 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 due to the primary exposure pathway. The overall toxicant risk is low due to the number of exposure pathways. The scale of impact would be a small number of individuals.

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.. Therefore, disturbance risk to this species is negligible.

Significance Determination

There are no expected long-term negative or positive significant impacts to black abalones, so the significance determination for this species is not significant.

- **Other Gastropods**

Toxicant risk

Other 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. 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 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 negligible, and the toxicant exposure risk is low due to the primary and secondary 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 a few individuals on the South Farallon Islands.

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 this 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 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 medium-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 individuals.

Disturbance risk
These invertebrates are not likely to be exposed to disturbance impacts from eradication operations; and therefore, no further analysis is warranted for these species.

Significance Determination
The significance determination for intertidal invertebrates is negligible since no long-term negative or positive impacts to the population 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.

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.

4.5.6.1.7 Impacts Table for Alternative B: Aerial Broadcast of Brodifacoum:

Table 4.2: Impacts of Alternative B on Biological Resources

Species	Significance determination	Duration of Toxicant Risk[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 with multiple exposure pathways[8]	Not Significant	Medium	High	High	High	Low/High	Short/Medium	Individ.	Individ.
Raptors with single exposure pathway[9]	Not Significant	Medium	High	Medium	High	Low/High	Short/ Medium	Individ.	Individ.
Peregrine Falcon[10]	Not Significant	Medium	High	High	High	Low/ High	Short/ Medium	Individ.	Individ.
Species	Significance determination	Duration of Toxicant Risk[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
Burrowing Owl[10]	Not Significant	Medium	High	High	High/	Low/ High	Short/ Medium	Individ.	Individ.
Common Raven[10]	Not Significant	Medium	High	High	High/	Low/ High	Short/ Medium	Individ.	Individ.
Western Gull	Not Significant	Medium	High	High	High	High	Medium	Regional	Regional
Other Gulls[11]	Not Significant	Medium	High	High	High	High	Medium	Regional	Regional
Ashy and Leach's Storm-petrel	Significant positive effect	Short	High	Low	Low	Low	Short	Individ.	Individ.
Cassin's Auklet	Not Significant	Short	High	Low	Low	Low	Short	Individ.	Individ.
Common Murre	Not Significant	Short	High	Low	Low	Low	Medium	Individ.	Individ.
Brown Pelican and Cormorants	Not Significant	Short	High	Low	Low	Medium	Short	Individ.	Individ.
Cackling Goose	Not Significant	Medium	High	High	High	Low	Short	Individ.	Individ.

Brant	Not Significant	Medium	High	Medium	High	Low	Short	Individ.	Individ.
Black Oystercatcher	Not Significant	Medium	High	High	High	High	Medium	Island	Island
Other Shorebirds[12]	Not Significant	Medium	High	High	High	Medium	Short	Individ.	Individ.
Songbird Insectivores/ Frugivores[13]	Not Significant	Medium	High	Medium	Medium	Low	Short	Individ.	Individ.
Songbird Insectivores[14]	Not Significant	Medium	High	Medium	Medium	Low	Short	Individ.	Individ.
Passerine Granivores[15]	Not Significant	Medium	High	High	High	Low	Short	Individ.	Individ.
Violet-green Swallow & Anna's Hummingbird	Not Significant	Medium	High	Low	Low	Low	Short	Individ.	Individ.
Northern Elephant Seal	Not Significant	Medium	High	High	Low	High	Medium	Island	Island
Other Pinnipeds[16]	Not Significant	Medium	High	High	Low	High	Medium	Island	Island
Marine Fish	Not Significant	Short	High	High	Medium	Low	Short	Individ.	Individ.
Salamanders	Not Significant	Medium	Medium	Medium	Medium	Low	Short	Island	Island
Terrestrial Invertebrates	Significant positive effect	Medium	None	Low	Low	Low	Short	Individ.	Individ.
Other Intertidal Invertebrates	Negligible	Medium	None	Low	Low	Low	Short	Individ.	Individ.
Species	Significance determination	Duration of Toxicant Risk[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
Black Abalone and Other Intertidal Gastropods	Negligible	Medium	None	Medium	Medium	Low	Short	Individ.	Individ.
Camel Cricket	Significant positive effect	Medium	None	Low	Low	Low	Short	Island	Island
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] Rough-legged hawk, red-tailed hawk, sharp-shinned hawk, northern harrier, Cooper's hawk, American kestrel, barn owl, long-eared owl, short-eared owl.
[9] Ferruginous hawk, white-tailed kite, northern saw-whet owl, merlin.
[10] Two outcomes listed: First – individuals remaining on island / Second – individuals captured and held in captivity.
[11] Ring-billed gull, California gull, herring gull, Thayer's gull, glaucous-winged gull, Heermann's gull, mew gull.
[12] Wandering tattler, black turnstone, whimbrel.
[13] Hermit thrush, American robin, varied thrush, Townsend's warbler, cedar waxwing, black phoebe.
[14] Yellow-rumped warblers, palm warbler, golden-crowned kinglet, ruby-crowned kinglet.
[15] Spotted towhee, chipping sparrow, savannah sparrow, fox 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, European starling, American pipit, lesser goldfinch.
[16] California sea lions, northern fur seal, Steller sea lion, Pacific harbor seal.

4.5.6.2 Impacts of Alternative C on Biological Resources: Aerial Diphacinone

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. A full description of the potential impacts to birds can be found in Section

The following is a breakdown of the direct and indirect toxicant and disturbance impacts to each of the identified bird species that are likely to be present during the implementation of Alternative C on the South Farallon Islands (See Table 4.3 for a summary of impacts to biological resources). Additionally, we have quantified the number of individuals per bird species that are likely to occur during operations by considering any individuals that may be present on the island during the eradication operations to be vulnerable to adverse impacts from this action alternative; however, this number does not indicate that all species present on the island are likely to be effected by implementing this alternative. The Scale of the Impact provides an estimate of the projected impact to the population.

4.5.6.2.1.1 Raptors:

- **Ferruginous Hawk**

Toxicant risk

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 mice or other species that have been exposed to the toxicant. Generally, ferruginous hawks primarily consume small-to medium-sized mammals (Bechard and Schmutz 1995). Based on their feeding habits the duration of risk for these hawks would be for the medium-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

Ferruginous hawks could be exposed to disturbances from both ground and air operations, which would likely cause them to leave 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three. The significance determination for ferruginous hawks is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Rough-legged hawk and Cooper's Hawk</u>**

Toxicant risk

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, rough-legged hawks consume small-to medium-sized mammals and a variety of birds(Bechard and Swem 2002). Cooper's hawks consume primarily medium-sized birds and some small mammals (Curtis et al. 2006). Based on their feeding habits the duration of risk for these hawks would be for the medium-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

Rough-legged and Cooper's hawks 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

The estimated number of rough-legged and Cooper's hawks that are likely to occur on the islands during project operations are between zero and three for both species. The significance determination for rough-legged and Cooper's hawks is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Northern Harrier and Red-tailed Hawk</u>**

Toxicant risk

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 and red-tailed hawks consume small- to medium-sized mammals, small birds, reptiles, and amphibians(Macwhirter and Bildstein 1996, Preston and Beane 2009). Based on their feeding habits the duration of risk for these hawks would be for the medium-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 and red-tailed hawks 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 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three red-tailed hawks and five and ten northern harriers. The significance determination for red-tailed hawk and northern harrier is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Sharp-shinned Hawk and American Kestrel</u>**

Toxicant risk

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 hawks would be for the medium-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 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

The estimated number of individuals likely to be occur on the islands during operations is one to three sharp-shinned hawks and one to five American kestrel. The significance determination for sharp-shinned hawks and American kestrel is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Merlin</u>**

Toxicant risk
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 species would be for the medium-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
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 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
The estimated number of individuals likely to occur on the islands during operations is between zero and three merlins. The significance determination for merlin is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Short-eared Owl and Long-eared Owl</u>**

Toxicant risk
Short-eared and long-eared owls occasionally visit the Farallones. 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 species would be for the medium-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
The estimated number of individuals likely to occur on the islands during operations is between zero and three short-eared and long-eared owls. The significance determination for short-eared

and long-eared owl is not significant since no long-term negative or positive impacts to the population are expected.

- **Barn Owl**

Toxicant risk

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 barn owls would be for the medium-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

The estimated number of individuals likely to occur on the islands during operations is between zero and three barn owls. The significance determination for barn owl is not significant since no long-term negative or positive impacts to the population are expected.

- **Northern Saw-whet Owl and White-tailed Kite**

Toxicant risk

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. Northern saw-whet owls and white-tailed kites consume primarily small mammals (Dunk 1995, Rasmussen et al. 2008). Based on their feeding habits the duration of risk for these owls would be for the medium-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

Northern saw-whet owls and white-tailed kites 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

The estimated number of individuals likely to occur on the islands during operations is between zero and three northern saw-whet owls and white-tailed kites. The significance determination for saw-whet owls and white-tailed kite is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Burrowing Owls</u>**

Toxicant risk

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, invertebrates, and small birds such as ashy storm-petrels (Mills 2006) (PRBO, unpubl. data). Based on their feeding habits the duration of risk for the remaining owls would be for the medium-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, transported, and held during operations. The scale of impact would be to the 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

The estimated number of individuals likely to occur on the islands during operations is between five and 20 burrowing owls. The significance determination for burrowing owls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Peregrine Falcon</u>**

Toxicant risk
A pair of Peregrine falcons resides on the Farallones and several non-breeding birds have been known to visit the Farallones regularly during the fall period. 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 the falcons would be for the medium-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 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 the mainland. The impacts associated with disturbance sensitivity for this alternative is low to 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, 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 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
The estimated number of individuals likely to occur on the islands during operations is between 25 and 28 peregrine falcons. The significance determination for peregrine falcon is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.2 Passerines Omnivores:

- **<u>Common Raven</u>**

Toxicant risk
In recent years, one to two common ravens have visited the islands sporadically, occasionally staying for extended periods. If present during eradication implementation, efforts would be made to capture and hold all individuals. Individuals not captured could be exposed to diphacinone through both primary and secondary exposure pathways by consuming bait pellets, mice or other species that have been exposed to the toxicant. Ravens are generalist omnivores and eat birds, mammals, eggs, insects, grains, fruit, garbage, and carrion (Boarman and Heinrich 1999). Based on their feeding habits the duration of risk for ravens would be for the medium-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

Common ravens 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 the mainland. The impacts associated with disturbance sensitivity for this alternative is low to 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, ravens 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 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

The estimated number of individuals likely to occur on the islands during operations is between one and two ravens. The significance determination for ravens is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Hermit Thrush, Varied Thrush, Cedar Waxwing, and American Robin</u>**

Toxicant risk

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 birds would be for the medium-term, the toxicant sensitivity would be low, 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 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

Hermit thrushes, varied thrushes, cedar waxwings, and American robins 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

The estimated number of individuals likely to occur on the islands during operations is between one and five hermit thrushes, four and 16 varied thrushes, two and seven cedar waxwings, and 5

and 17 American robins. The significance determination for hermit thrush, varied thrush, cedar waxwing, and American robin is negligible since no long-term negative or positive impacts to the population are expected.

- **European Starling**

Toxicant risk

Non-native European 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 medium-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 island. The impacts associated with disturbance sensitivity 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 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

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 songbirds would be for the medium-term, the toxicant sensitivity would be low, and the toxicant exposure risk is high due to the range of 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

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 island. The impacts associated with disturbance sensitivity 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 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 20 and 34 American pipits. The significance determination for American pipit is negligible since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.3 Passerine Insectivores:

- **Black Phoebe and Townsend's Warbler**

Toxicant risk
Black phoebes and Townsend's warblers could be exposed to diphacinone through secondary exposure pathways. Both species are primarily insectivorous, catching flying insects and other arthropods (Wolf 1997, Wright et al. 1998). Based on their feeding habits the duration of risk for these songbirds would be for the medium-term, the toxicant sensitivity would 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 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
Black phoebe and Townsend's warbler 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 are 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
The estimated number of individuals likely to occur on the islands during operations is between 12 and 14 black phoebe and three and nine Townsend's warblers. The significance determination for black phoebe and Townsend's warbler is negligible since no long-term negative or positive impacts to the population are expected.

- **Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler and Palm Warbler**

Toxicant risk
Golden-crowned kinglets, ruby-crowned kinglets, yellow-rumped warblers and palm warblers 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 insectivores would be for the medium-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
Golden-crowned kinglets, ruby-crowned kinglets, yellow-rumped warblers and palm warblers 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 are 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
The estimated number of individuals likely to occur on the islands during operations is between zero and five golden-crowned kinglets, four and five ruby-crowned kinglets, seven and 15 Audubon's yellow-rumped warblers, and 19 and 25 myrtle yellow-rumped warblers. The significance determination for golden-crowned kinglet, ruby-crowned kinglet, yellow-rumped warbler, and palm warbler is negligible since no long-term negative or positive impacts to the population are expected.

- **<u>Violet-green Swallow</u>**

Toxicant risk
Violet-green swallows could be exposed to diphacinone through secondary exposure pathways by consuming insects that have been exposed to the toxicant. Violet-green swallows feed exclusively on flying insects (Brown et al. 1992). Based on their feeding habits the duration of risk for these swallows would be for the medium-term, the toxicant sensitivity would be low, 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
Violet-green swallows 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
The estimated number of individuals likely to occur on the islands during operations is between zero and two violet-green swallows. The significance determination for violet-green swallow is negligible since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.4 Nectivores/Insectivores:

- **<u>Anna's Hummingbird</u>**

Toxicant risk
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 hummingbirds would be for the medium-term, the toxicant sensitivity would be low, 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

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 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

The estimated number of individuals likely to occur on the islands during operations is between 14 and 21 Anna's hummingbirds. The significance determination for Anna's hummingbird is negligible since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.5 Passerine Granivores:

- **Fox Sparrow, White-crowned Sparrow, Golden-crowned Sparrow, Dark-eyed Junco, Western Meadowlark, Chipping Sparrow, Spotted Towhee, Savannah Sparrow, White-throated Sparrow, Red-winged Blackbird, Brewer's Blackbird, Purple Finch, Pine Siskin, Lesser Goldfinch**

Toxicant risk

Fox sparrows, white-crowned sparrows, golden-crowned sparrows, dark-eyed juncos, Western meadowlarks, chipping sparrows, spotted towhees, savannah sparrows, white-throated sparrows, red-winged blackbird, brewer's blackbirds, purple finches, pine siskins, and lesser goldfinches 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 birds would be for the medium-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 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 island. The impacts associated with disturbance sensitivity 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 on the Farallon Islands.

Significance Determination

The estimated number of individuals likely to be present on the islands during operations is between two and 11 fox sparrows, two and 8 white-crowned sparrows, two and 30 golden-crowned sparrows, four and eight "Oregon" dark-eyed juncos, zero and three "slate-colored" dark-eyed juncos, two and 13 western meadowlarks, zero and three chipping sparrows, two and four savannah sparrows, zero and six white-throated sparrows, one and 23 red-winged

blackbirds, one and three Brewer's blackbirds, zero and four purple finches, two and eight pine siskins, and one and four lesser goldfinches. The significance determination for these species is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.6 Shorebirds:

- **<u>Wandering Tattler and Black Turnstone</u>**

Toxicant risk

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. Tattlers and turnstones 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 shorebirds would be for the medium-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

Wandering tattlers and black turnstones 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 are medium, the duration of the disturbance would be for the short-term, and the scale of impact would be to the island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between two and five wandering tattlers and 80 115 black turnstones. The significance determination for wandering tattler and black turnstone is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Black Oystercatcher</u>**

Toxicant risk

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 occasionally forage in upland habitats. Based on their feeding habits the duration of risk for these shorebirds would be for the medium-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 island population.

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 island. 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.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 30 and 60 black oystercatchers. The significance determination for black oystercatcher is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Whimbrel</u>**

Toxicant risk
Whimbrels 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. Whimbrels consume marine invertebrates, including 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 shorebirds would be for the medium-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
Whimbrels 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 are medium, 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
The estimated number of individuals likely to occur on the islands during operations is between nine and 11 whimbrels. The significance determination for whimbrel is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.7 Seabirds:

- **<u>Western Gull</u>**

Toxicant risk
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 medium-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 regional population.

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 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 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 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. Because of their long life span, population level impacts were considered to be long-term if impacts were detectable after 20 years (Appendix N). The significance determination for western gulls is not significant since hazing activities are expected to keep non-target mortality below the threshold of 1,700 western gulls; thus no long-term negative or positive impacts to the population are expected.

- **<u>Ring-Billed Gull</u>**

Toxicant risk

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 gulls 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 entire Farallones Island population.

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 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 medium-term, and the scale of impact would be to the entire Farallon Island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between zero and three ring-billed gulls. The significance determination for ring-billed gull is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>California Gull</u>**

Toxicant risk

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 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 entire Farallon Island population.

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 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 medium-term, and the scale of impact would be to the Farallon Islands population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 500 and 1,000 California gulls. The significance determination for California gull is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Glaucous-winged Gull</u>**

Toxicant risk

All gulls would be actively hazed during implementation operations to decrease their risk of exposure to toxicant. However, glaucous-winged gulls could be exposed to diphacinone 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 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 Farallones Island population.

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 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 medium-term, and the extent of the impact would be to the Farallones Island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 150 and 400 glaucous-wing gulls. The significance determination for glaucous-wing gull is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Mew Gull</u>**

Toxicant risk

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 gulls 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 entire Farallones Island 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 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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between two and 35 mew gulls. The significance determination for mew gull is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **<u>Herring Gull</u>**

Toxicant risk
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 medium-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 entire Farallones Island population.

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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is between 100 and 350 herring gulls. The significance determination for herring gull is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **Heermann's Gull and Thayer's Gull**

Toxicant risk

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, 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 medium-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 entire Farallones Island population.

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 medium-term, and the scale of impact would be to the Farallones Island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 12 and 18 Heerman's gulls and 10 and 50 Thayer's gulls. The significance determination for Herman's and Thayer's gulls is not significant since any long-term negative or positive impacts to the population are not expected to be significant.

- **Cassin's Auklet, Ashy Storm-petrel, Leach's Strom-petrel**

Toxicant risk

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; 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 short-term, the toxicant sensitivity would be low, 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 sensitivity to the toxicant and the number of exposure pathways. The scale of the impact would be to the few individuals that are on the island during the operational window.

Disturbance risk

These species could be exposed to disturbances from ground and air operations. However, except for a small number of remaining ashy storm-petrel chicks early in the operational period, these species would most likely only be present at night and not susceptible to ground or air operations. The impacts associated with disturbance sensitivity for this alternative are low because the majority of seabirds would not be present during operations. The duration of the disturbance would be for the short-term, and the scale of impact would be entire island population.

Significance Determination

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 250 Leach's storm-petrel. 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 would experience disturbance from ground and air operations and from hazing for the duration of the project (up to 105 days). The significance determination for Cassin's auklet is not significant since no long-term negative or positive impacts to the population are expected. Nur et al. (2013) showed that the removal of house mice and associated burrowing owl predation on ashy storm-petrels would likely result in an increased Farallon ashy storm-petrel population (see Sections 1.2.2.2 and 4.5.3.2). Because the similar Leach's storm-petrel also likely experiences impacts from burrowing owl predation, we assume that Leach's storm-petrels also would benefit from mouse removal and reduction in owl predation. Thus, 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.

- **<u>Common Murre</u>**

Toxicant risk

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 short-term, the toxicant sensitivity would be low, 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 sensitivity to the toxicant and the remote nature of a possible exposure pathway. The scale of the impact would be to the individuals that are on the island during the operational window.

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 short-term, and the scale of impact would be entire island population.

Significance Determination
The estimated number of common murres likely to occur on the islands during operations is expected to be up to 200,000 individuals. The significance determination for common murre is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>Brown Pelican, Brandt's Cormorant, Double-crested Cormorant, Pelagic Cormorant,</u>**

Toxicant risk
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 short-term, the toxicant sensitivity would be low, and the toxicant exposure risk is low since there is only one 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 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 island or away from the islands. The impacts associated with disturbance sensitivity 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 that are seen at this time on the island.

Significance Determination
The estimated number of individuals likely to occur on the islands during operations is expected to be up to 1,000 brown pelicans, 2,000 Brandt's cormorants, 100 double-crested cormorants, and 200 pelagic cormorants. The significance determination for these species is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.1.8 Waterfowl:

- **<u>Cackling Goose</u>**

Toxicant risk
Cackling geese could be exposed to diphacinone through primary and secondary exposure pathways. Cackling geese are primarily herbivorous and consume grass, grain, aquatic invertebrates, and insects (Mowbray et al. 2002). On the Farallones, cackling 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 medium-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
Cackling geese 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 are high, 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

The estimated number of individuals likely to occur on the islands during operations is between one and 705. The significance determination for cackling geese is not significant since no long-term negative or positive impacts to the population are expected.

- **Brant**

Toxicant risk

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 medium-term, the toxicant sensitivity would 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 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 island. The impacts associated with disturbance sensitivity for this alternative are high, 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

The estimated number of individuals likely to occur on the islands during operations is between one and 850 brants. 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 Non-breeding Pinnipeds:

- **Steller Sea Lion**

Toxicant risk

Steller sea lions breed on the Farallones but will not be breeding during the proposed implementation of this alternative. Steller sea lions could be exposed to diphacinone through primary and secondary exposure pathways. Pinnipeds primarily consume marine fish and invertebrates, while pups have been known to suckle on rocks. On the Farallones, these species are found along the immediate shoreline. Based on their feeding habits the duration of risk for pinnipeds would be for the medium-term, the toxicant sensitivity would be low, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish, 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 fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the entire Farallones Island population.

Disturbance risk

Steller sea lions are typically sensitive to nearby human activities and would be exposed to disturbance from ground, air, and gull hazing operations. The impacts of these 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 island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 145 and 300 Steller sea lions. 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. Ground, air and hazing operations would disturb individual Steller sea lions for up to 105 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no long-term negative or positive impacts to the population are expected.

- **<u>California Sea Lion, Northern Fur Seal, and Pacific Harbor Seal</u>**

Toxicant risk

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 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 low, and the toxicant exposure risk is low due to fact that is highly unlikely that pelagic fish, 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 fish by utilizing a deflector to prevent bait from entering the waterways. The scale of impact would be to the entire Farallones Island population.

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. The impacts of these 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 island populations.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 70 and 140 Pacific harbor seals, 11,000 and 21,500 California sea lions, and 34 and 125 northern fur seals. 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 pinnipeds would be harmed as a result of direct or indirect toxicant consumption. Ground, air and hazing operations would disturb individual pinnipeds for up to 105 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no long-term negative or positive impacts to the population are expected.

4.5.6.2.2.2 Breeding Pinnipeds:

- **<u>Northern Elephant Seal</u>**

Toxicant risk

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 along the immediate shoreline. Based on their feeding habits the duration of risk for pinnipeds would be for the medium-term, the toxicant sensitivity would be low, and the toxicant exposure risk is high due to the range of secondary toxicant exposure pathways. 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 entire Farallon Islands population.

Disturbance risk

Northern elephant seals do not often react to nearby human activities. They would be exposed to disturbance from ground, air, and gull hazing operations. 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. However, every effort will be made to minimize disturbance risk to these 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 island population.

Significance Determination

The estimated number of individuals likely to occur on the islands during operations is between 65 and 135 northern elephant seals. 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. Ground, air and hazing operations would disturb individual elephant seals for up to 105 days; however the disturbance levels from these activities would not reach a Level A harassment under the MMPA. The significance determination for pinnipeds is not significant since no long-term negative or positive impacts to the 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 medium due to the sensitivity to the toxicant and the number of exposure pathways. The scale of impact would be to the entire population of this subspecies of arboreal salamander as they are endemic to the South Farallon Islands. Also, in an effort to mitigate potential unforeseen impacts to salamanders, up to 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 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 short-term, and the scale of impact would be to the entire population of this subspecies of arboreal salamanders since they are endemic to the South Farallon Islands.

Significance Determination

There is enough anecdotal evidence to support the assertion that mice are at minimum competing with salamanders on the Farallon Islands, but the level of uncertainty is too great to determine if mouse eradication will significantly benefit salamanders (40CFR 1502.22). Also, potential negative impacts from eradication operations are considered to be not significant. For these reasons, the significance determination for arboreal salamanders is not significant.

4.5.6.2.4 *Impacts on Fish*

- **Marine Fish**

Toxicant risk

Marine fish could be exposed to diphacinone through both primary and secondary exposure pathways by consuming bait pellets, invertebrates, or other fish that have been exposed to the toxicant. Based on their feeding habits the duration of risk for these fish would be for the short-term since bait pellets would dissolve within a few hours, the toxicant sensitivity would be medium, and the toxicant exposure risk is high due to the existence of a primary and secondary toxicant exposure pathway. However, most fish species near the Farallones are either predators or planktivores that are unlikely to come in contact with or consume a bait pellet. However, measures will be taken to minimize bait drift into the marine environment; see Section 2.10.7.7 for details. The overall toxicant risk is medium due to the short duration of potential exposure, sensitivity to the toxicant, and the number of 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. However, 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) therefore, the toxicant sensitivity would be negligible. Based on their feeding habits the duration of risk for camel crickets would be for the medium-term and the toxicant exposure risk is low due to the primary exposure pathway. The overall toxicant risk is low due to the low sensitivity of insects to the toxicant. The scale of impact would be to the total 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 short-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 since with 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 disturbance from ground operations during project implementation.

- **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 medium-term. The overall toxicant risk is low due to the sensitivity to the toxicant and the number of exposure pathways. The toxicant sensitivity would be negligible, and the toxicant exposure risk is low due to the primary exposure pathway. The scale of impact would be to a few individuals.

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 a few individuals.

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 ground operations during project implementation.

Intertidal Invertebrates

- **Black Abalone**

Toxicant risk

Black abalones are intertidal gastropod mollusks that feed on plankton, kelp, and algae. Abalone could be exposed to diphacinone through a primary exposure pathway. 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, diphacinone consumption by abalone is not known not cause mortality (Primus et al. 2005). Based on their feeding habits the duration of risk for black abalone would be for the medium-term. The toxicant sensitivity would be negligible, and the toxicant exposure risk is medium due to the primary and secondary exposure pathway. 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 number of exposure pathways. The scale of impact would be a small number of individuals.

Disturbance risk
Black abalones are not likely to be exposed to disturbance impacts from eradication operations since there is only one individual found in the intertidal area and personnel would actively avoid disturbing it. Therefore, disturbance risk to this species is negligible.

Significance Determination
There are no expected long-term negative or positive significant impacts to black abalones, so the significance determination for this species is not significant.

- **<u>Other Gastropods</u>**

Toxicant risk
Other gastropods, like owl limpets, black turban snails, and several dorid nudibranch species, could be exposed to diphacinone through primary exposure pathways. 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, diphacinone consumption by abalone is not known not cause mortality (Primus et al. 2005). Based on their feeding habits the duration of risk for black abalone would be for the medium-term. The toxicant sensitivity would be negligible, and the toxicant exposure risk is medium due to the primary and secondary exposure pathway. 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 single individual found at the South Farallon Islands.

Disturbance risk
Black abalones are not likely to be exposed to disturbance impacts from eradication operations since there is only one individual found in the intertidal area and personnel would actively avoid disturbing it. Therefore, disturbance risk to this species is negligible.

Significance Determination
The significance determination for camel crickets is significant since with the eradication of mice anticipated to have significant positive benefits to the population on the Farallones. These long-term beneficial impacts outweigh the short-term adverse impacts associated with the Alternative C.

- **<u>Other Intertidal Invertebrates</u>**

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 medium-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 individuals.

Disturbance risk
Invertebrates are not likely to be exposed to disturbance impacts from eradication operations; and therefore, no further analysis is warranted for this species.

Significance Determination
The significance determination for intertidal invertebrates is negligible since no long-term negative or positive impacts to the population 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.

4.5.6.2.7 Impacts Table for Alternative C on Biological Resources: Aerial Broadcast of Diphacinone

Table 4.3: Impacts of Alternative C on Biological Resources

Species	Significance determination	Duration of Toxicant Risk[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 with multiple exposure pathways[8]	Not Significant	Medium	Medium	High	Medium	Low	Short	Individ.	Individ.

Raptors with single exposure pathway[9]	Not Significant	Medium	Medium	Medium	Medium	Low	Short	Individ.	Individ.
Peregrine Falcon[10]	Not Significant	Medium	Medium	High/ None	Medium /None	Low/ High	Short/ Medium	Individ.	Individ.
Burrowing Owl[10]	Not Significant	Medium	Medium	High/ None	Medium /None	Low/ High	Short/ Medium	Individ.	Individ.
Common Raven[10]	Not Significant	Medium	Medium	High/ None	Medium /None	Low/ High	Short/ Medium	Individ.	Individ.
Western Gull	Not Significant	Medium	Medium	High	Medium	High	Medium	Regional	Regional
Other Gulls[11]	Not Significant	Medium	Medium	High	Medium	High	Medium	Regional	Regional
Ashy and Leach's storm-petrels	Significant positive effect	Short	Low	Low	Low	Low	Short	Individ.	Individ.
Cassin's Auklet	Not Significant	Short	Low	Low	Low	Low	Short	Individ.	Individ.
Common Murre	Not Significant	Short	Low	Low	Low	Medium	Short	Individ.	Individ.
Brown Pelican and Cormorants	Not Significant	Short	Low	Low	Low	Low	Short	Individ.	Individ.
Cackling Goose	Not Significant	Medium	Low	High	Low	High	Short	Individ.	Individ.
Brant	Not Significant	Medium	Low	Medium	Low	High	Short	Individ.	Individ.
Black Oystercatcher	Not Significant	Medium	Low	High	Low	High	Medium	Island	Island
Species	Significance determination	Duration of Toxicant Risk[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
Other Shorebirds[12]	Not Significant	Medium	Low	High	Low	High	Short	Individ.	Individ.
Songbird insectivores/ frugivores[13]	Negligible	Medium	Low	Medium	Low	Low	Short	Individ.	Individ.
Songbird Insectivores[14]	Negligible	Medium	Low	High	Low	Low	Short	Individ.	Individ.
Passerine granivores[15]	Negligible	Medium	Low	High	Low	Low	Short	Individ.	Individ.
Violet-green Swallow & Anna's Hummingbird	Negligible	Medium	Low	Low	Low	Low	Short	Individ.	Individ.
Northern Elephant Seal	Not significant	Medium	Low	High	Low	High	Medium	Island	Island
Other Pinnipeds[16]	Not significant	Medium	Low	High	Low	High	Medium	Island	Island
Marine Fish	Negligible	Short	Low	High	Low	Low	Short	Individ.	Individ.
Salamanders	Not Significant	Medium	Low	Medium	Low	Low	Short	Island	Island
Terrestrial	Significant	Medium	None	Low	Low	Low	Short	Individ.	Individ.

Invertebrates	positive effect								
Intertidal Invertebrates	Negligible	Medium	None	Low	Low	Low	Short	Individ.	Individ.
Black Abalone and Other Intertidal Gastropods	Negligible	Medium	None	Low	Low	Low	Short	Individ.	Individ.
Camel Cricket	Significant positive effect	Medium	None	Low	Low	Low	Short	Island	Island
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] Rough-legged hawk, red-tailed hawk, sharp-shinned hawk, northern harrier, Cooper's hawk, American kestrel, barn owl, long-eared owl, short-eared owl.
[9] Ferruginous hawk, white-tailed kite, northern saw-whet owl, merlin.
[10] Two outcomes listed: First – individuals remaining on island / Second – individuals captured and held in captivity.
[11] Ring-billed gull, California gull, herring gull, Thayer's gull, glaucous-winged gull, Heermann's gull, mew gull.
[12] Wandering tattler, black turnstone, whimbrel.
[13] Hermit thrush, American robin, varied thrush, Townsend's warbler, cedar waxwing, black phoebe.
[14] Yellow-rumped warblers, palm warbler, golden-crowned kinglet, ruby-crowned kinglet.
[15] Spotted towhee, chipping sparrow, savannah sparrow, fox 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, European starling, American pipit, lesser goldfinch.
[16] California sea lions, northern fur seal, Steller sea lion, Pacific harbor seal.

4.6 Consequences: Social and Economic Environment

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 one of PRBO and the Service's highest priorities. If the No Action alternative is selected, PRBO and the FWS 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 prevent injury to personnel.

4.6.1.3 *Alternative B: Aerial Brodifacoum and Alternative C: Aerial Diphacinone*

If either Alternative B or Alternative C is selected, the subsequent safety protocols will be followed during the operation. The Farallon 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. The significance determination for both action alternatives is not significant since every effort will be made to prevent injury to personnel.

4.6.2 <u>Refuge Visitors and Recreation</u>

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 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

The area immediately surrounding the South Farallon Islands (within approximately 0.5 miles) likely would be closed to boaters during aerial bait application operations for safety reasons, for 21 and 30 days. These closures would be a minor short-term inconvenience to Refuge visitors. 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 three permitted recreational shark cage diving ventures operate within 0.5 miles of the islands almost daily (weather permitting) from late September until late November. Closures around the island could result in lost shark diving days.

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 further 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.

4.6.3 <u>Fishing Resources</u>

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 area immediately surrounding the South Farallon Islands (approximately 0.5 miles) would 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 the islands. Thus, operations no impacts to fishing resources in the area are expected. The significance determination is negligible.

4.6.4 Social and Economic Resources

4.6.4.1 Analysis framework for historical and 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 wooden 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 negligible.

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. Permitted recreational shark cage diving ventures that operate within 0.5 miles of the islands would likely experience short-term negative economic impacts during the bait application period. The economic impact to shark diving operations is 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.

4.7 Unavoidable Adverse Impacts

The analysis presented in this DEIS 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. 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 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
  - Ongoing impacts to ashy and Leach's storm-petrel populations would continue as a result of ongoing hyperpredation by burrowing owls.
- Mammals
  - Mice present an ongoing risk to marine mammals because of their ability to transmit diseases. Adverse impacts would ensue if disease transfer were to occur.
- Amphibians
  - Suspected 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 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, may 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.
- 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, ravens, 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, may 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.
- 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, ravens, 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 stellar 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 nineteenth century 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. After cats and rabbits were removed from the Farallones, vegetation began to grow back in areas of the islands that rabbits had removed them, and nesting seabird bird populations benefitted without the predation pressure from cats and habitat competition from rabbits.

- Lighthouse – The lighthouse was constructed in 1853 and managed by on island staff from the U.S. Lighthouse Service and U.S. Coast Guard until it was automated in 1972. Lighthouse construction likely caused substantial disturbance to island habitats; however, the extent of the impact is unknown. Uncounted numbers of rocks from the islands were used to construct rock several walls. This 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, but also created habitat for these same 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, primarily crevice nesting seabird, of native birds 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 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 Carpentry Shop still exists. All others were removed prior to refuge establishment. Impacts from their construction are unknown, but probably resulted in substantial disturbance and destruction of seabird nesting 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 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. This information is of value to Refuge Managers since replacement of nest box soil is a relatively inexpensive and non-invasive management action. While overt signs of lead poisoning are not routinely observed, some feather samples did contain lead concentrations comparable to those found at the Midway Atoll (~ 30 ppm), an island with significant lead poisoning events due to a history of lead-based paint use (Aceituno et al. 2012).

- Rock wall construction – An extensive system of rock walls were constructed in the 19th century mainly as part of trail construction but also for temporary structures, such as for seabird egg storage and to surround the water catchment pads. Rocks used were obtained locally and may 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 mid-nineteenth century to collect drinking water including two water catchment pads, a settling tank, a 10,000 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.
- Commercial seabird egg collection – Seabird eggs, mainly common murres, were collected during the nineteenth century severely impacting seabird breeding success during that time (*ca*.1848 – 1900). 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 200,000 or more birds (PRBO, unpubl. data; USFWS, unpubl. data) is still well below the estimated 1,000,000 present when egging began (Carter et al. 2001).

- 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 rhinocerous 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, 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 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 have increased by about 17 percent between 2007 and 2012 (PRBO, unpubl. data), a demonstration of the positive effects of the project.

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). Of these, sea level rise is most applicable to this terrestrial analysis. Regional predictions (IPCC 2007) for North Central Pacific Gyre area calls for increases of 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 increasing rainfall and wind speeds and more heavy precipitation associated with increases in sea surface temperatures at all sites. 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 Gulf of the 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 Ninos 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.

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 (PRBO unpubl. data). This represents approximately five percent of the islands' surface area and would include much of the intertidal areas where pinnipeds currently haul out, as well as pocket beaches and gulches around the island. As a result, these areas would become inaccessible, forcing the animals to move higher up onto the marine terrace or to abandon the colony. This redistribution of pinnipeds would, in turn, impact seabird habitat by reducing the available nesting areas and causing the destruction of 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.

- 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. PRBO Conservation Science conducts the majority of the scientific research on the Farallon Islands in conjunction with the Refuge staff and visiting researchers. PRBO 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 and population demography 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.

    - 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 unintrusive 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 4 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.

    - 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.

- 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.

- 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.

- Population status 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 night per month per site from April to August.

- 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 wintering patterns – During the falls of 2007-2012, owls were captured in mist-nets or traps and banded in a study of use patterns by migrating and overwintering birds. Several birds were resighted at roost sites during the day. In the fall of 2009 and 2010, several captured owls were also affixed with radio transmitters to assist tracking.

- Landbird Monitoring – Standardized area searches are used through the fall to assess bird migration, surveying daily for all non-breeding birds. Color banding of focal passerine species is used to access stopover duration.

- Aerial census of murre and cormorant colonies – Aerial photographic surveys are conducted cooperatively by the Refuge, Humboldt State University, and CDFW, and University of California Santa Cruz, as part of a statewide survey of common murre, Brandt's cormorant and double-crested cormorant breeding colonies. Colonies are photographed using a 35 mm or digital camera with 200-300 mm lenses from a twin-engine Partanavia airplane. Photographs are taken at an altitude of 700–1,000 feet above the colony. Nest and bird counts are obtained later.

- Pinniped 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.

- 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 September 1 (or the first fall rain) and end when salamanders retreat underground following the raining 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 SEFI. Point and photographic quadrants are visited one to two times annually or less frequently. Surveys are conducted during minus tides, typically in February, August, and/or November). The goals are 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.

- Pinniped monitoring – NMFS conducts annual aerial surveys to count numbers of breeding threatened Steller sea lions, California sea lions, and harbor seals, as part of larger-scale surveys.

- Vegetation Monitoring – This study, initiated in 2012, is intended to monitor changes in relative abundance and species composition of vegetation before and after proposed mouse removal. Vegetation monitoring would be conducted to monitor the recovery of native plants post mouse eradication. Thirty three circular plots of 10 m diameter across the breadth of island habitats will be assessed through observational surveys. 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 (i.e. quarterly) These visual surveys likely only cause short-term impacts to individuals.

- 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, but sometimes in winter. Takes three to five days to complete. Includes greasing, corrosion removal, re-painting, etc.

  - 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. The use of herbicides and hand-pulling are regularly utilized to remove and control the spread of invasive vegetation. The removal of invasive house mice may either assist decrease the spread of certain invasive plants since mice consume plant seeds and plant parts. However, mice also consume native plant parts, potentially impacting their populations, and thus removal of mice may benefit native plants.

  - 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 but can happen in 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).

4.8.4 Future Actions

- Invasive plant control – The majority of effort to control invasive plants includes: a) a one-week effort in early to mid-August each year, five to seven personnel, treating invasive plants on SEFI, especially New Zealand spinach. Most work is on slopes and marine terrace of south side of island; and b) plant pulling efforts that occur in winter-spring. Intensity varies from year to year based on staffing and funding availability.

- Farallon Island Nest Site Improvements – The nest site improvement project is funded by the Cosco Busan Trustee Council. This project would likely be initiated in the fall or winter of 2015 and are expected to have long-term benefits to the islands seabirds. 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 rocky crevices.

  - 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.

  - The second component of the project is to create nesting habitat for crevice nesting seabirds such as the ashy storm-petrel by using old concrete slabs and other old on-island construction materials that have no current use. The materials would be broken up and arranged into rock piles for nesting habitat. This project would provide up to 60 additional nesting sites for storm-petrels.

4.8.5 Summary of Effects from Past, Present, and Future Projects

Physical Resources

- Water
  - None of the past, present, or foreseeable future projects have or are likely to have any negative or positive effects on water.
- 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 and have 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 result in extreme high tides and storm events that could increase erosion.
- Wilderness

- None of the past, present, or foreseeable future projects have or are likely to have any long-term negative or positivity effects on wilderness character.

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. 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 ranges between 150,000 and 200,000 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 19th century from intensive seal hunting. The first individual returned to breed on the Farallones in 1996 and the population has steadily been increasing to approximately 500 individuals currently. 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 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 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 still pose a potential threat to personnel safety; however, there have been no recorded incidences of lead poisoning.
- 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 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 past, present, and reasonably foreseeable future projects on these resources in the future. It is unclear what indirect impact the continued presence of mice will have on the Farallon ashy storm-petrel population in the furure. However, reducing the numbers of wintering burrowing owls on the islands will likely have positive impacts for the Farallon ashy storm-petrel population (Nur et al. 2013).

Physical Resources

- Water
  - The No Action Alternative would only result in negligible adverse impacts to water resources. 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 the No Action alternative to the impacts of these other actions would be imperceptible.
- Geology/Soil
  - Mice have had perceptible impacts on geology or soil on the Farallon Islands by ripping up swaths of soil with their burrows. Ongoing and future scientific research projects would not have any perceptible impacts on geology or soils, nor would future invasive plant control or nest site improvements. The No Action alternative would not result in any perceptible change to the cumulative impact scenario.
- Wilderness
  - Mice impact the natural characteristics of wilderness on the Farallon Islands. Ongoing and future scientific research projects would not have any lasting adverse impacts on wilderness character and could lead to efforts to further restore natural species composition which would enhance wilderness character.

Invasive plant control efforts would enhance wilderness character by restoring more natural conditions. The incremental contribution of the No Action alternative to these other actions would be noticeable.

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 planned nest site improvement project could improve nesting success rates for auklets and storm-petrels while also providing additional nesting habitat for storm-petrels. Under the No Action alternative, the net effect of house mice and burrowing owls would be to negatively impact the South Farallon Islands ashy and Leach's storm-petrel populations. Climate change affects would likely exacerbate modeled indirect impacts of mice on the Farallon ashy storm-petrel population. 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. In addition, mice can act as a disease vector for marine mammals. The incremental contribution of the No Action alternative to projected climate change-related effects on mammals is imperceptible.
- Amphibians
  - Competition for resources and possible predation by mice, increased temperatures and changes in the food supply due to climate change are the major threats to amphibians on the Farallon Islands. The incremental contribution of the No Action alternative on salamanders is noticeable.
- Marine Fish
  - 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 the No Action alternative on marine fish is imperceptible.
- Invertebrates
  - Predation by mice, increased temperatures and changes in the food supply due to climate change are the major threats to amphibians on the Farallon Islands. The incremental contribution of the No Action alternative on salamanders is noticeable.
- Vegetation
  - Predation by mice combined with the effects of climate change 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 the No Action alternative would be noticeable.

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. 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 have to comply with existing safety protocols. The contribution of the No Action alternative to 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), and climate change, which could alter the composition and distribution of fish around the islands. 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 Historical Resources
  - The majority of the threats to cultural and historical resources came from past projects to remove structures. The added effect from the No Acton Alternative is imperceptible.

4.8.8 Summary of Cumulative Impacts under Alternatives B

4.8.8.1 Summary of Combined Affects 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 impacts related to past, present, and reasonably foreseeable future projects. Similarly, the expected positive long-term impacts of Alternative B 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 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. 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 quality of wilderness by removing an invasive species which would also result in benefits to a 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 short-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 partially offset the potential 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 short-term disturbance impacts from hazing, bait broadcast, and other 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 noticeable.
- Amphibians
  - No anticipated negative impacts are expected for amphibians from Alternative B. 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 anticipated 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 anticipated negative impacts are expected for invertebrates from Alternative B. 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 B is expected to have a positive effect on the invertebrates on the 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 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 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 Historical 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 to cultural resources is likely to be imperceptible.

4.8.9 Summary of Cumulative Impacts under Alternatives C

4.8.9.1 Summary of Combined Affects 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 short-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 partially offset the potential 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 short-term disturbance impacts from hazing, bait broadcast, and other 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
    - No anticipated negative impacts are expected for amphibians from Alternative C. 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. For ashy and Leach's storm-petrels in particular, individuals would continue to be impacted by predation from burrowing owls 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. 2013), 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

The NEPA scoping process (40CFR 1501.7) was used to determine the scope of the analysis and to identify potential issues and opportunities related to the Proposed Action. A summary of the scoping and public involvement process for the proposed project is as follows:

The NEPA scoping process for the eradication of house mice from the Farallon Islands involved both internal and external scoping. The internal scoping process included review of the biological, physical, and social issues associated with eradicating mice from the Farallones, as well as a review of the all of the available methods for eradicating mice from the Farallones, which can be found in the Alternatives Selection Process Report (Appendix C). The Service, PRBO, and IC collaborated to identify the impacts of mice on the South Farallon Islands ecosystem, as well as the potential benefits to ecological services, including species recovery, from mouse removal. The external scoping process involved consultation with cooperative and regulatory agencies that have specialist expertise or a stake in the outcome of the project, and two 45 day public scoping periods, the first in 2006 for the original EA and the second in 2011 for the EIS, prior to the preparation of the Draft EIS. In addition to the two public meetings, the Service held a meeting on July 29, 2011 with interested agencies early in the alternatives development process.

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 Scoping and Review

- A planning and work team consisting of Service, PRBO, and IC staff held regular meetings to prepare the draft plan. The team involved and consulted with the National Wildlife Research Center 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

As part of the project scoping process, the Service opened two 45-day 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 26, 2011 through June 10, 2011 for the current EIS. During the two scoping period's interested members of the public and interested agencies were encouraged to comment on the scope of the project and identify the important 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 took all substantive comments into consideration during the preparation of this Draft EIS (See Appendix O for a full summary).

This Draft Environmental Impact Statement will be made available for review by the public during the 45-day Public Comment period to allow the public to provide input on the content of the DEIS. This comment period will include at least one public information session, during which Service staff and partners would be available to provide information and answer questions in person. Availability of the Draft EIS and information on the comment period and public information sessions will be advertised in the Federal Register, by mail to all interested parties who have requested information, and in local media as appropriate. After the comment period closes, the Service will address all substantive comments received, make changes to the DEIS as necessary, and circulate the Final EIS along with all substantive public comments and/or a summary of public comments if a large number are received.

5.5 Recipients of Requests for Comment for the DEIS

5.5.1 <u>Government Recipients</u>

- EPA

- USDA
- CDFW
- NOAA-NMFS
- NOAA-GFNMS
- Cal DPR
- Cal EPA

5.5.2 Public Recipients

TO BE COMPLETED

5.6 Comments Received for DEIS

TO BE COMPLETED

5.6.1 Agency Comments

TO BE COMPLETED

5.6.2 Public Comments

TO BE COMPLETED

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U.S. Fish & Wildlife Service

Farallon National Wildlife Refuge

1

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

Photos Courtesy of Island Conservation

Draft Environmental Impact Statement

South Farallon Islands Invasive House Mouse Eradication Project

Appendices

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

Prepared by:

San Francisco Bay National Wildlife Refuge Complex
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August 2013

8 Appendices

8.1 Appendix A – Project Feasibility and Non-Target Risk Trial Report

Farallon Islands Restoration Project

A Report on Trials undertaken to inform Project Feasibility and Non-Target Risk Assessments

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March 28, 2013

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1.1 EXECUTIVE SUMMARY

A field trial completed in November 2010 was successful in addressing several objectives identified as important in planning for a proposed eradication of invasive house mice on the South Farallon Islands of the Farallon National Wildlife Refuge. The results from the trial will inform the development of

eradication alternatives as well as possible non-target mitigation measures to be considered during project planning.

Key findings of the trial were as follows:

- Mice were exceptionally abundant on the South Farallon Islands in November 2010, with over 93% trapping success and more than 250 uniquely marked individual mice captured within a 0.25ha study site. Mark-recapture data indicated mouse densities of up to 1297 mice per hectare, representing one of the highest recorded population densities for anywhere in the world.

- Mice were distributed across the island including West End but variation in density from site to site was high. Many mice were active during the day during the fall months on the South Farallon Islands.

- Although mice in reproductive condition have been trapped year round on the South Farallon Islands, very few mice were found to be reproductively active in November. Reduced breeding activity and apparent food scarcity at this time of year marks this season as the best in which to undertake a mouse eradication.

- Mice exhibited no sign of any Vkorc1 alleles associated with anticoagulant resistance, confirming there is no known genetic barrier to successful eradication if anticoagulants were to be used.

- A 1g cereal bait pellet containing the fluorescent dye pyranine was readily accepted and appears to be highly palatable to Farallon mice.

- Applying rodent bait at 18kg/ha provided four days of bait availability after an initial application. Only one to two days of availability was achieved following a subsequent application at 18kg/ha in one area and 9kg/ha in another. The period over which bait will be available is expected to be longer during an operation as mouse numbers will be reduced after the first application of bait and if consumption of bait by gulls can be minimized. Consequently, EPA label rates of 18kg/ha and 9kg/ha specified for Brodifacoum-25D Conservation are considered sufficient to ensure that all mice have time to consume sufficient bait to ingest a lethal dose for an eradication operation utilizing a second-generation anticoagulant as the rodenticide.

- Following the application of rodent bait 18 kg/ha and 9kg/ha more than 96% of trapped mice showed evidence of exposure to bait. For similar reasons as those stated above, EPA label rates of 18kg/ha and 9kg/ha are considered sufficient for an eradication operation to ensure all mice are exposed to bait.

- Western gulls were observed consuming rodent bait and it is concluded that individual western gulls present on the islands during a mouse eradication would be at risk of primary and secondary poisoning. The implementation of a hazing program is recommended to prevent western gulls from consuming bait pellets and inhibit learnt behavior.

- Consumption of rodent bait by gulls could reduce the amount of bait available to mice and hazing of gulls is recommended to maximize the likelihood of mouse eradication success.

- No exposure to pyranine (a fluorescent dye) was observed in two burrowing owls inspected during the trial now any of the fecal pellets found. However, individual burrowing owls present on the island are still considered to be at risk because they are expected to consume poisoned mice.

- The hand-broadcast of non-toxic bait pellets containing a fluorescent dye in salamander habitat on the island found no evidence of salamander or invertebrate exposure. Camel crickets exposed in the same way did consume trace amounts of the cereal grain pellets. However, camel crickets, because of their physiology, are not at risk from anticoagulants such as diphacinone and brodifacoum.

- Two bait station designs tested were readily used by mice and successfully excluded gulls.

1. INTRODUCTION

The South Farallon Islands, comprised of Southeast Farallon Island (SEFI) and West End Island (WEI), provide important habitat for seabirds and pinnipeds, and support some of the world's largest seabird populations including Ashy Storm-Petrel (*Oceanodroma homochroa)*, Brandt's Cormorant (*Phalacrocorax penicillatus)* and Western Gull (*Larus occidentals* (Ainley and Boekelheide 1990, Warzybok and R. 2011). House mice (*Mus musculus*), introduced to the South Farallon Islands sometime during the 19th century, indirectly and possibly directly affect burrow nesting seabird populations and are expected to be impacting other native and endemic species.

The impacts of House mice on species and ecosystems are described in Mackay (2011b). As observed on other islands around the world, introduced house mice pose a significant threat to seabird populations (Ainley and Boekelheide 1990, Sydeman et al. 1998, Cuthbert and Hilton 2004). On the South Farallon Islands, mice also provide a food source that supports an overwintering population of migratory burrowing owls, which in spring switch to Ashy Storm-Petrels (*Oceanodroma homochroa*) as prey. Ashy Storm-Petrels are a rare species whose largest breeding colony occurs on the South Farallon Islands (Carter et al. 2008). Other recorded impacts of mice include predation or competition with many native and endemic reptile and invertebrate species (Newman 1994b, Ruscoe 2001b).

To eliminate these impacts and allow species and ecosystem recovery, the USFWS is currently assessing the potential for removing mice from the Refuge. A series of trials has been completed to inform planning for a possible eradication attempt. This report documents the findings of recent trials that aimed to assess the efficacy of eradication techniques, quantify potential risks to non-target wildlife and evaluate a potential mitigation measure to reduce risk to non-target species.

Although a wider suite of methods is under consideration, trials focused on the use of rodent bait containing an anticoagulant rodenticide. The application of anticoagulant rodenticides is the only method that has been used successfully to remove mice from islands (Keitt et al. 2011, Mackay et al. 2011). Early analysis of options for the removal of house mice identified gulls as a potential non-target species at risk from a mouse eradication (Howald et al. 2003b). Although widely distributed along the western US seaboard, the South Farallon Islands are home to the world's largest colony of western gulls (Ainley and Boekelheide 1990). Consumption of rodent bait poses not only a risk to gulls but also to the operation, as gulls could consume sufficient bait to create gaps in bait coverage. Successful eradication of mice requires all individuals within the mouse population to be exposed to the technique (Bomford and O'Brien 1995).

Native reptiles and terrestrial mammals are absent from the Farallon Islands, but an amphibian, the Arboreal salamander (*Aneides lugubris farallonensis*) occurs on Southeast Farallon Island. The species is endemic to mainland California and Baja California where it is distributed primarily along the coast, with populations on some offshore islands and in the Sierra Nevada foothills. The Farallon subspecies is not considered threatened but is only found on the South Farallon Islands. Farallon salamanders are primarily insectivorous, are not considered at risk from the application of rodent bait and are expected to benefit as a result of mouse eradication (Newman 1994b, Baber et al. 2007a). However, their endemic status warrants additional analysis and risk to salamanders was assessed as part of our trials.

The endemic Farallon camel cricket (*Farallonophilus cavernicolus*) is not considered to be at risk and evidence (e.g. Green et al. 2011) suggests that cricket abundance will increase on the islands once House mice are removed. A pilot census was undertaken in accessible caves on Southeast Farallon to inform the development of baseline surveys to monitor relative cricket abundance before and after mouse eradication.

In the event that mice are detected on the Farallon Islands after the proposed eradication, knowing the provenance of individuals is important to verify whether the eradication failed or the island biosecurity system was breached. For this reason, samples of mouse DNA were collected from SEFI and WEI for long-term storage and future analysis. Genetic analysis was also undertaken to confirm the subspecies of House mouse present, their geographic origin, and to determine if mice on the islands are resistant to anticoagulants.

2. OBJECTIVES

- Assess mouse abundance by using mark-recapture techniques and establish protocols for tracking seasonal changes in mouse abundance on SEFI.
- Determine the reproductive status of mice during the fall.
- Determine the persistence of the fluorescent dye pyranine in mice.
- Evaluate the palatability of proposed bait to mice and their preference for this food over natural food sources.
- Apply a non-toxic bait product to a portion of SEFI in order to assess the availability of bait pellets over time and the proportion of the mouse population exposed to bait pellets.
- Collect and archive samples of DNA from island mice.
- Confirm if South Farallon Islands mice are resistant to anticoagulant rodenticides.
- Assess the risk of primary or secondary rodenticide exposure to western gulls, burrowing owls and salamanders using a non-toxic bait applied at the target application rate.
- Determine if camel crickets will eat rodent bait.
- Identify a potential method for monitoring the change in abundance of camel crickets over time.
- Determine acceptability of two bait station designs to mice.
- Confirm the effectiveness of two bait station designs to isolate gulls from bait exposure.
- Map and characterize caves to inform operational planning for a future mouse eradication attempt.

3. METHODS

3.1 Mouse Abundance

Index of Abundance

Prior to broadcasting rodent bait, a 45m x 45m grid of 100 traps spaced at 5m intervals was set and checked for five consecutive nights within the intended baiting zone in order to develop an Index of Abundance for mice (Fig. 1).

Monthly mouse trapping

Thirty three permanent mouse trapping locations were established on SEFI for conducting monthly mouse trapping as a means of establishing a monthly index of activity throughout the year. In addition to the 28 sites previously used in USFWS mouse trapping studies conducted from 2001-2004 (Irwin 2006a), five new locations were established in the Lighthouse Hill area to obtain a more representative sample from this habitat type. Sites were marked with white PVC, aluminum tags, and had GPS coordinates recorded (Fig. 1).

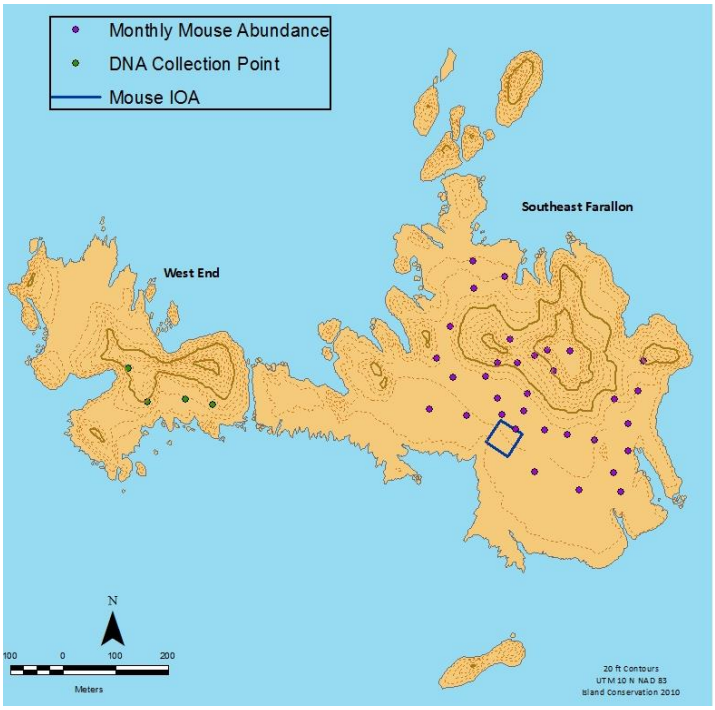

Fig. 1. Location of the Index of Abundance trapping grid and monthly mouse trapping locations.

3.2 Mouse Reproductive Status

All mice trapped during our trials were assessed for reproductive activity, including descended testes in males and perforate vaginas and enlarged mammae in females.

3.3 Biomarker Persistence in Mice

To guide our interpretation of the mouse exposure field study described below, a study of captive Farallons mice was used to determine how long pyranine persists in the gastrointestinal tract after consumption. Pyranine fluoresces green when exposed to ultraviolet light (UV). Twelve mice were fed a non-toxic form of Brodifacoum-25D Conservation (Bell Laboratories, Inc. Madison, WI, EPA Reg. No.

56228-37) infused with 0.2% pyranine during a six-day no choice trial undertaken on the island. Two mice were also kept as a control.

The twelve mice were divided into three different exposure groups with four mice in each group. Two adult males and two adult females in good condition were randomly placed in each group. On the first day of the study, mice in Group 1 were fed an amount of non-toxic bait equivalent to half the amount of Brodifacoum-25D Conservation required for ingestion of a LD50 (approximately 0.5 g). Mice in Group 2 were fed an amount equivalent to the LD50 (approximately 1 g) and Group 3 was fed twice the LD50 amount (approximately 2 g). Quantities were based on estimates that a mouse must eat 1-2.6% of its body weight of 20ppm brodifacoum bait to achieve acute oral toxicity (Fisher 2005a). Mice in the exposure group were fed non-toxic pellets without pyranine on the second, third, and fourth days of the trial. All mice were individually housed and provided with *ad libitum* water.

All mice were checked daily for four days for the presence of fluorescence under UV light at both the mouth and the anus.

3.4 Bait Palatability and Preference

A two-choice food preference trial was conducted to determine consumption rates and food preferences. The tests were conducted in a laboratory setting on-island and continued for eight days, with each mouse housed individually. Ten adult mice were given a choice between non-toxic bait pellets with pyranine and locally sourced natural food alternatives included coleopteran larvae and fresh local vegetation (endemic *Lasthenia maritima* and invasive *Hordeum murinum leporinum*). The natural foods used in the trial were selected based on a description of Farallon mouse diet by Hagen (2003a). Each mouse was supplied daily with 2.8g of bait pellets and 2.06g of the naturally occurring food items, totaling 4.86g of food per day. Every day, the amount of each food type (natural food or bait pellet) consumed by individual mice during the previous 24 hours was determined based on the amount of food remaining in the cage.

3.5 Rodent Bait Availability

In order to assess the bait application rates required to ensure all mice have access to a lethal dose of bait during an eradication operation a bait availability trail was undertaken on SEFI. To provide an indicator of a starting application rate to use in the trial non-toxic bait was initially hand broadcast at 36kg/ha over a 0.25 ha plot at North Landing (Fig. 2). Based on observations of bait disappearance from this area, a larger 6.2 ha plot was split into two: Area A (western half) measuring 3 ha and area B (eastern half) measuring 3.2 ha. Non-toxic rodent bait was initially hand broadcast at a density of 18 kg/ha in both areas. Five days later, bait was hand broadcast at 18 kg/ha in Area A and 9kg/ha in Area B.

Immediately after bait had been hand broadcast, 10 bait availability monitoring transects (six in Area A and four in Area B) of 1 m x 50 m were calibrated so they contained the number of pellets representative of the bait application rate used in that area. Transects were then checked daily to determine the availability of bait pellets over time (Fig. 2). In an attempt to assess how the availability of pellets was affected in the absence of gull consumption, four exclusion cages (two in each area) were established (Fig. 2). The 2.4m x 2.4m exclusion cages were made of wood and chicken wire and allowed mice to enter and feed on bait pellets, but prevented gulls from accessing bait. Bait pellets within exclusion cages were counted on a daily basis.

3.6 Mouse Biomarker Exposure Rates

An indication of efficacy can be gauged by measuring exposure rates to non-toxic bait infused with pyranine. A core trapping grid was established in both Area A and B (Fig. 2). Two traps were placed at each point of a 2m x 2m grid across an area of 18m x 18m. On the second day following each bait application, trapping was initiated and continued for a total of two nights. Traps were checked daily and captured mice were assessed for exposure to pyranine. All mice testing positive for exposure were removed from the population each day.

Immigration transect trapping was conducted concurrent with core grid trapping in both Areas A and B. Each transect extended from the edge of the core trapping plot to at least 90 meters beyond the edge of the baited area (Fig. 2). Two traps were placed at 10m intervals along the transect. Traps were opened concurrently with core trapping grid traps and were checked in an identical fashion.

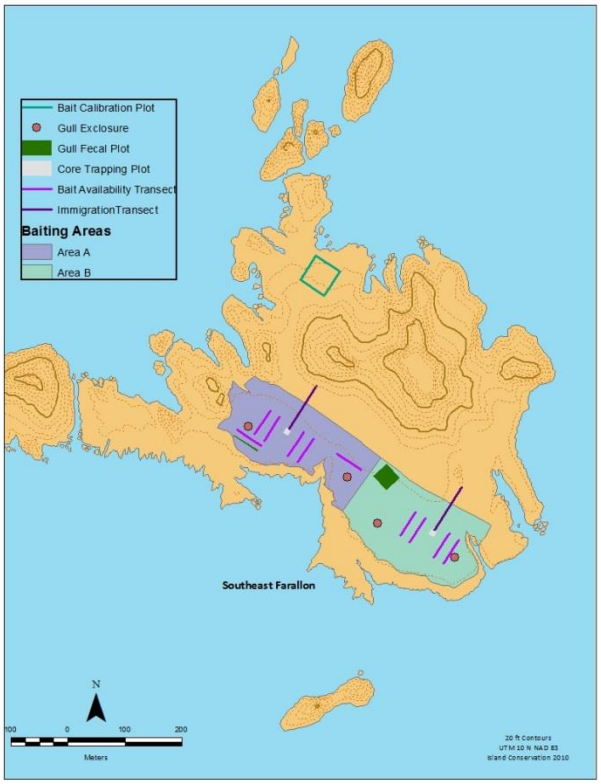

Fig. 2. A map of baited areas, availability transects, immigration transects, core trapping grids, gull fecal plots, and gull exclusion cages

3.7 Mouse DNA Sampling and Genetic Analysis

In the event that mice are detected on the islands subsequent to an eradication attempt, archived DNA samples will allow a determination of whether the operation failed or mice were reintroduced. Tail tissue samples were collected from a number of locations across SEFI and WEI (Fig. 1.). Mice were trapped using Sherman Live traps and had the last 1cm of tail tissue removed and stored in a buffer solution.

DNA samples were also sent to the University of North Carolina where they were compared using a Mouse Diversity Array and 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*. (Didion et al 2012). Heterozygosity of

Farallon mice was compared with European House mice, and the geographic origin of Farallon mice was inferred from phylogenetic clustering. Possible anticoagulant resistance in the mice was assessed by examining Vkorc1 alleles, which encodes a protein critical for blood clotting. Mutations in Vkorc1 in rodents are associated with resistance to Warfarin, a first-generation anticoagulant. Several species of rodents are known to have resistance alleles, including *M. spretus*.

3.8 Non-target Species Risk Assessment

During the period that non-toxic bait containing pryanine was available, attempts were made to quantify the level of exposure that might occur during a mouse eradication to western gulls, burrowing owls, salamanders and other species.

Western gulls

Following each bait broadcast, western gulls were allowed to naturally congregate and forage on bait pellets without any human interference. Over the course of the eight days that bait was available, daily surveys were conducted in an attempt to document instances of gulls consuming bait pellets and quantify the proportion of the population observed to be feeding on rodent bait. Personnel were stationed on Lighthouse Hill during the early morning and late afternoon hours to count the number of gulls present or feeding within baited areas.

As with mice, gulls which consume pyranine excrete feces which fluoresce under UV light. In an effort to further quantify the proportion of the gull population consuming bait, two fecal plots were demarcated one on the helipad and one on the gull roost west of Mirounga Beach (Fig. 2). Following the first bait application, the total number of fecal deposits was recorded daily, as were the number of deposits which tested positive for fluorescent dye. No monitoring was undertaken prior to bait application so naturally occurring rates of fluorescence (Sztukowski 2011) were not established.

Pyranine can be used to detect not only primary but also secondary consumption (Stephenson et al. 1999). In conjunction with ongoing research being conducted on the island, burrowing owls captured in mist nets were inspected for signs of the pyranine fluorescent dye. Owl fecal pellets were also collected and examined for UV fluorescence.

Salamanders

Cover boards were put out in the Marine Terrace study area in order to assess exposure of salamanders (Fig. 3). Boards were set out in October 2010, prior to the trial in order to allow salamanders some time begin using the boards. Non-toxic bait pellets containing pyranine were hand broadcast at ~18 kg/ha in known salamander habitat along half of the salamander cover board monitoring area along North Landing Trail (Fig. 3). Monitoring with a UV light underneath and around 100 salamander monitoring boards was completed three days after bait application to assess if any salamanders or invertebrates showed evidence of fluorescence that would indicate biomarker exposure.

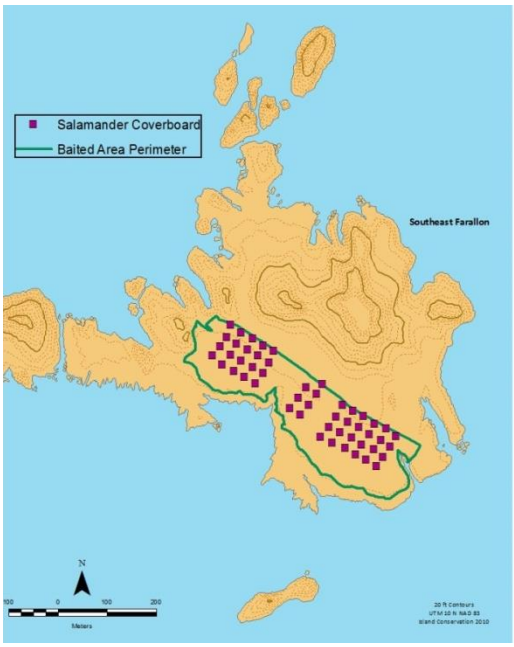

Fig. 3. Salamander cover board locations in relation to baited areas

Other non-target species

Observations of bait take or scavenging of mouse carcasses by other species were recorded.

Secondary poisoning risks

An evaluation of secondary poisoning risks was made by monitoring the fate of mouse carcasses positioned within baited areas. A varying number of carcasses were set out on a daily basis and checked daily thereafter. Western gulls have been identified as being particularly vulnerable to the use of rodent bait containing rodenticide because they are omnivorous scavengers and individuals of this species will be present on the South Farallon Islands during the time of year that a mouse eradication might be undertaken.

3.9 Use of Bait Stations to Mitigate Non-target Species Risk

Two different bait station types housing non-toxic rodent bait were field tested on the Farallones to assess if they would restrict gulls from accessing and consuming bait. The Protecta (Fig. 4) is a commercially available bait station made of impact-resistant, injection molded plastic (Bell Laboratories, Inc., Madison WI). It can be staked to the ground for security. The box opens from the side for servicing using an Allen key wrench. Its dimensions are 6” x 5” x 2.5”. A second type of bait station was constructed solely for the purposes of the trial (Fig. 5). A PVC conduit box with PVC tube extensions on either side allowed two entry points for mice. The top of the conduit body unscrews for inspection and refilling with bait.

Ten Protectas and 10 novel bait stations were deployed on Southeast Farallon Island from November 8 – 17, 2011. Stations were evaluated in a paired test, with each pair 1m apart, and each pair of stations separated by 10m from adjacent pairs. Both bait stations were attached to redwood boards approximately 12 inches square and 2 inches thick, which secured them to the ground and made them more resistant to disturbance by gulls or pinnipeds. Bait stations were left out unbaited for two days to season them before being filled with 20g of non-toxic bait pellets (~20 pellets @ ~1g each). The non-toxic bait pellet used in the bait stations was brodifacoum (25D Conservation) because these were known to be palatable to Farallon mice.

Fig. 4. Protecta bait station (bait blocks depicted were not used in this trial)

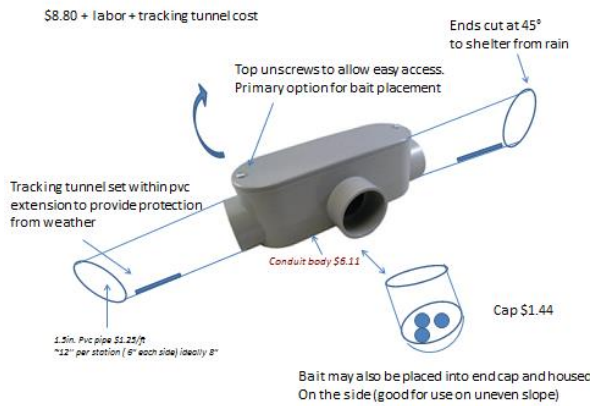

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Fig. 5. Novel bait station (developed by Island Conservation)

Acceptability of bait stations to mice was evaluated by two measures; mouse visitation and bait consumption. Mouse visitation was evaluated by placing tracking pads inside the entrance of each station. A tracking pad consists of a strip of felt moistened with peanut oil and oil based black ink and fastened to a length of white absorbent paper. Once a mouse enters the station and steps on the felt pad, its tracks are imprinted on the paper. Each day, the ink pads were inspected for mice tracks and collected. Bait consumption was quantified by weighing and recording the bait remaining on a daily basis. Bait was replenished to maintain 20g of bait, and new ink pads inserted daily to track mouse activity. Relative differences in acceptability between station designs were determined by having stations placed in pairs at each site.

To assess the ability of bait stations to exclude gulls, stations were placed at known gull roosts where gulls were roosting near Low Arch and Mussel Flats on the Marine Terrace of Southeast Farallon. Observations were made daily at a distance throughout the day to assess if gulls or other species were investigating or disturbing the stations or accessing bait pellets.

3.10 Camel crickets

Several caves on SEFI are inhabited by the endemic Farallon camel cricket. Presence and general abundance of these crickets were noted for designing future invertebrate surveys. Non-toxic bait was hand-broadcast at similar densities as for salamanders inside Rabbit Cave where camel crickets are abundant. A UV spotlight was used the day after bait application to determine consumption of bait by

camel crickets. In addition, four caves were surveyed for the presence of camel crickets. At each site, estimates were made of the number of individuals, the portion of the cave that harbored the majority of crickets, distance from the entrance, and their location (wall, ceiling, or floor).

3.11 Treatment of Caves

Numerous caves, coves, and coastal features on SFI may require special attention during a mouse eradication. To investigate the extent and evaluate potential options for treating these sites, caves were visited and mapped using GPS equipment. Some rough measurements of the dimensions of the geographic features of some of the caves were also made.

4. RESULTS AND DISCUSSION

4.1 Mouse abundance

Out of 500 possible trap nights, 434 mouse captures were recorded. Trap success averaged 93% on all but the first night, when trap door setting sensitivities may have resulted in a lower trap success rate of 62%. A total of 250 different individuals were captured and marked in the trapping period in the 0.2 ha trapping area. Recapture rates of marked individuals on nights 2 through 5 were: 35%, 40%, 56% and 66%, respectively. Mice were extremely abundant and easily trapped, likely due to a combination of high population levels and a scarcity of other food resources. Mice were commonly seen foraging throughout the daylight hours, as well as at night, but traps were only left open at night.

While final density estimates have not been calculated, preliminary analysis suggests densities of mice of up to 1297 per hectare in the study area at this time of year. Mouse densities at these levels have only rarely been reported elsewhere and usually only during plague-level irruptions in a few locales world-wide. Abundance levels found on SEFI are ten times greater than reported densities in most island or mainland environments. The likelihood that mice were hungry and readily trappable on the island during this time of year bodes well for an eradication attempt undertaken during this period, as it is more likely they will accept bait under stressed and food deprived conditions.

While specific mouse home-range studies were not conducted during the trial, the five-night mark-recapture study resulted in 101 mice that were captured at least twice, and some as many as five times. The mean maximum distance moved for mice captured two or more times was 11.7m. Of recaptured mice, 82% moved less than 16m between most distant captures. A further 10% of recaptured mice moved as much as 24m. Only six mice moved more than 35m, and the longest recapture distance was 43m. While the size of the trapping grid (45m) may have biased some of the longer ranging results downward, 95% of the maximum distances moved on SEFI are within the expected diameters (10-29m) for reported mouse home ranges reported for house mice in another temperate island environment (Pickard 1984b).

Monthly monitoring of mouse activity is ongoing.

4.2 Mouse Reproductive Status

The live-trapping of over 900 individual mice on SFI during the November 1-22 period revealed no pregnant females and only three males that were scrotal and five that were partially scrotal. Thus while some breeding may occur during this time of year, it would be considered a rare event based on our

results. This also bodes well for an eradication attempt during this time, as it means that the risk of juvenile weanling mice being missed by any of the bait application events is low.

4.3 Pyranine Persistence in Mice

During the lab trials, all mice that were fed the pyranine-infused bait tested positive for external sign of fluorescence (on mouth or anus) under UV exposure after 24 and 48 hours. On the third day (72 hours) however, one of the twelve mice tested negative for the presence of pyranine. By day four (96 hours) ten of twelve mice showed no external evidence of fluorescent dye. Although necropsy was available for the field trial, based on the results of the pyranine trial, trapping field to assess levels of exposure during the field trial was concluded within 72 hours of bait broadcast to avoid false negatives.

4.4 Bait Palatability and Food Preference

Mice in the bait preference trial consumed an average of 3.8g of food each day, with individual consumption ranging between 2.7g and 4.7g. Consumption was on average about 20% of their body weight each day. All ten mice included in the trial preferred bait pellets over the natural food items provided. Preference for rodent bait also increased over the course of the trial from 50% on the first day to 63% and above on day two and for the duration of the study. Over the course of the trial, bait pellets on average constituted 62% of mouse diet (by weight) with naturally occurring foods making up the remainder.

Opportunistic observations made of mice after food choices were first presented showed that rodent bait was usually eaten first. In only one of ten instances, was coleopteran larva eaten first. Visual observations also confirmed that bait pellets were easily picked up, handled and carried by mice. This was also noticed in the field where pellet caching was seen at burrow entrances. Overall, bait trial results indicated that the bait being considered was readily accepted by the mice, and that all mice had consumed the non-toxic equivalent of an LD50 within 48 hours.

4.5 Bait Availability

Monitoring of bait availability transects showed that after the first application at 18kg/ha, bait remained available to mice for at least four nights. This period of time has been the target exposure period for past rodent eradication projects that used second-generation anticoagulants. However, the rate of bait disappearance appeared to accelerate after Day 3 and on the fourth day after bait application, bait had disappeared from all but one transect (Figs 6 and 7). Bait was removed at an average rate of 3.6kg/ha/day, with daily uptake rates per plot ranging from 1.6-6.3 kg/ha/day over five days.

Rates of bait disappearance observed after the second application were much higher with most bait gone from availability transects in both areas the day after its application. Bait disappeared overnight from many transects monitored in Area B where bait was applied at 9kg/hand. Bait persisted a little longer in Area A where bait was applied at 18kg/ha but still disappeared within two days on most transects. Mouse abundance in Area B was an order of magnitude higher than in Area A and the increased rate of bait disappearance observed in Area B is considered attributable to mice. Bait within the gull exclusion cages established in Area B also disappeared in less than two days ruling out gulls as a factor strongly influencing bait disappearance in this area.

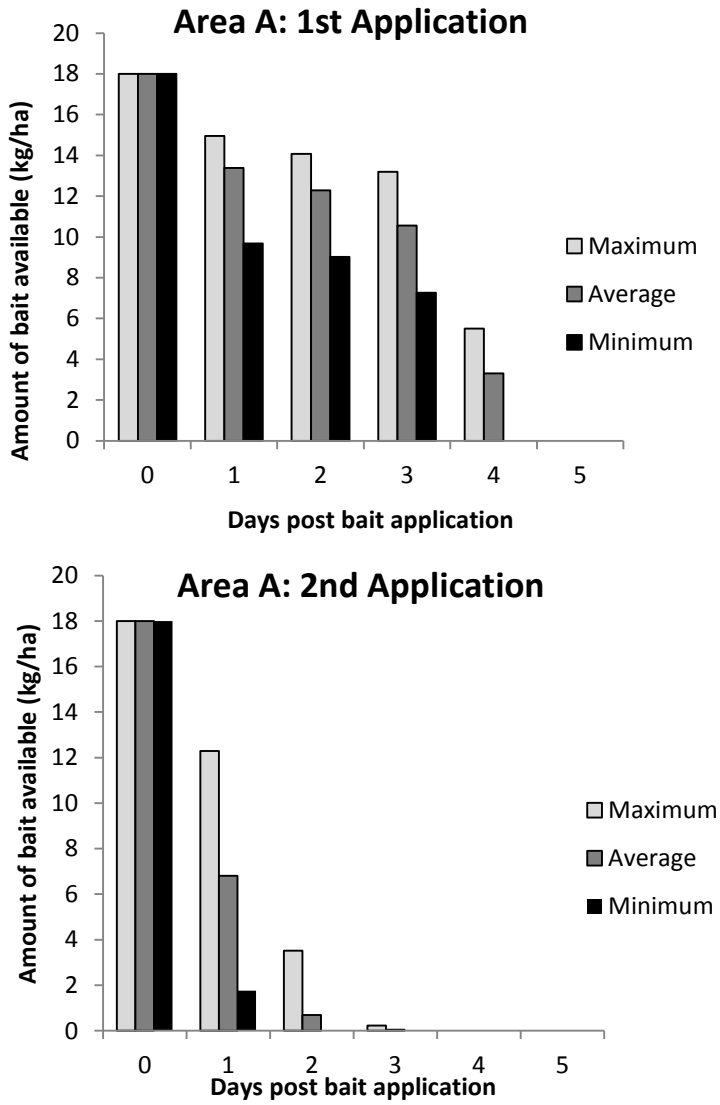

Fig. 6. Bait availability over time in Area A on SEFI following two applications of rodent bait (1g pellets) at 18kg/ha across a 3 ha trial area.

In Area B, bait disappeared from within gull exclusion cages after both applications at a significantly faster rate than bait outside ($t = 4.47$, $df = 10$, $p < 0.01$). The opposite trend was observed in Area A ($t = -5.06$, $df = 10$, $p < 0.01$) suggesting that consumption of bait by gulls did contribute to bait disappearance there. Observations of greater numbers of gulls foraging in Area A support this view. By the time of the second application, individual western gulls roosting along the Marine Terrace had clearly learnt to identify rodent bait as a food item and were observed foraging in increasing numbers in both areas but most intensively within Area A. Although sample sizes are considered too small to be representative, results from Area A indicate that it is possible that gulls could consume a significant amount of rodent bait if no gull hazing is undertaken. Consumption of bait by gulls appeared to increase over the course of the trial and increased consumption by gulls may partially explain the greater rates of bait disappearance observed after the second application.

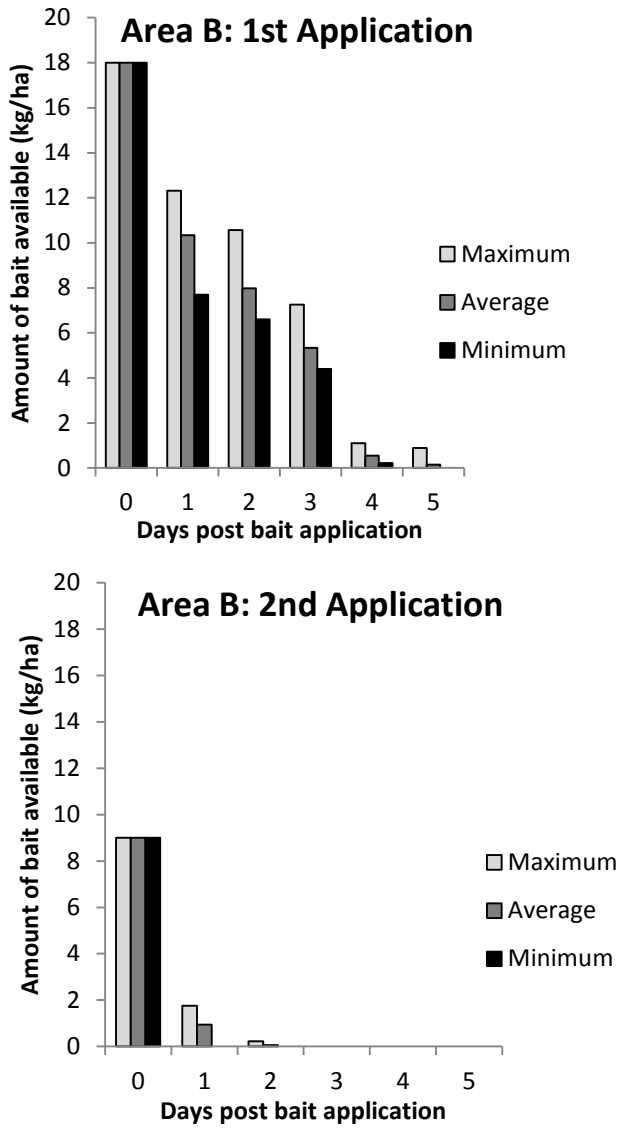

Fig. 7. Bait availability in Area B over time on SEFI following two applications of rodent bait (1g pellets) at 18kg/ha and 9kg/ha across a 3.2ha trial area.

The study area was located in a favored roosting site for western gulls and the impact of gulls was very different between the two baited areas. Consequently, our results may not be representative of the influence gulls could have during a mouse eradication. Our results suggest that the impact of gulls on bait availability is likely to vary across the island and over time. Nevertheless, there is a risk that gulls could reduce the amount of bait available to some mice. The potential increased risk that this poses to the proposed eradication is another valid reason for implementing a hazing program as a mitigation strategy during a mouse eradication attempt.

4.6 Mouse Biomarker Exposure Rates

The trap results indicated a very high rate of exposure to bait in the core trapping grids. Four trap nights were conducted in each of the two core trap grids with areas A and B. On the trapping grid within Area A, 100% of trapped mice had consumed bait as evidenced by the presence of pyranine after each of the two applications at 18kg/ha. A total of 13 mice were captured in grid A, amounting to 2% trapping success.

On the trapping grid with Area B mouse trapping success rates were much higher, with 25 mice captured after the first application (6.5% trap success) and 129 mice captured after the second bait application (32% trap success). All 25 mice trapped after the first bait application (18kg/ha) tested positive for fluorescent dye (100% exposure) (Table 1). After the second application at 9kg/ha, five of the 129 mice trapped on the core trapping grid and one mouse caught within the baited area but on the immigration transect showed no evidence of fluorescent dye (Table 1). The overall rate of exposure recorded from within Area B was 97%.

Table 1 Mouse Trap Results for Biomarker Presence

Trap Area	# Traps Set	# Mice	# Positive	% Positive	# Negative	% Negative
Core Grid A Nov. 12	200	2	2	100	0	0
Core Grid A Nov. 13	200	2	2	100	0	0
Core Grid A Nov. 17	200	3	3	100	0	0
Core Grid A Nov. 18	200	6	6	100	0	0
Core Grid A - Total	**800**	**13**	**13**	**100**	**0**	0
Core Grid B Nov. 12	200	16	16	100	0	0
Core Grid B Nov. 13	200	9	9	100	0	0
Core Grid B Nov. 17	200	32	31	97	1	3
Core Grid B Nov. 18	200	97	93	96	4	4
Core Grid B Total	**800**	**154**	**149**	**97**	**5**	**5**
Inner Immigration A	40	16	16	100	0	0
Inner Immigration B	40	17	16	94	1	6
Outer Immigration A	16	11	1	9	10	91
Outer Immigration B	40	25	0	0	25	100

As no barrier existed to prevent mice from immigrating into baited areas, transient mice could have been trapped before being exposed to bait. The probability that immigration occurred is supported by the huge increase in the number of trapped mice in Area B on the night two after the second application. However, it is also possible that resident mice did not have access to bait or chose not to eat it. Consumption by con-specifics and gulls is likely to have reduced the availability of bait to resident mice. In an eradication operation competition with con-specifics will be eliminated after the first application of bait, but based on our results, gull consumption can be expected to increase overtime unless hazing is undertaken.

Palatability of rodent bait was confirmed by the captive choice study and the high rates of bait consumption observed during the field trial and it is considered unlikely that mice chose not to eat the bait especially as the population was likely food limited during the trial. Despite the capture of unexposed mice the results indicate that application of rodent bait at the rates used in the trial would have a high likelihood of exposing all mice on the South Farallon Islands.

4.7 Mouse DNA and Genetic Analysis

A total of 100 DNA tissue samples were collected during the trial, with 50 from each of SEFI and WEI. These samples have been stored for future analysis. Genetic analysis was conducted on the 25 House mice (11♂, 14♀) collected from around the residential area on Southeast Farallon Island. Diagnostic alleles assigned the subspecific origin of the Farallon mice to be overwhelmingly of *M. domesticus* origin (Fig. 8) (Didion et al. 2012b).

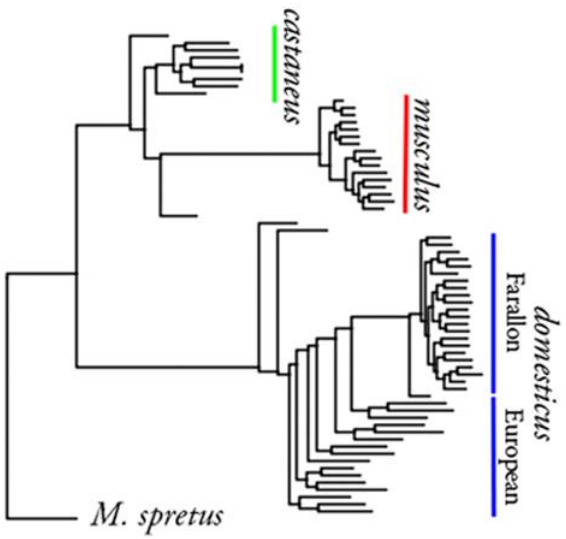

Fig. 8. Origins of introduced house mice found on Southeast Farallon Island

Heterozygosity was higher in Farallon mice than European mice (9.3% vs 8.8%), with no evidence of inbreeding, which suggests that diversity was maintained by rapid population expansion following colonization. The geographic origin of Farallon mice, inferred from phylogenetic clustering revealed two common lineages. Maternally, Farallon mice belong to the BritIsl.5 haplotype group, which is found in northern UK, Germany, Scandinavia and former British colonies and differs only slightly from classical inbred strains. Paternally, Farallon mice cluster with samples from the Mediterranean. Thus, Farallon mice appear to be a mixture of two European lineages (Didion et al. 2012b).

Vkorc1 encodes a protein that is critical for blood clotting. Mutations in Vkorc1 in rodents are associated with resistance to Warfarin, an anticoagulant that is used as a rodenticide. Several species of rodents are known to have resistance alleles, including *M. spretus*. It was recently shown that *M. m. domesticus* from the Mediterranean (specifically Spain) have received *M. spretus* resistance alleles by adaptive introgression. 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. It was concluded that there is no known genetic barrier to an eradication utilizing a rodenticide for Farallon mice (Didion et al. 2012b).

4.8 Non-target Species Risk Assessment

Western gulls

The total number of western gulls was highly variable during the trial period, ranging from day to day from approximately 500 to 4000 individuals. Numbers also increased over the trial period. The population is thought to shift sporadically from mostly non-breeding, intertidal-roosting gulls in November to a larger percentage of territorial, breeding gulls later in December and January. Breeding birds begin to spend more time on potential breeding sites throughout the island in advance of their breeding season, with the earliest egg-laying dates generally occurring in late April, when up to 17,000 gulls may be present on the island. Daily gull counts continue to be conducted by PRBO staff.

A total of 324 hours of visual observations of gull foraging within the baited area were recorded. Over the first 24 hours after the first application fewer than 12 western gulls were seen foraging on bait in a few small areas. By the second day, 188 gulls were observed consuming pellets in baited areas and by the third day, 233 gulls were seen consuming pellets. On days four and five, the fraction of foraging gulls

dropped below 12% of the total number of gulls present within the Marine Terrace area, perhaps due to a paucity of remaining bait (Fig. 9). Following the second application of bait, the number of gulls foraging on bait grew from 22% to 43% of the gulls present in the study area, likely in response to the second bait application. On average, 27% of the gulls present on the Marine Terrace were observed foraging on bait over the course of the eight days that bait was available within the study area.

On average, 27% (range 0 – 67%) of gull feces monitored with a UV spotlight following the application of rodent bait showed signs of pyranine. While this figure agrees with the relative proportion of gulls seen foraging on bait, because we did not establish a baseline to determine naturally occurring fluorescence, it is possible that this method overestimated the proportion of the population exposed.

The significantly higher rates of bait disappearance observed outside of gull exclusion cages in Area A together with our observations of gulls highlight the potential influence that gulls could have on bait availability for mice. The increase in the number of gulls foraging on rodent bait over the course of the trial suggests that identifying rodent bait as a food source was a learned behavior. Additional gulls appeared to be drawn in to an area because of the presence of foraging gulls. A hazing program should aim to attempt if at all possible to prevent any gulls from foraging on bait to limit the potential for behavioral transmission. Most gull foraging activity observed during the trial occurred in the first two hours after sunrise and in the two hours preceding sunset. This pattern could be exploited in a gull hazing program.

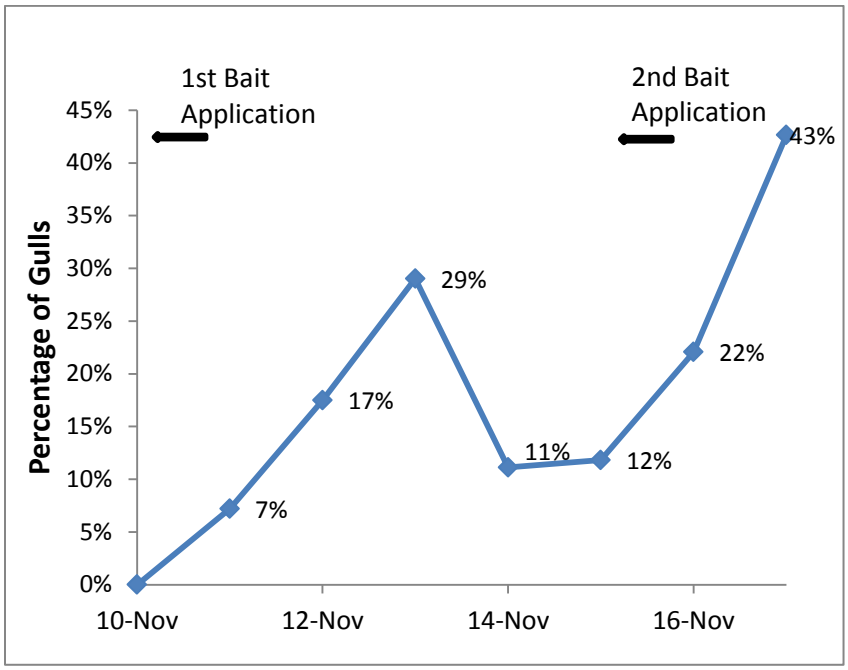

Fig. 9. Percentage of gulls in study area observed feeding on bait

Burrowing owls

A total of 10-12 burrowing owls were likely present on the islands during the November trial, many of which had been captured and banded and/or fitted with a radio-transmitter as part of ongoing research. Two owls were captured in mist nets and examined under UV light for exposure to the fluorescent dye, but neither individual showed any sign of pyranine. A total of 26 fresh burrowing owl casts were also collected from 10 locations within and near the study area both before and after bait application. None showed any that would have indicated exposure to pyranine. However, based on other studies (e.g.

Stephenson et al. 1999), it is likely that during a mouse eradication burrowing owls would be at risk of exposure to rodenticide by consuming dead or dying mice. The results of our study with regard to burrowing owls are considered inconclusive.

Salamanders

Inspection of cover boards before and after the application of bait revealed just six salamanders and none of these showed any signs of having being exposed to rodent bait. A further five salamanders were captured outside of the area where bait was applied and these too showed no signs of exposure. Invertebrates under or near cover-boards were also examined also with no evidence of exposure.

Other species

Although invertebrates were seen consuming bait, no consumption by other non-target species was noted. However, raptors and corvids present during a mouse eradication should still be considered to be at risk.

Secondary poisoning risks

Scavenging of mouse carcasses was observed during the trial. Eighteen of 23 carcasses set out within Area A and B disappeared within five days ($\overline{x} = 2.8$ days) of being placed. Although most scavenging of carcasses appeared to be by other mice, some mouse carcasses could have been scavenged by western gulls or ravens (*Corvus corax*).

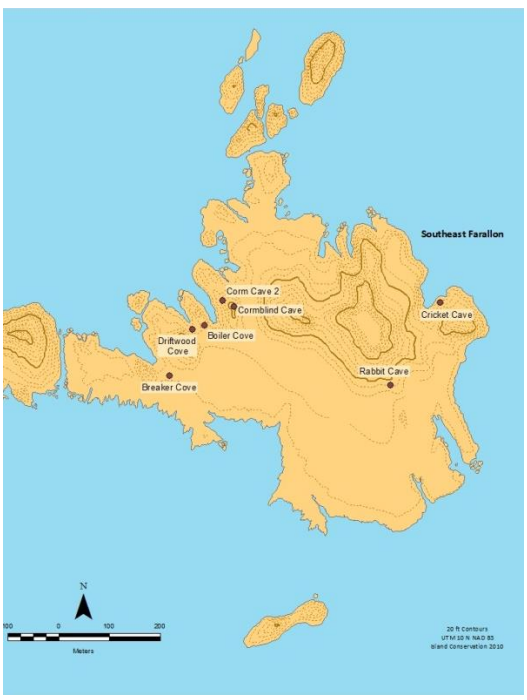

Fig. 10. Caves and coves inspected during the November 2010 trial and recorded on GPS units

4.9 Use of Bait Stations to Mitigate Non-target Species Risk

As evidenced by the tracking rates and bait consumption observed, both bait stations tested were readily used by mice and no discernible difference could be detected in the use of either type of station. Similar tracking rates and levels of bait consumption were recorded between the two models of bait station tested. No evidence for neophobia was observed. Both stations were effective at protecting bait from rain or wind driven spray.

No observations were made during the trial of gulls or other non-target wildlife taking bait from bait stations and it is concluded that both station types would be effective at excluding potential non-target species. Attaching stations to redwood boards was effective at eliminating potential disturbance by gulls or pinnipeds. In several cases, elephant seals were observed crawling over bait stations, yet these stations remained intact and upright. Once again both bait station designs performed equally in this regard. Fixing bait stations to boards allowed stations to be readily moved around whereas this would have been more difficult with other proposed methods such as rock anchors.

In summary, both bait station types trialed were readily used by mice and were effective at excluding non-target wildlife and it is considered that either design could be used during the proposed eradication. However, if bait stations are to be used as a secondary method in an eradication attempt, it is recommended that consideration be given to the additional operational risk that this entails. Using different methods for bait application adds complexity to operational planning and creates a greater risk of gaps in bait coverage between areas where the application method is different. Bait station operation span a greater time period than those where bait is hand or aerial broadcast adding complexity to the timing of an operation.

It is recommended that a gull hazing trial be undertaken on the South Farallon Islands to explore further mitigation options for western gulls.

4.10 Camel crickets

Surveys with a UV spotlight after rodent bait had been spread in Rabbit Cave indicated that camel crickets did ingest bait. Farallon camel crickets are not considered at risk because invertebrates do not have the same blood clotting system as vertebrates and are generally not susceptible to anticoagulants (Shirer 1992 in Ogilvie et al. 1997b). Experiments exposing other Orthopterans such as locusts (*Locusta migratoria*) (Craddock 2003a) and tree weta (*Hemideina crassidens*) (Morgan and Wright 1996a) to second-generation anticoagulants illustrate the lack of susceptibility. Camel crickets are also considered an unlikely pathway for secondary poisoning of other native wildlife except perhaps mice because they are only found in caves.

Interestingly crickets that had ingested the non-toxic rodent bait containing biomarker were easier to see and census with the UV light than traditional methods employing regular head lamps. In some cases estimates of cricket abundance quadrupled; it was easier to see crickets fluorescing under the UV lights. The number of crickets estimated from each cave prior to UV inspection were: Rabbit Cave: 100; Spooky Cave: 300-500; Northern Corm Blind Cave: 100; Cricket Cave: 1100; Small Shubrick Cave: 30. Data from these pilot surveys will inform a long-term camel cricket monitoring program, and distribution and abundance will be assessed before and after the proposed mouse eradication attempt.

4.11 Treatment of Caves

Fig. 10 shows a map of the caves that were visited and mapped during the trial. Other cave locations may still need to be inventoried prior to operational planning. Caves have the potential to harbor mice and it is recommended that rodent bait is spread within caves during a mouse eradication attempt. An inventory of the cave systems should be made and this should be used during implementation of a mouse eradication to ensure all potential mouse territories are targeted.

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Biosecurity Plan

FARALLON NATIONAL WILDLIFE REFUGE BIOSECURITY PLAN: PREVENTION OF RODENT INCURSION AND RODENT DETECTION RESPONSE

**** THIS IS A WORKING DOCUMENT—DO NOT CITE ** v. 2013-07-25**

DRAFT REPORT

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EXECUTIVE SUMMARY: PREVENTING RODENT INCURSION AND RODENT DETECTION RESPONSE FOR THE FARALLON NATIONAL WILDLIFE REFUGE

In order to mitigate the risk of a rodent reinvasion of the Farallon National Wildlife Refuge following an eradication effort, a biosecurity plan to prevent and detect rodent incursions must be implemented. Southeast Farallon Island hosts a biological research station that is operated year-round by U.S. Fish and Wildlife Service (FWS), PRBO Conservation Science (PRBO), 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. Biosecurity measures will focus on the packaging and assessment of all cargo transported to the island, on-island surveillance, and contingency responses in the case of rodent detection on the island. The pre-departure and post-arrival quarantine measures include the reduction and re-packaging of supplies, packaging in rodent-proof containers, the visual assessment of all cargo at multiple stages, and the careful unpacking of cargo inside buildings. In order to inform outside agencies of quarantine measures, it is critical that informational briefings, contract and Special Use Permit language, and public outreach be a component of the biosecurity plan. Surveillance measures will include the assessment of vessels and aircraft and the regular deployment and maintenance of rodent control and detection devices around landing areas and buildings. If evidence of a rodent incursion was encountered, contingency response measures would be implemented including treating the area with rodenticide applied by bait stations, live trapping, snap trapping, sticky pads, or by a combination of these methods. The biosecurity measures that are outlined in the plan must be continued and refined as needed by all staff, volunteers, cooperators, contractors, and other visitors, in perpetuity. The plan will be implemented by both FWS and PRBO, and will include appropriate staff training.

INTRODUCTION

The United States Fish and Wildlife Service (FWS), PRBO Conservation Science (PRBO), and Island Conservation (IC) are in the process of developing an Environmental Impact Statement (EIS) for a proposed house mouse (*Mus musculus*) eradication effort on the Farallon National Wildlife Refuge (Refuge), California. The conservation benefits that would follow the proposed house mouse eradication will only be fully realized if mouse or other rodent reinvasions are prevented. Biosecurity plans and quarantine measures must be implemented if any eradication effort is to be considered successful in the long term.

Southeast Farallon Island (SEFI) hosts a biological research station that is operated year-round by PRBO and FWS personnel that require a steady influx of supplies in order to maintain operations. Personnel and supplies are regularly transported to the island by way of ocean-going vessels and less frequently by helicopters. Because the transport of consumable goods, supplies and personal gear occurs from a variety of vessels from different ports of call, there is a substantial risk of a rodent incursion following a completed eradication effort. In addition, rodents could also be reintroduced to the islands via shipwreck on or adjacent to the islands, or from a rodent swimming from a nearby visiting boat to the islands. To mitigate the risk of a rodent reinvasion following an eradication effort, a biosecurity plan must be implemented prior to the eradication effort and continued indefinitely.

The three basic elements of biosecurity that will be utilized in this plan are quarantine, surveillance and contingency responses. Currently, implementation, oversight and funding responsibility for biosecurity measures for the Refuge are the responsibility of FWS and PRBO. PRBO will be the primary lead for managing biosecurity measures on all PRBO-managed transports, including Farallon Patrol, other personnel and supply transports, and PRBO contractor and cooperator transports. FWS will be the lead for the implementation of measures on FWS-managed transports, including all FWS personnel and supply transports, and FWS contractor and cooperator transports.

FWS and PRBO have historically and continue to practice portions of the quarantine element of the biosecurity measures in a non-standardized format. For instance, it is general practice to package all foodstuffs into rodent proof containers (i.e., ActionPackers®, sealed buckets, coolers, etc.) All other consumables and supplies that are transported are typically repackaged or sealed in water resistant material in order to protect it during transport and transfer. In addition, the complex process involved with transferring cargo from mainland-based marine vessels on to SEFI provides its own biosecurity measure. All personnel and cargo must be transferred at sea, usually at a mooring buoy located approximately 115 meters from the island. The transfer occurs from a larger mainland-based "long-haul" vessel to a smaller "landing" vessel, which is permanently stationed at the Refuge. The "landing" vessel is then either hoisted onto SEFI with personnel and supplies aboard, or personnel and supplies are physically transferred from the "landing vessel" onto a land-based platform. This multiple stage process of transferring cargo between vessels and from vessel to land provides a quarantine measure that can prevent rodent incursions from occurring directly from the "long-haul" vessel to the island. However, presently there are no restrictions in place that require the long-haul vessels to maintain rodent free certifications, which would prevent rodent infestation of cargo during transport and potentially prevent some rodents from swimming from the vessel to the island. Indeed, this would be difficult to manage and enforce since many private and commercial vessels of various types transport personnel and supplies to the island, sometimes on short notice. Thus, biosecurity measures must focus on the assessment and packaging of supplies, equipment, and personal gear transported to the island, on-island surveillance, and contingency responses in the case of rodent detection on the island. A necessary part of this biosecurity plan must be that all cargo be assessed, prior to transport to the islands or prior to coming ashore, by trained FWS staff or trained individuals designated by FWS.

The biosecurity measures outlined in this plan were guided by a review of the document entitled "Review of Rat Invasion Biology, Implications for Island Biosecurity" (Russell et al., 2008).

Potential pathways for rodent introduction to SEFI include: marine vessels, helicopters and their associated cargo. Biosecurity measures for each of these pathways are described in the following table.

BIOSECURITY MEASURES

PATHWAY	BIOSECURITY MEASURE
CARGO TRANSPORTED ON VESSELS OR HELICOPTERS (PRBO Farallon Patrol and charters; FWS charters and contractors; NOAA and NOAA charters; Special Use Permit or cooperator charters; fishing and sightseeing charters; U.S. Coast Guard or other military; Other not listed)	PRE-DEPARTURE QUARANTINE: a) Requirement for everyone coming ashore to reduce off-the-shelf packaging and re-pack in thoroughly cleaned rodent-proof containers. • All cargo must be in sealed duffel bags, suitcases or other sealed containers. • Bulky items that cannot be packed in containers, such as pipes or other items with hollow portions will need to be assessed, and if possible sealed to prevent rodent entry. b) Visually assess all cargo for signs of rodents or potential rodent entry points, especially containers of foodstuffs and large equipment before loading on to long-haul vessel or aircraft. • Recommend that all items loaded onto vessels or aircraft be self-inspected for holes, cracks or other signs of potential rodent entryways. • If any deficiency is found, cargo must be re-packed prior to arrival or it will not be permitted on the island.
PATHWAY	**BIOSECURITY MEASURE**
CARGO TRANSPORTED ON VESSELS OR HELICOPTERS (PRBO Farallon Patrol and charters; FWS charters and contractors; NOAA and NOAA charters; Special Use Permit or cooperator charters; fishing and sightseeing charters; U.S. Coast Guard or other military; Other not listed)	POST-ARRIVAL QUARANTINE: a) Visually assess all cargo as it is being loaded on to landing vessel or unloaded off of aircraft. • Island staff supervisor and/or assistant will visually assess all cargo to ascertain if it is packaged in required containers. • Bulky items not in containers will be visually assessed to ascertain that there is no possibility of rodent stowing, such as inside pipes or other hollow portions of supplies and equipment. b) Require that anything not packaged to specifications will be assessed for rodent intrusion and re-packed prior to placement on landing vessel or it will be rejected and not permitted on island. c) Visually assess all cargo as it is being unloaded from landing vessel or aircraft on to landing staging areas. • Staff unlading cargo will provide visual assessment of containers for possible holes, cracks or other signs of potential rodent entryways.

	• If entryways are detected, item will be quarantined immediately and unpacked in a secure area to check for the possible presence of rodents. d) As soon as practicable, unpack and visually assess all cargo inside buildings. • All island visitors will be instructed on unpacking procedures of all cargo to include self-inspection for the presence of rodents or rodent sign. • Recommend that food be unpacked in closed-off kitchen area. • Recommend that all cargo be first unpacked indoors to reduce the risk of a rodent escaping to the outdoors. • If rodent is detected, immediate quarantine of room and/or building will be implemented to make certain rodent does not escape to outdoors. • If rodent escapes, immediate response measures will be undertaken that follow a specified contingency response plan (to be written).
PATHWAY	**BIOSECURITY MEASURE**
CARGO TRANSPORTED ON VESSELS OR HELICOPTERS (PRBO Farallon Patrol and charters; FWS charters and contractors; NOAA and NOAA charters; Special Use Permit or cooperator charters; fishing and sightseeing charters; U.S. Coast Guard or other military; Other not listed)	SURVEILLANCE: a) Recommend that rodent control* and detection** devices combined with self-inspection for rodent sign be employed at least 7 days prior to trip to island on applicable long-haul vessels. • As funds allow, provide rodent detection/removal kits for all boat and aircraft owners or operators. b) Employ and maintain rodent control and detection devices at select portions of the island where rodent introduction and detection are most likely, including structures, boat landings, and helicopter landing area. CONTINGENCY RESPONSE: • Maintain control and detection devices around landing areas and appropriate buildings at least once per day until there are no detections for 30 consecutive days.

VESSEL (attended or unattended) WRECKS ON OR ADJACENT TO ISLANDS	SURVEILLANCE: • If practicable, assess the likelihood that the vessel may harbor rodents. • If practicable, deploy and maintain rodent control and detection devices around adjacent emergent land for 30 consecutive days after incident. CONTINGENCY RESPONSE: • If practicable, maintain rodent control and detection devices around emergent land at least once per day until there are no detections for 60 consecutive days.
HELICOPTERS THAT LAND WITHOUT CARGO (U.S. Coast Guard; military; FWS, contractor , Special Use Permit or cooperator charters; Other)	PRE-DEPARTURE QUARANTINE: • Inform agency, charter company, or pilot of the necessity to maintain a rodent free aircraft. • If practicable, prior to departure from mainland visually assess aircraft passenger and cargo area for rodent signs. SURVEILLANCE: • Employ and maintain rodent control and detection devices at select portions of the island where rodent introduction and detection are most likely, including structures, boat landings, and helicopter landing area.
PATHWAY	**BIOSECURITY MEASURE**
HELICOPTERS THAT LAND WITHOUT CARGO (U.S. Coast Guard; military; FWS, contractor , Special Use Permit or cooperator charters; Other)	CONTINGENCY RESPONSE: • Maintain control and detection devices around areas of operation at least once per day until there are no detections for 30 consecutive days.

OTHER BIOSECURITY CONSIDEREATIONS

BIOSECURITY ISSUE	BIOSECURITY MEASURE
Ensure that biosecurity measures continue to be maintained and refined as needed by all staff, cooperators, and contractors in perpetuity.	• Continually evaluate the Biosecurity Plan and modify as needed. • Prior to any trip, information will be provided to all visitors describing the rules and guidelines for packing. Emphasis will be on the importance of keeping Refuge rodent free as well as identifying specific measures which reduce the possibility for future rodent introductions. Information can be

	disseminated through the Special Use Permit process, pre-trip packets to visitors and contractors, and employee training.
Transport vessels may not take adequate steps to reduce likelihood of being infested with rodents.	• Require informational briefing to vessel owners and operators prior to them being permitted to provide transport. • Thoroughly assess cargo before offloading to island.
Contractors, cooperators, special use permittees, and other visitors may not implement quarantine measures when packing supplies.	• Include language in contracts, cooperative agreements, Special Use Permits, volunteer agreements, and other applicable documents requiring adherence to biosecurity measures.
Commercial and private vessels within the vicinity of the islands may be infested with rodents capable of swimming to the islands.	• Disseminate information describing the importance of keeping the Refuge rodent free through FWS, PRBO, and other public outreach and education programs.
FWS and PRBO may not be trained in the techniques to readily detect and rapidly respond to rodent incursions.	• Provide required rodent detection/rapid response training to existing staff and cooperators.

*****Control devices may include bait stations, live traps, sticky traps, and snap traps, as well as an integrated approach that includes a combination of these devices.
**Detection devices include track pads and chew blocks, as well as an integrated approach that includes a combination of these devices.

RODENT DETECTION RESPONSE

Following an eradication effort, a quantity of registered pesticide bait product(s), live traps, sticky traps, snap traps, track pads and chew blocks would be stored at the SEFI field station. FWS and PRBO would appropriately store, secure, and label all pesticides and associated materials on the Refuge, ready for use should rodents be detected. All use of pesticide bait would be in accordance with the bait product's label.

If a rodent sign were encountered or a rodent sighting occurred, rodent detection devices (as described above) would be established in the area of the sign or sighting. Confirmed rodent presence would initiate a rodent removal response to eradicate an incursion. The area surrounding the confirmed rodent detection either would be treated with rodenticide applied by bait stations or by live trapping, snap trapping, sticky pads, or by a combination of these methods. Detection devices placed in and beyond the treatment area would be monitored as frequently as practicable during the eradication period, and until the point at which rodents have not been detected for at least 30 consecutive days. Eradication of the invading rodent population would be adaptively managed to minimize risk to non-target species while maximizing the probability of removing all target individuals.

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8.2 Alternatives Selection Report

Alternatives Selection Process Report

For the Farallon House Mouse Eradication DEIS

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Executive Summary

This report summarizes the process used to select action alternatives to be developed and analyzed in a draft Environmental Impact Statement (EIS) to eradicate invasive house mice from the South Farallon Islands, which are part of the Farallon National Wildlife Refuge, California. Home to more than 300,000 breeding seabirds, the Farallon National Wildlife Refuge supports the largest seabird colony in the contiguous United States, as well as important populations of marine mammals, the endemic Farallon arboreal salamander (*Aneides lugubris farallonensis*),the endemic Farallon camel cricket (*Farallonophilus cavernicolas*), and a unique plant community. House mice were inadvertently introduced to these islands in the nineteenth century by early human occupants.

Invasive house mice are directly and indirectly negatively impacting the native biological resources of the South Farallon Islands. Of particular concern is the rare ashy storm-petrel (*Oceanodroma homochroa*). This small and rare seabird species is nearly endemic to coastal California, with about half of the world population breeding on the Farallones (Carter et al. 2008). One of the major factors affecting the Farallon ashy storm-petrel population is high predation rates from wintering burrowing owls (*Athene cunicularia*; Nur et al. 2012). These owls arrive on the island as fall migrants who remain and persist into the winter on a diet primarily of invasive house mice. The cyclic house mouse population peaks in the fall when owls arrive, with densities as high as 1,200 mice per hectare, one of the highest recorded rodent densities on any island. After the mouse population crashes in early winter, the owls switch to alternative prey to survive, killing hundreds of storm-petrels each year. Based largely on impacts of invasive rodents on other islands, it is believed that invasive house mice are impacting other parts of the Farallones' native ecosystem, including the endemic salamander, invertebrates including the endemic cricket, and plant communities. The U.S. Fish and Wildlife Service (Service) has identified mouse eradication as a critical step toward reducing the impacts of mice and restoring the island's ecosystem (USFWS 2009).

In 2011, the Service began the process of preparing an Environmental Impact Statement (EIS) in compliance with the National Environmental Policy Act to assess the most appropriate action alternatives for eradicating invasive house mice from the South Farallon Islands. To decide which action alternatives to include in the Draft EIS, the Service utilized a Structured Decision Making (SDM) approach known as the Alternatives Selection Process. 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, forty-nine mouse removal methods were assessed including mechanical, theoretical, and chemical methods with 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 Service management and policy guidelines;

b) Be feasible to implement; and

c) Meet human safety and logistical guidelines.

A second parallel 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 was done within a series of matrices to provide a quantitative comparative analysis of potential alternatives. This approach was intended to allow decision makers to 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 attributes in total were scored and analyzed for each method.

Based on the information reviewed, assessed, and scored the Service selected two action alternatives to be developed and analyzed in the draft EIS:

1) Aerial broadcast of the rodenticide brodifacoum as the primary technique; and

2) Aerial broadcast of the rodenticide diphacinone as the primary technique.

These two methods met all of the Minimum Operational Criteria and ranked among the top ten methods within the matrix analysis. The two alternatives include the only products legally available and registered for island rodent eradication use in the United States: Diphacinone 50–Conservation and Brodifacoum 25-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.

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1. Introduction

○ Description of the Problem

The Farallon Islands, or Farallones, within the Farallon National Wildlife Refuge (Refuge), are home to more than 300,000 breeding seabirds, with over 200,000 of them on the South Farallon Islands. These islands support the largest seabird breeding colony in the contiguous United States. Located offshore of the central California coast within the productive California Current Upwelling System, this unique ecosystem supports important populations of a variety of other species as well. There are five species of breeding pinnipeds including the threatened Steller sea lion (*Eumatopias jubata*), the endemic Farallon arboreal salamander (*Aneides lugubris farallonensis*), several species of terrestrial invertebrates including the endemic Farallon camel cricket (*Farallonophilus cavernicolus*), nesting Peregrine Falcons (*Falco peregrinus*), over 400 species of migrant birds, and a diverse intertidal plant and invertebrate community. The unique terrestrial plant community is dominated by the native, annual, maritime goldfield (*Lasthenia maritima*), a species endemic to seabird nesting islands along the California and Oregon coasts.

The Refuge was established by President Theodore Roosevelt in 1909 under Executive Order 1043 as a preserve and breeding ground for marine birds. In 1969 the Refuge was expanded to include the South Farallon Islands, the largest islands of the Farallon group. Because of their size and diversity of habitats, these islands historically held the largest and most diverse populations of wildlife and plants. However, the South Farallones have been impacted dramatically by human use since the early 19th century (White 1995). Since its inclusion in the Farallon National Wildlife Refuge, the U.S. Fish and Wildlife Service (Service), along with its partners PRBO Conservation Science and others, have been working to protect and restore the islands' habitats and native wildlife and plant communities.

House mice (*Mus musculus)* were inadvertently introduced to the South Farallon Islands in the 19th century by early human visitors. Typical of island ecosystems worldwide where this or similar species have been introduced, house mice have both direct and indirect negative impacts on the native biological resources of the South Farallones. Following an annual cycle of abundance, the Farallon mouse population peaks in the fall months when densities have been measured at over 1,200 mice per hectare (3,000 per acre), one of the highest densities ever recorded for the species (MacKay 2011). As part of the efforts to restore the native ecosystems of the islands, in the mid-2000s the Service began investigating the possibility of eradicating the invasive house mice) from the South Farallon Islands. In 2009, the Service published the Farallon National Wildlife Refuge Final Comprehensive Conservation Plan and Environmental Assessment (CCP; USFWS 2009), which provided guidelines and goals for managing the islands over the next 15 years. The CCP described eradication of invasive house mice as one of those goals.

After several years of research, field trials, and planning the Service decided in early 2011 to prepare an Environmental Impact Statement (EIS) in compliance with the National Environmental Policy Act (NEPA) of 1969 as a means of analyzing the potential impacts to the affected environment from the chosen range of alternatives. In order to move forward with the eradication of mice from the Farallon Islands, the Service must consider the environmental impacts of the actions proposed in compliance with NEPA. Specifically, federal agencies must consider the environmental impacts of a reasonable range of

alternatives for implementing an action, and make the public aware of the environmental impacts of each of the action alternatives presented.

The Service released a public Notice of Intent (NOI) to prepare the EIS and initiated a Public Scoping period in April 2011. After reviewing comments from both the general public and other agencies, the Service concluded that a broad range of alternatives needed to be considered and initially assessed in a thorough and transparent manner to assist the Service in deciding which action alternatives to fully analyze in the draft EIS. A variety of mechanical and chemical methods have been used or potentially could be used for mouse removal. Our goal was to assess those methods for their potential to eradicate mice from the islands as well as their potential impacts on the affected environment. This report and decision tool documents the process that the Service and its partners used to analyze and review potential mouse removal methods for inclusion in the Draft EIS as action alternatives.

○ Objectives

1. Identify a reasonable range of alternatives that meet the Purpose and Need for action based on input from project scoping (and in conformance with 40 CFR 1502.14 & 43 CFR 46.415).

2. Explore and assess each alternative to be considered according to a set of established *Minimum Operational Criteria, Environmental Concerns, and Operational Considerations*.

    a. Rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated (§1502.14(a)).

    b. Use the NEPA process to identify and assess the reasonable alternatives to proposed actions that will avoid or minimize the adverse effects of these actions on the quality of the human environment (§1502(e)).

    c. The range of alternatives discussed in Environmental Impact Statements shall encompass those to be considered by the ultimate agency decision-maker (§1505.1(e), §1502.2(e)).

3. Systematically accept or dismiss alternatives from further consideration for development in the Draft EIS based on whether they meet the *Minimum Operational Criteria* for success.

4. Objectively assess the applicability of non-target species mitigation measures to remaining alternatives to inform which alternatives will be developed as Action Alternatives in the Draft EIS for the Farallon Mouse Eradication project.

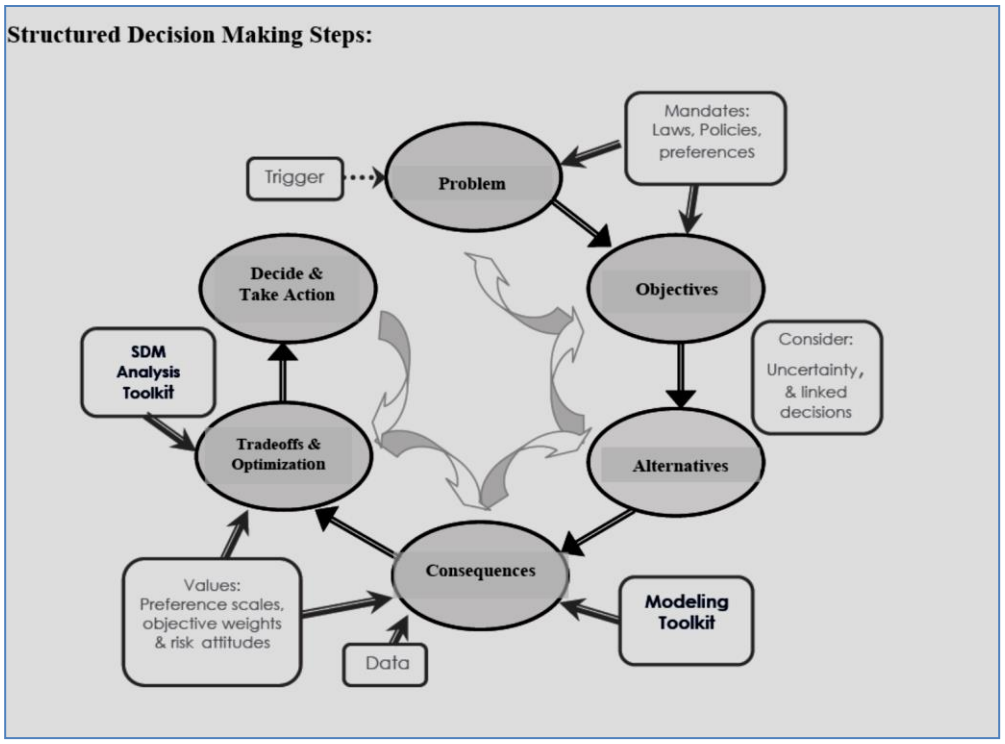
5. Fully document the Alternatives Selection Process and the rationale used to select alternatives based on the *Minimum Operational Criteria, Environmental Concerns,* and *Operational Considerations.*

2. Methods

The Alternatives Selection Process is a quantitative decision tool that utilizes available data and the expertise of eradication and island resource specialists to systematically and objectively analyze and compare potential action alternatives to include in the Draft EIS. The methods analyzed within this tool were included if they had the potential to meet the Service's management goal of protecting and restoring the ecosystem of the Farallones, particularly seabirds and other native biological resources, by eradicating non-native house mice and eliminating their negative impacts on the island ecosystem. In addition, potential alternatives were considered based on comments received during the NEPA scoping process, as well as potential alternatives that have had some history of use in rodent eradication or control operations throughout the world.

In total, 49 methods were analyzed: 6 non-rodenticide methods including trapping and immunocontraception, as well as 15 rodenticides with up to three different application methods. While a combination of methods is probable for any of the proposed action alternatives, this preliminary analysis only assessed the primary methods that would be used if implemented. In an effort to minimize the amount of uncertainty within the model, the analyses did not assess the myriad of possible combinations of methods available. Furthermore, this model is not intended to provide a full scale impacts analysis of all 49 methods; rather it is intended to allow decision makers to compare the potential impacts of each method to island resources, identify trade-offs between methods, and determine which methods have the greatest potential to effectively eradicate mice from the Farallon Islands. A full impacts analysis will be conducted for all action alternatives included in the EIS.

Every method was first filtered to establish a subset of potential alternatives that would meet the Minimum Operational Criteria. The Minimum Operational Criteria Checklist is a coarse filter that provided a framework for eliminating methods that were either unsafe for personnel, logistically or technically infeasible (timing and availability), or contrasted with the Service's guidelines for management of the Refuge. Additionally, each method was then scored for its potential impact to island resources (biological, physical and social), its availability for



use and its potential for successfully eradicating mice from the Farallon Islands. The scores allowed for easy comparison of the potential alternatives to better understand the relationship between various operational considerations and environmental concerns.

○ Model Approach

The process of selecting a reasonable range of methods to fully analyze as action alternatives in an EIS typically does not require a comparative analysis of methods; however, the Service felt that the best way to address the comments and concerns of stakeholders, permitting agencies, and the public was through the development of a comprehensive, multi-attribute, uncertainty model that analyzed a wide array of potential alternatives in a transparent and impartial manner (Figure 1).

The Service employed a modified Structured Decision Making (SDM) approach, which is a general term describing an organized problem oriented approach to decision making that is focused on achieving a specific goal. Structured Decision Making is rooted in decision theory and risk analysis that integrates science and policy explicitly (FWS 2008). Additionally, the Service has regularly utilized this tool over the last 20 years for endangered species management, developing Comprehensive Conservation Plans and Habitat Management Plans, as well as numerous other applications. The steps to SDM begin with: 1) defining the problem; 2) identifying management objectives; 3) identifying alternatives to choose from; 4) identifying the consequences of different alternatives; 5) identifying tradeoffs bet

Figure 1: FWS 2008 Fact

objectives; 6) explicitly identifying the uncertainties within the model; 7) identifying the risk tolerance (the level of acceptable risk) of the decision makers; and finally 8) making an informed decision (FWS 2008).

SDM provides a framework for decision makers to balance the biological or environmental goals of a project with societal objectives such as social justice, economic benefits, or health and safety. Moreover, SDM is designed to allow risk managers to make decisions in the presence of substantial biological uncertainty by adopting the Precautionary Principle. The Precautionary Principle states that “lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (1992 UN Rio Declaration – Agenda 21). Precautionary approaches to natural resources management are intended to highlight the gap between scientifically supported data with the need for decision makers to present defensible rationale for their choices (Gregory and Long 2009). Tools like SDM allow decision makers to assess and aggregate multiple objectives in an effort to identify tradeoffs between objectives and impacts to resources. Aggregation and integration of several factors across multiple metrics is the preferred method of analysis despite the debate around the strengths and limitations of this technique between scientists and decision makers (Bell et al. 2001 and Ohlson et al. 2005).

Selecting action alternatives for mouse eradication on the Farallon Islands is an ideal scenario for utilizing SDM and multi-attribute analysis. This is due to the fact that decisions about the management of invasive species encompass attributes that are typically addressed by multi-attribute decision analysis given that the outcomes of management activities are uncertain, there are multiple, conflicting objectives, and there are many stakeholders with differing and often opposing viewpoints (Maguire 2004). Furthermore, SDM decision analysis can provide insights into important elements of the project

to remove mice from the Farallones that are typically neglected in ecological analyses due to a lack of available data. SDM explicitly provides a quantitative and conceptual framework around the problem in an effort to help decision makers use scientific data and frame the problem in a manner that will aid in the decision making process. The overall intent of this type of modeling is to document the key exposure pathways and the resources that are sensitive to change, not to provide an impacts analysis for each method assessed.

The Alternatives Selection Model was built to identify the range of alternatives that will be included in the draft EIS by utilizing a combined matrix method (consequence table) and expert modeling approach. Matrix modeling and expert judgment are often used in concert to evaluate the potential impacts of a given method that clearly projects the expected outcomes (Ohlson 2005). The knowledge and experience of experts can typically be valuable at documenting the most important system vulnerabilities, as well as to project the outcomes of an action in the face of uncertainty (See Appendix B for Expert Bios). The value of utilizing a matrix method of analysis is that it efficiently summarizes the trade-offs that may exist across strategies or across objectives, prioritizes methods, and allows decision makers to select methods based on the personal values and risk tolerances of the given decision maker (Ohlson 2005).

In order to assess the multitude of possible methods available for mouse eradication, we developed a course filter (Minimum Operational Criteria) that would identify the methods that met human safety standards, are logistically feasible to implement, and comply with the Service's refuge and resource management guidelines. In addition, we then scored each method through a set of matrices (Environmental Concerns Matrix, Operational Considerations Matrix, and Combined Matrix) for its potential impacts to island resources and its potential for successfully eradicating mice from the Farallones. Together, the Minimum Operational Criteria and the set of matrices identified the methods of eradication that are most likely to meet the Services objective of eradicating mice from the Farallones, while minimizing impacts to the islands' and nearby ocean's resources.

The following is the list of products that were developed to evaluate and rank the potential alternatives in a manner that identified tradeoffs, managed uncertainties, and were transparent and easy to understand (See Appendix A for Products 1-6 and accompanying CD for Products 7-12).

List of Products Developed for the Alternatives Selection Model:

1. **List of Minimum Operational Criteria**
2. **List of Operational Tools and Methods**
3. **List of Important Operational Considerations, Environmental Concerns, and Potential Mitigation Measures** to evaluate in Matrices
4. **An Analysis of Mouse Control vs. Eradication**
5. **Comparison of Mouse and Rat Ecology**
6. **Conceptual Model of the Alternative Selection Process** scores methods for:

7. **Minimum Operational Criteria Checklist** assesses each method as a course filter
8. **Matrices evaluating the Methods for Environmental Concerns**
    a. *Biological Resources Worksheet* (Short Term Negative Impacts)
    b. *Overall Environmental Concerns Matrix*
9. **Operational Considerations Matrix** scores methods
10. **Combined Matrix** that combines scores from the *Overall Environmental Concerns Matrix* and the *Operational Considerations Matrix*
11. **Mitigation Matrix** that includes a subset of potential alternatives that meet the Minimum Operational Criteria and are evaluated for mitigation potential
12. **Potential Alternatives List** with a described outcome from the Alternatives Selection Process

1.1 Potential Alternatives

Forty-nine potential alternatives were analyzed within the alternatives selection decision tool. The following is a brief description of how each potential alternative is likely to be implemented if chosen for full analysis in the Draft EIS.

1.1.1 Non-Rodenticide Methods

Live Trapping –This would involve the setting and checking of live-traps across all parts of the South Farallon Islands, and removing all captured mice from the traps. The captured mice would likely be euthanized humanely on site and incinerated for human and environmental health reasons. This technique would involve accessing on foot all portions of all islands and conducting daily trapping efforts repeatedly for months or, more likely, years. If traps were placed every 10 meters, approximately 5,000 traps would be necessary to cover the islands (49 ha). Traps would need to be checked, re-baited, reset, and mice removed daily. If each person checked and baited up to 100 traps per day, at least 50 personnel on foot would be required to check the 5,000 traps daily. Given the steep and rugged terrain of much of the Farallon Islands, actual time or personnel needed would be significantly greater especially when mice are at cyclic high numbers. Some areas are not safely accessible on foot. Most likely potential impacts to non-target resources from the application method include destruction of habitat from frequent trampling, frequent and long-term disturbance to marine mammal haul-outs and breeding areas, and frequent and long-term disturbance to seabird breeding areas. The latter two would likely result in large-scale loss of the annual productivity of many Farallon species, including abandonment of certain areas. This method is most frequently used as a non-lethal research tool and has no record of success in an island rodent eradication.

Snap Trapping –This method would likely involve much of the same personnel effort as the live-trapping technique above, although the mice would already be dead when captured so would not need to be euthanized. Over 5,000 traps would be required with traps placed at 10 m spacing. Traps may need to be checked daily for weeks, or, more likely, years. If each person checked, removed, re-baited, and reset 100 traps per day, 50 personnel on foot would be required to check the 5,000 traps daily. Given the steep and rugged terrain of much of the Farallon Islands, actual time or personnel needed would be significantly greater especially when mice are at cyclic high numbers. Some areas are not safely accessible on foot. Most likely potential impacts to non-target island resources from the application

method include destruction of habitat from frequent trampling, frequent and long-term disturbance to marine mammal haul-outs and breeding areas, and frequent and long-term disturbance to seabird breeding areas. The latter two would likely result in large-scale loss of the annual productivity of many Farallon species, including abandonment of certain areas. This method is most used for rodent control on a very local level and has no record of success in an island rodent eradication.

Non-native Predator introduction – This technique would involve the introduction of an unknown number of non-native predators (such as cats or snakes) that are known to prey on rodents in the hope that they would prey on and kill every mouse on the islands. This method may provide some means of partial control of mouse numbers on the Farallones. But its use has never been documented in an eradication setting and it is highly unlikely to fully eradicate mice from the islands. Also, there is a high risk of major impacts to native wildlife on the islands from introduced predators, as well as a high risk of such an introduced predator becoming naturalized on the islands.

1.1.2 Theoretical Methods (not yet developed or ready for field testing)

Immunocontraception – This technique utilizes a form of mammalian birth control delivered aerially in a food pellet that would theoretically inhibit conception and reproduction of mice. While research is being conducted into control efforts for rats using this technology, no registered product exists in the U.S. for any rodent in a deliverable or permitted format, and none of the methods currently being tested are expected to be available or registered for mouse eradication on islands, or any other purposes, in the near future. Since mice live up to 18 months or more before they die naturally of old age, this product likely would have to be delivered to every mouse on the island for at least two years to have a chance at eradication of all the mice. Bait would likely need to be continually delivered periodically for many months or years.

Disease -Like immunocontraception, the technique of introducing a fatal disease that would kill only mice has been researched for decades, but no product or process is currently available to field test for eradication. Theoretically, if developed in the future, this technique might involve aerially introducing infected mice or food dosed with some infectious agent that could kill mice. A number of exposure attempts would likely be necessary during different portions of the island and throughout the year, possibly over years.

Genetic Engineering –Another theoretical technique, that if developed would likely involve multiple releases on the islands of genetically modified house mice that might cause the eradication of mice by producing a sex-bias (daughterless method) so severe that mouse reproduction might eventually cease. Some lab and small field trial work on mosquitoes suggests that this might be a possibility for mouse control in the future, but this technique is at least 5-10 years away, if ever, from being ready for any practical field use for eradication.

1.1.3 Rodenticide Methods

A variety of chemicals have been developed to kill rodents. These chemical rodenticides are typically delivered in an ingestible form such as a bait pellet made up largely of grain materials. Table 1 summarizes the recognized classifications and subclassifications of rodenticides and the products assessed. The different classes vary in their physical means of inducing mortality, time to induce mortality, effectiveness at causing mortality, and effects on non-target species, soil and water. Most have been developed and used as rodent control agents, mainly for rats (*Rattus* spp.). A small number have been used for island rat or mouse eradications. Two products have been most widely and successfully used for rodent eradications: brodifacoum and diphacinone. These same two are the only

products registered in the U.S. for island eradication purposes. Others may be legal or illegal for use for other purposes.

Table 1. List of rodenticides assessed in this report, including classification and description.

Classification	Sub classification	Description	Products assessed
Nontoxic		A highly soluble and biodegradable cellulose maize product that blocks the digestive system of rodents, without impacting other mammals or birds. It causes rodent death by dehydration, blood thickening, and circulatory collapse. It requires multiple feedings for 4-7 days, of at least 10-15 grams per mouse, and can only be applied through a bait station operation. This technique has never been trialed or used in an eradication setting.	Eradibait
Acute		A rodenticide that acts rapidly and causes death shortly after ingestion.	Zinc phosphide, Bromethalin, 1080 (Sodium fluoroacetate), Strychnine
Subacute		A rodenticide that causes death between 24 and 48 hours after ingestion.	Cholecalciferol
Chronic	1st generation anticoagulant	A rodenticide that prevents coagulation (clotting) of the blood and requires multiple doses to induce mortality. It takes at least 48 to 72 hours for the anticoagulant effect to develop.	Diphacinone, Warfarin, Chlorophacinone, Pindone, Coumatetralyl
	2nd generation anticoagulant	A rodenticide that prevents coagulation (clotting) of the blood and may require just a single dose to induce mortality. It takes at least 48 to 72 hours for the anticoagulant effect to develop.	Brodifacoum, Bromadiolone, Difethialone, Flocoumafen

- *Available Broadcast Methods:*

Aerial Broadcast: This approach involves the use of a sophisticated helicopter delivery system that utilizes a custom designed and calibrated agricultural hopper with Digital GPS mapping electronics. The hopper allows practitioners to spread bait at designated rates over the entire island in a systematic way. Aerial broadcast is effective at quickly spreading bait over large areas, including areas not accessible on

foot. One treatment can be accomplished on the Farallones in a few hours. Two treatments separated by a week or two are usually conducted when using second generation anticoagulants, acute toxicants, and subacute toxicants. Three or more treatments may be necessary if using first generation anticoagulants since they require multiple feeds to cause a lethal response to target individuals, more bait is needed to successfully eradicate every mouse, and mice need to be exposed to the toxicant for 2 to 3 weeks at minimum. For this method, it was assumed that implementation would be conducted during the fall months when impacts to Farallon breeding birds and marine mammals would be minimized. Thus, the most likely potential impacts to non-target resources from the application method include short-term disturbance to marine mammal haul-outs and seabird roosting areas, and mortality of non-target species from both primary and secondary consumption of rodenticide.

Hand Broadcast: This method would require broadcasting bait by hand over the entirety of the islands on foot. Bait would be spread using over 5,000 designated baiting points spaced 10 m apart.). Given the steep and rugged terrain of much of the Farallon Islands, in order to complete one treatment on 50 ha, 50-100 people might be needed to allow for the marking of each bait point and to execute the simultaneous baiting of all 5,000 points on all islands in one to two days. Some areas are not safely accessible on foot and thus could not be baited. Two applications would be required for second generation anticoagulants, acute toxicants, and subacute toxicants, whereas 3 or more applications may be required for first generation anticoagulants. For this method, it was assumed that implementation would be conducted during the fall months when impacts to Farallon breeding birds and marine mammals would be minimized. Thus, the most likely potential impacts to non-target resources from the application method include potential destruction of habitat from trampling, short-term disturbance to marine mammal haul-outs and seabird roost sites, and mortality of non-target species from both primary and secondary consumption of rodenticide.

Bait Station: Bait stations are box-like enclosures with small entryways designed to be attractive to rodents, but difficult to navigate for other species such as birds. Bait station methods involve securing bait stations in a manner that will enable them to hold and deliver rodenticides or other bait delivered products, including disease and immunocontraception, to every mouse on the island. Bait station operations are typically left in place for several months, and up to two years to ensure 100% delivery to all mice. Approximately 5,000 bait stations would be required and secured at 10 m spacing to cover the entire island, and would need to be checked every other day for several weeks, then potentially less frequently for several months and for as long as two years or more. A crew of approximately 10 -15 people would be needed for at least 20 days on island to construct, transport and install (secure) the 5,000 bait stations, assuming a rate of up to 50 bait stations installed per person per day. Approximately 100 people would be needed to fill all 5,000 bait stations the first day, as one person can fill one bait station every 10 minutes (= 6/hour x 8 hours = 48-50/day/person). Given the steep and rugged terrain of much of the Farallon Islands, approximately 50-100 people likely would be required to check and refill each of the 5,000 stations every other day for several weeks or months; and 15-20 people would be needed to check and refill the stations once per week for several months or years. Some areas are not safely accessible on foot and thus could not be baited. Most likely potential impacts to non-target resources from the application method include destruction of habitat from frequent trampling, frequent and long-term disturbance to marine mammal haul-outs and breeding areas, frequent and long-term disturbance to seabird breeding areas, and mortality of non-target species mainly from secondary

consumption of rodenticide. The latter two would likely result in large-scale loss of the annual productivity of many Farallon species, including abandonment of certain areas.

○ Steps to Developing the Alternative Selection Model

The steps taken to develop the Alternatives Selection Model are illustrated below and are meant to describe the process used to produce all of the matrices and Minimum Operational Criteria for the model, as well as identify trade-offs and assess the risk tolerance of the Service and its partners.

- **Develop a matrix that can be used to determine if a potential alternative meets the Minimum Operational Criteria**
  - **A.** Evaluate each method to determine if it meets all of the Minimum Operational Criteria
  - **B.** Provide a justification for dismissing an alternative that does not meet the Minimum Operational Criteria

- **Describe the difference between control and eradication operations**

- **Describe the differences between mouse and rat ecology**
  - **A.** Information about rats (*Rattus* spp.) and rat eradications that can be used to inform the planning of a mouse eradication, and how mice are different from rats.

- **Develop a conceptual model illustrating the Alternatives Selection Process**
  - **A.** The conceptual model should provide a visual representation of the modeling process.

- **Develop matrices (Biological Resources Worksheet and Overall Environmental Concerns) that evaluate the potential alternatives for Environmental Concerns**
  - **A.** Identify all major environmental concerns for use within the matrix.
  - **B.** Develop matrices for short-term negative impacts to individuals of each species or group of species.
  - **C.** Determine how each environmental concern will be evaluated and scored within the matrix,
  - **D.** Score and total each method for environmental concerns.

- **Develop a matrix that evaluates the alternatives for Operational Considerations**
  - **A.** Identify all of the operational issues for use within the matrix.

B. Score and total each method for operational considerations.

- **Develop a combined matrix that includes the potential alternatives that meet the Minimum Operational Criteria**

  A. Combine scores from the Overall Environmental Concerns Matrix and the Operational Consideration Matrix to determine the overall score for each method.

  B. Rank the scores in order from smallest to largest to identify the methods that are likely to have the greatest likelihood of successfully eradicating mice from the islands combined with the least impact on island resources .

- **Develop a mitigation matrix that includes the potential alternatives that meet the Minimum Operational Criteria**

  A. Determine the amount of relief (score) each mitigation measure will have on the overall impact to the Environmental Concerns and Operational Considerations.

  B. Combine scores from the Operational Considerations Matrix and Mitigated Environmental Concerns to determine the Total Mitigated Score of the alternative.

- **Develop a ranked list of potential alternatives that meet the Minimum Operational Criteria and determine which of the potential alternatives will be dismissed or considered and evaluated fully within the EIS**

  A. FWS and its partners will determine which alternatives from the list will be developed in the EIS based on the results of the model, the identified trade-offs, and their tolerance for risk.

1.2 Scoring

Each method was scored for a suite of potential impacts and operational considerations using a range from zero to three. The lower the score the less impactful the method was projected to be to island resources, or the more likely the method was expected to satisfy the operational considerations. The scoring was a relative comparison of the methods evaluated in this analysis and was not intended to be used for comparison with other methodologies not assessed herein. This approach allowed us to compare the potential impacts and operational capacity of each alternative in light of uncertainties associated with these methods and their potential to successfully eradicate mice from the Farallon Islands in a manner that imparts the minimum impact to non-target species. The scoring system that was used for each matrix is explained in greater detail within the following discussion. Where data gaps were present, scores were determined by utilizing known information for similar methods. For example, a rodenticide was scored similarly to related rodenticides if information was lacking on its impact to island resources.

1.2.1 Environmental Concerns Matrix (Products 8a and 8b)

The Environmental Concerns Matrix was split into the Biological Resources Worksheet, which compared the impacts of the potential alternatives on biological resources, and the Overall Environmental Concerns Matrix, which includes impacts to all of the affected environment's resources including physical, social, and biological.

Biological Resources Worksheet *(Product 8a)*

The Biological Resources Worksheet analyzes the likely expected short-term impacts to one individual for each of the biological resources on the Farallon Islands for Toxicant hazard (T), Disturbance risk (D), and Habitat alteration risk (H). A score of zero indicates that the impact to the resource is expected to be negligible. A score of one indicates that the impact to the resource is expected to be relatively low. A score of two indicates that the impact to the resource is expected to be relatively moderate, and a score of three indicates that the impact to the resource is expected to be relatively high. Scores were not meant to be absolute impact assessments, but to be categorical scores relative to the other methods assessed. Scores were added together for all of the biological resources to obtain a total score. The total score was then incorporated into the Overall Environmental Concerns matrix to obtain the overall score for the environmental concerns for each potential alternative. Table 2 illustrates the scoring methodology for biological resources. Toxicant hazard refers to potential for an individual to be exposed to lethal doses of toxicant (for potential alternatives using rodenticides). This takes into account both a species susceptibility to toxicant effects, as well as its potential to consume the toxicant. Disturbance risk refers to the individual's potential to be impacted by implementation activities. Examples of disturbance impacts include animals moving from breeding, resting or foraging areas, being trampled, or abandoning breeding sites. Habitat alteration risks refers to an individual's susceptibility to likely habitat changes resulting from implementation activities, such as trampling of vegetation, dislodging rocks, or placement of materials such as traps or bait stations. In the case of introduced plants, extensive ground-based operations will likely lead to spread of invasive plant seeds, which attach to personnel shoes and clothing; this is another type of habitat alteration.

Table 2 – Scoring Methodology for Biological Resources

	Toxicant Hazard (Exposure + Toxicity)	Disturbance Risk	Habitat Alteration Risk (Long-term)

0	A score of zero indicates no toxicant hazard. The species is either not susceptible to toxicant effects or will not be exposed to the toxicant (e.g., no toxicant hazard).	A score of zero indicates that the species is at a negligible risk from disturbance impacts (e,g., no expected impact due to disturbance).	A score of zero indicates that the species is at a negligible risk from habitat alteration (e.g. no expected impact to habitat)
1	A score of one indicates that the species is at a low risk or toxicant hazard. These individuals may be affected by high doses of toxicant but do not have a clear exposure pathway and thus are unlikely to consume lethal doses of toxicant.	A score of one indicates that the species is at a low risk from disturbance impacts and will likely recover very quickly after implementation has ceased.	A score of one indicates that the species is at a low risk from habitat alteration and any impacts to habitat will likely be short-term (e.g. minor short-term impacts to habitat)
2	A score of two indicates that the species is at a moderate level of risk, has at least one exposure pathway, and is moderately susceptible to the toxicant (e.g., consumption of toxicant is possible and could result in mortality).	A score of two indicates that the species is at a moderate risk from disturbance and is likely to experience some impact from disturbance.	A score of two indicates that the species is at a moderate risk from habitat alteration and could be negatively impacted for the short-term (e.g. Impacts to habitat that could impact the individual for the breeding season)
3	A score of three indicates that the species has more than one exposure pathway, is susceptible to toxicant effects, and is highly likely to either consume bait directly or other species that consumed bait (e.g., consumption of toxicant is highly likely and will likely cause mortality).	A score of three indicates that the individual is highly likely to be exposed to disturbance impacts such as lost productivity, long-term or permanent departure from the islands, injury or death.	A score of three indicates that the species is highly likely to be impacted by habitat alteration (e.g. restoration of the habitat or several years of recovery will likely be needed)

Overall Environmental Concerns Matrix *(Product 8b)*

The Overall Environmental Concerns Matrix provides scores for the impacts of each potential alternative to physical and social resources combined with the total score from the Biological Resources Worksheet. The physical and social resources are scored from zero to three; zero is negligible impact, one is low impact, two is moderate impact, and three is high impact. For the most part, all of the physical and social resources were similarly scored for all of the potential alternatives since none are likely to have significant impacts to any of these resources. Table 3 illustrates the scoring for the physical and social resources.

Table 3. Scoring methodology for physical and Social resources.

	Disturbance Impact or Length of Exposure to Physical and Social Resources
0	A score of zero indicates that the resource is likely to experience negligible disturbance impacts or the length of exposure is likely to be negligible (e.g.. persistence in soil is for a few days or expected impacts to social resources are negligible).
1	A score of one indicates that the resource is likely to experience minor disturbance impacts or the length of exposure is likely to be minimal (e.g., persistence in soil is for a few weeks or expected impacts to social resources are low)
2	A score of two indicates that the resource is likely to experience moderate disturbance impacts or the length of exposure is likely to be for a moderate period (e.g. persistence in soil is for a few months or expected impacts to social resources are moderate).
3	A score of three indicates that the resource is likely to experience high levels of disturbance impacts or the length of exposure is likely to be for a long period (e.g. persistence in soil is for more than 6 months or expected impacts to social resources are high)

1.2.2 Operational Considerations Matrix (Product 9)

The Operational Considerations Matrix analyzes the potential for each method to be used to successfully eradicate all mice from the Farallon Islands. This matrix looks at the efficacy of the method at eradicating mice, its legal availability, physical availability, safety to humans, logistics, research needs, and the time needed to obtain registration with the EPA and make island eradication ready prior to implementation. Each operational consideration is scored from zero to three, where zero represents the least risk and three has the most risk. However, since each operational consideration is different, they have individual scoring methods. Table 4 displays the scoring method for each operational consideration.

Table 4. Scoring methodology for Operational Considerations.

Value	Efficacy	Legal Availability	Physical Availability	Time to trial for Registration & Island use	Personnel Safety	Logistical Feasibility	Research Needs
3	Ineffective at eradicating mice	Illegal to use in the U.S.	No known source to obtain for eradication	5 or more years to trial for registration and island use	High risk to personnel from operations	Unfeasible due to access, timing, other logistics	Exorbitant research required for eradication
2	Low likelihood of eradicating mice	Not legally available in the U.S.	Needs a redesign to be used for eradication purposes	3 to 5 years to trial for registration and island use	Moderate risk to personnel from operations	Low feasibility due to access, timing, other logistics	Extensive research required for eradication
1	Moderate likelihood of eradicating mice	Legal for other purposes in the U.S. but not eradication	Could be manufactured but is not readily available	1 to 3 years to trial for registration and island use	Low risk to personnel from operations	Moderate feasibility due to access, timing, other logistics	Some research required for eradication
0	High likelihood of eradicating mice	Legal to use for eradication purposes	Sold commercially for eradication purposes	0 to 1 year to trial for registration and island use	Negligible risk to personnel from operations	High feasibility due to access, timing, other logistics	Little research required for eradication

2 Results

2.1 Minimum Operational Criteria Checklist

The Minimum Operational Criteria checklist is a coarse filter that requires all methods to meet a set of standards for further consideration as potential action alternatives in the Draft EIS. Each potential action

alternative is required to be consistent with selected Farallon National Wildlife Refuge management guidelines, be feasible to implement, and meet all safety and logistic requirements. Methods that do not satisfy all the Minimum Operational Criteria were removed from further consideration and will be included in the EIS in the section: Alternatives Considered and Dismissed. Even though many potential methods did not meet the minimum operational criteria, all 49 methods were scored and ranked in the parallel assessment method, as described in Section 3.2.

The seven methods that passed through the Minimum Operational Criteria filter are shown in Table 5. All of these include the aerial application of rodenticide products that are currently registered with the EPA for some purpose in the U.S. Two are registered for island eradication use for non-native rodents, and five are registered for some type of control use but not for island eradication and conservation purposes (Table 5). Potential action alternatives that would utilize mechanical means as the primary method of operation, including the use of snap traps or live traps, did not meet the Minimum Operational Criteria because they did not meet Service's safety and logistical guidelines since they require the use of extensive ground measures over the entire island, which is considered to be highly unsafe for personnel due to steep and unstable terrain, logistically unfeasible because of the inaccessibility of many areas, and highly impactful to island resources from the repeated disturbance to individuals and habitats. Similarly, all of the rodenticide methods that primarily would utilize ground operations (hand baiting or bait stations) were eliminated for the same human safety, logistical feasibility and unacceptable habitat and disturbance impacts. Furthermore, none of these techniques have ever been used successfully to eradicate mice on large islands.

Most rodenticide methods did not meet Minimum Operational Criteria because they are not currently registered for use in the United States, making the method infeasible to implement in the near future. This is primarily due to the large amount of time associated with developing a bait product, product manufacturing, conducting lab and field trials for registration with the U.S. Environmental Protection Agency (EPA), as well as conducting field trials in an eradication setting. In addition, there is a high degree of uncertainty of the efficacy of the unregistered potential. Many are either less effective on mice, and/or would likely have equal impacts on non-target species as the available registered methods (Howald, 2011 unpublished report). Thus, years of research and development may or may not show these currently unregistered products to be either effective or safe for mouse eradication.

Table 5. Minimum Operational Criteria for eradicating invasive house mice from the South Farallon Islands, including the seven potential methods that passed all criteria.

Minimum Operational Criteria				
Operational Category	**Consistent with Farallon Refuge Management Guidelines**	**Feasible to implement (available & registered, or able to register and trial on an island within 2 years)**	**Meets safety and logistical guidelines**	**Meets all Minimum Operational Criteria**

Aerial Cholecalciferol (subacute)	yes	yes	yes	yes
Aerial Warfarin (1st generation)	yes	yes	yes	yes
Aerial Diphacionone (1st generation)	yes	yes	yes	yes
Aerial Chlorophacinone (1st generation)	yes	yes	yes	yes
Aerial Brodifacoum (2nd generation)	yes	yes	yes	yes
Aerial Bromadiolone (2nd generation)	yes	yes	yes	yes
Aerial Difethialone (2nd generation)	yes	yes	yes	yes

○ Scoring Potential Alternatives

In general, potential alternatives that required aerial application scored lower for disturbance and habitat alteration risk because they required minimal ground operations, some ground-based methods (e.g., hand baiting) received moderate scores for disturbance and habitat alteration risk because they only required ground operations for a short period of time, and methods with extensive ground operations (e.g., bait stations and live trapping) received high scores for disturbance and habitat alteration because they required extensive and repeated ground operations for an extended period of time. The latter group would entail frequent disturbances to seabird and pinniped breeding and resting areas, likely resulting in major impacts including extended abandonment of large areas, abandonment of nests or pups, crushing of seabird nesting burrows, dislodging of rocks, injury to pinnipeds from trampling and flushing, damage to plant communities from trampling, among others.

Potential alternatives that utilized acute, sub-acute, and second generation anticoagulant rodenticides scored higher than first generation anticoagulants for toxicant risk because of their higher toxicities, while methods that did not include toxicants received negligible (0) scores for toxicant hazard. The score for toxicant hazard was based on three factors: exposure potential, toxicity to the resource, and the type of rodenticide. Therefore, a toxicant may be highly toxic to an individual but receive a low score for toxicant hazard if the individual is not likely to be present at the time of implementation or there is no foreseeable pathway of exposure to lethal doses (e.g., seabirds that primarily eat pelagic fish will be at a negligible toxicant risk since they are unlikely to come in contact with the toxicant through primary or secondary exposure pathways). Toxicant risk to invertebrates and plants is low to moderate because rodenticides are not known to be toxic to these resources. Marine mammals scored low fortoxicant risk because they are highly unlikely to consume rodenticide in the large quantities required to have toxic effects. Birds, such as gulls, scored high for toxicant risk because of their likelihood of consuming lethal doses of toxic bait pellets, as well as the possibility of consuming dead mice or other organisms killed by

rodenticide ingestion. Certain raptors, such as Peregrine Falcons and Burrowing Owls, scored high for toxicant risk because of their risk of secondary exposure by feeding on either birds that had been exposed to rodenticide (falcon or owl) or mice exposed to rodenticide (owl).

Generally, methods that are not currently legally available (registered for island conservation purposes in the United States) scored higher than those that are currently registered due to the research needs, physical availability of the method, and the time needed to trial and register a product for island use. Potential alternatives with a limited or nonexistent history of successful rodent eradication received higher scores for operational efficacy risk than methods with a history of successful eradication use. Methods that required intensive ground-based activity scored higher than those that could be applied aerially (for reasons described above) and methods that have the potential to eradicate mice but are not available scored higher than those currently available for use at this time.

2.2 Ranked List of All Potential Alternatives

The Combined Matrix (Product 10) incorporates the scores from the Overall Environmental Concerns Matrix (Product 8b) and the Operational Considerations Matrix (Product 9) to provide a ranked list of alternatives.

The ranked methods were then compared to the results of the Minimum Operational Criteria. Eight of the top eleven ranking methods are aerial rodenticide methods (Table 6). Seven of these rodenticide methods successfully passed the Minimum Operational Criteria (Table 5) and were considered for inclusion in the draft EIS as potential action alternatives. Aerial broadcast of pindone did not meet all of the Minimum Operational Criteria due to the length of time needed to trial and register for island use.

Immunocontraception, disease, and genetic engineering methods all ranked relatively high, as they are non-toxic methods that could potentially be effective at eradicating mice in the future. However, at this time they are all still in the theoretical design and planning stage (Dr. Cheryl Dyer of Synestech and Dr. David Threadgill of North Carolina State University pers. comm.), and consequently are not available to be considered as viable action alternatives.

The hand broadcast, bait station, and trapping methods had the highest scores (most impactful) primarily because they did not meet the safety and logistical requirements, but also because all of these methods require repeated foot traffic over the entire island for many months/years, which would have unacceptable long-term negative impacts to important seabird breeding areas and pinniped haul outs on the islands.

Table 6. Top ranked potential action alternatives based on total combined scores of the Environmental Concerns and Operational Concerns matrices.

Possible Action Alternatives	Total Environmental Concerns (8a + 8b)	Total Operational Considerations (9)	Total Combined Score (10)
Immunocontraception *	9	16	25

Aerial Warfarin	17	8	25
Disease *	9	19	28
Aerial Diphacinone	21	6	27
Genetic Engineering*	12	17	29
Aerial Cholecalciferol	23	8	31
Aerial Chlorophacinone	23	9	32
Aerial Brodifacoum	32	3	35
Aerial Bromadiolone	30	6	36
Aerial pindone*	24	13	37
Aerial Difethialone	33	6	39

* Alternatives eliminated from full consideration because they did not meet the Minimum Operational Criteria listed in Product 1.

2.3 Mitigation Matrix

The Mitigation Matrix (Product 11) was designed to compare methods that met the minimum operational criteria under both mitigated and unmitigated operations. A suite of mitigation measures that may be included in the design of action alternatives for the draft EIS were applied and valued for the potential alternatives that met the Minimum Operational Criteria. Mitigation measures that were included in this portion of the analysis involve techniques that could be employed to reduce the potential impacts of rodenticides and disturbance to non-target resources, depending on the method used. Several of these techniques have been used successfully in previous rodent eradications. Mitigation measures to reduce risk of toxicant exposure from rodenticide methods included: 1) gull hazing to reduce their risk of consuming toxic bait; 2) carcass removal of all dead animals found to reduce the risk of secondary toxicant exposure to predators and scavengers ; 3) raptor capture and hold to eliminate the risk of those individuals to secondary exposure to toxicant by preying on organisms that were otherwise exposed to toxicant; 4) capture and hold of suitable numbers of endemic arboreal salamanders and Farallon camel crickets in the unlikely case that reintroduction is necessary to protect against population level impacts to those species; 5) using a bait deflector on the coastline; and 6) tarping the water catchment pad to protect the island drinking water supply. Mitigation measures to reduce risk of wildlife disturbance included, for aerial broadcast methods, controlled helicopter flights to partially habituate and slowly and safely flush marine mammals during baiting operations. The mitigation measures in this analysis represent the type of mitigation measures that could be incorporated into operational plans for the action alternatives developed in the draft EIS; however, it is too early in the planning process to determine precisely which measures will ultimately be used during

project implementation. Additional mitigation measures not used in this preliminary analysis may also be considered and eventually employed.

Furthermore, the implementation of some mitigation measures such as bird hazing may reduce the toxicant impacts to some species (e.g., gulls) that may also result in temporary disturbance impacts to other species (e.g., marine mammals). As a result, the overall scores for the mitigated methods are, in general, about the same as for the unmitigated methods, but these scores are not weighted for relative importance. These factors will need to be considered thoroughly as part of the decision making process on a preferred alternative.

Table 7 provides a comparison of mitigated and unmitigated scores for the seven potential alternatives. In addition, the table provides mitigated and unmitigated scores for the seven alternatives without any consideration of potential disturbance impacts to illustrate the differences both with and without mitigation for toxicant risk to non-target resources. Basically, with mitigation, the toxicant risk can be reduced to low or negligible levels for most non-target resources on the islands. Additionally, the table identifies the key trade-off between potential gull mortality due to toxicant exposure and increased disturbance to both birds and marine mammals with extensive mitigation (i.e., gull hazing).

Table 7. Comparison of the mitigated and unmitigated scores for all 7 potential alternatives that met the minimum operational criteria and ranked in the top ten. Scores with and without disturbance impacts were included to better illustrate how mitigation measure will likely decrease the lethal exposure of rodenticides to non-target species.

Alternative	Total Unmitigated Score[1]	Total Mitigated Score[2]	Total Unmitigated Score without Disturbance[3]	Total Mitigated Score without Disturbance[4]
Aerial Warfarin	25	33	15	13
Aerial Diphacinone	27	33	17	11
Aerial Chlorophacinone	31	37	21	15
Aerial Cholecalciferol	31	37	23	17
Aerial Brodifacoum	35	38	27	16
Aerial Bromadialone	39	41	31	19
Aerial Difethialone	39	42	31	20

[1]Total Combined Score from Table 6 and Matrix 10.
[2] Total Combined Score from Table 6 adjusted when mitigation measures for rodenticide toxicant risk and disturbance are incorporated (Matrix 10).

[3] Total Combined Score from Table 6 adjusted when potential impacts to non-target resources from disturbance are not considered (Matrix 10).
[4] Total Combined Score from Table 6 adjusted when potential impacts from disturbance are not considered but mitigation measures to reduce toxicant risk to non-target resources are included (Matrix 10).

3 Conclusions

The Alternatives Selection Process utilized a Structured Decision Making (SDM) approach to analyze and evaluate 49 potential alternatives for inclusion in the proposed Farallon Islands mouse eradication Draft EIS. SDM is widely used by the Service to evaluate alternatives, identify priority areas for conservation, and to develop programmatic planning documents. The Alternatives Selection Process evaluated each method for its potential impacts to island resources, as well as its ability to fulfill all of the operational requirements for invasive house mouse eradication on the Farallon Islands.

3.1 Potential Action Alternatives

Of the 49 potential alternatives that were initially assessed in the model, a total of seven met the Minimum Operational Criteria and were analyzed further under a scenario incorporating measures to mitigate, or reduce, potential impacts to non-target resources. All seven potential action alternatives incorporated an aerial application of rodenticide as the primary mouse removal method.

The seven potential action alternatives included:

- One sub-acute toxicant: cholecalciferol;
- Three 1st generation anticoagulants: chlorophacinone, warfarin, and diphacinone
- Three 2nd generation anticoagulants: brodifacoum, bromadiolone, and difethialone.

Of the seven rodenticides meeting the Minimum Operational Criteria, only two have products that are currently registered with the EPA for conservation use and thus are legally available for rodent eradication on islands in the United States: diphacinone (D50 Conservation) and brodifacoum (25D Conservation and 25W Conservation).

Of the 47 successful mouse eradications world-wide, 98% (all but one) used brodifacoum or a closely related second generation anticoagulant. The application of rodent bait containing brodifacoum is the only method with a demonstrated history of success for eradicating mice from islands worldwide. However, it does pose a greater risk than subacute or 1st generation anticoagulants to non-target species such as birds. However, diphacinone, which is less toxic to birds, has never been successfully used for a mouse eradication, although it has been used successfully for rat eradications

The other five rodenticides that met the Minimum Operational Criteria are not registered for island eradication use and have properties generally similar to one of the two available rodenticides. None of the five unregistered compounds have been proven more effective at eradicating mice than one of the two available, registered products. Furthermore, no new products are currently in development or are likely to be available and trialed in an island eradication setting within the time-frame preferred for this

project. Also, several of the unselected compounds (including warfarin, chlorophacinone, and bromadiolone) have a history of resistance, while cholecalciferol has a history of bait shyness and resistance. Difethialone is a compound that has a very long half life in soil (635 days).

Table 8 illustrates the outcome of each of the seven potential action alternatives and a summary of the primary justifications for their dismissal from further consideration in the draft EIS as action alternatives. The results of the minimum operational criteria and the ranked analyses identified two possible eradication methods as available and appropriate for consideration as action Alternatives in the EIS: aerial diphacinone and aerial brodifacoum.

Table 8. Potential action alternatives for development in a draft EIS for house mouse eradication from the South Farallon Islands, based on results of this study.

Potential DEIS Action Alternatives Meeting the Minimum Operational Criteria		
Alternative	**Suggested Outcome**	**Justification for dismissal or inclusion as an Action Alternative**
Aerial Diphacinone	**Action Alternative in EIS**	**Registered for conservation on islands, has history of use for rodent control and eradication; however, has a history of bait shyness[1]**
Aerial Brodifacoum	**Action Alternative in EIS**	**Registered for conservation on islands, has history of success for mouse control and eradication**
Aerial Warfarin	Dismissed	Not registered for conservation on islands, impacts likely similar to Diphacinone, history of resistance[2]
Aerial Cholecalciferol	Dismissed	Not registered for conservation on islands, history of resistance* and bait shyness[1]
Aerial Chlorophacinone	Dismissed	Not registered for conservation on islands, impacts likely similar to Diphacinone
Aerial Bromadiolone	Dismissed	Not registered for conservation on islands, impacts likely similar to Brodifacoum, history of resistance[2]
Aerial Difethialone	Dismissed	Not registered for conservation on islands, impacts likely similar to Brodifacoum, long soil half life

[1] Bait shyness is a taste aversion, often associated with ill feelings, to a toxicant that typically results in individuals who will avoid consuming enough bait to meet the toxic threshold.
[2] Bait resistance is a genetic mutation that prevents the individual from experiencing the toxic effects of the toxicant.

Additional unregistered and untested theoretical techniques for mouse removal were identified as having some potential to eradicate mice from islands in the future, but these techniques are likely several from being tested and successfully employed in an island eradication setting, if at all. Because of the pressing need to remove the destructive invasive mice from the Farallones and the high uncertainty

of currently unregistered products to become available for successful implementation makes these products extremely difficult and undesirable to develop as action alternatives for mouse eradication from the Farallon Islands. Thus, it is recommended that the Service develop the two currently registered products for island rodent eradications, diphacinone and brodicafoum, using the safest and most effective method of aerial broadcast, as action alternatives in the draft EIS for mouse eradication at the South Farallon Islands.

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3. Appendices

Appendix A: Model Products

Product 1 - Minimum Operational Criteria for Action Alternatives

A. Must be Consistent with the Farallon National Wildlife Refuge Management Guidelines

I. *Mission of the National Wildlife Refuge System*

II. *Mission of the Farallon National Wildlife Refuge*

III. *Farallon Comprehensive Conservation Plan*

IV. *U.S. Department of Interior Policy on Introduced/Invasive Species*

V. *Wilderness Act Minimum Requirements*

VI. *Endangered Species Act Take Requirements*

VII. *Migratory Bird Treaty Act*

B. Implementation of the Alternative is Feasible to Implement

I. *Product is available and registered for conservation eradication or could affordably be developed and registered for conservation eradication within 2 years (including research, trialing, manufacturing, registering, planning, and implementing)*

C. Alternative Meets with Personnel Safety and Logistical Guidelines

I. *Is the alternative safe and unlikely to put personnel at undo physical risk and can it be implemented without accessing large, relatively inaccessible portions of the island by foot?*

Product 2 – Operational Tools and Methods

- *Tools include*:
  - Live Trapping
  - Snap Trapping
  - Disease
  - Genetic Engineering

- Immunocontraception
- Non-native Predator introduction
- Rodenticides:
    - Tools
        - Non-toxic
            - Eradibait
        - Acute
            - Zinc phosphide
            - Bromethalin
            - 1080 (Sodium Fluoroacetate)
            - Strychnine
        - Subacute
            - Cholecalciferol
        - First Generation Anticoagulant
            - Warfarin
            - Chlorophacinone
            - Diphacinone
            - Pindone
            - Coumatetralyl
        - Second Generation Anticoagulant
            - Brodifacoum
            - Bromadiolone
            - Difethialone
            - Flocoumafen
        - Aerial broadcast
        - Bait Stations

- Hand Broadcast

- **Product 3 – Environmental Concerns, Operational Considerations, and Potential Mitigation Measures**

Environmental Resources of Concern

Physical Resources

- Water, including drinking water supply and the surrounding ocean. No freshwater resources besides captured drinking water exist on the islands.
- Soil
- Wilderness

Issues to Consider

- Risk of water contamination – solubility and persistence
- Risks to wilderness character
- Risk of soil contamination or compaction

Biological Resources

- Seabirds: western gulls, ashy storm-petrels, Leach's storm-petrels, other cavity nesters (pigeon guillemont and tufted puffin), other surface nesters (double-crested cormorant, Brandt's cormorant, pelagic cormorant, and common murre), burrow nesters (Cassin's auklet and rhinoceros auklet), and other gulls (California gull, glaucous-winged gull, herring gull, thayer's gull, Heermann's gull, etc.)
- Shorebirds - black oystercatchers (resident breeder), black turnstone, wandering tattler, whimbrel, and several other occasional or rare visitants.
- Raptors: burrowing owl, peregrine falcon, other raptors (American kestrel, red-tailed hawk, common raven, and several other rare or occasional transient species)
- Passerines: All (migrants) except breeding common ravens which was included with raptors
- Marine mammals: Steller sea lion, northern elephant seal, all others (California sea lion, northern fur seal, and harbor seal)
- Farallon arboreal salamanders

- Invertebrates –
    - Terrestrial: All, including Farallon camel cricket, kelp fly, beetles (Lepidoptera) , spiders, etc.
    - Marine: All, including mussles *(Mytilus californianus*), &), limpets (such as *Lottia scabra* and *L. giganita*), barnacles (such as *Chthamalus dalli*/*Balanus glandula* and *Tetraclita rubescens*), colony anemone *(Anthopleura* elegantissima), etc.
- Vegetation –
    - Native: All. The most common species include maritime goldfield (or "Farallon weed", *Lasthenia maritima*"); sticky sandspurry *(Spergularia macrotheca*); and miner's lettuce (*Claytonia perfoliata*).
    - Introduced Vegetation: All. The most common species include New Zealand spinach (*Tetragonia tetragonoides*), ripgut brome (*Bromus diandrus*)*;* foxtail barley (*Hordeum murinum leporinum),* cheeseweed (*Malva parviflora*) and buckhorn plantain (*Plantago coronopus*).

- Nearshore fish: All
- Human health and safety

<u>Issues to Consider</u>

- T = Toxicant hazard (toxicity + exposure = toxicant risk)
- D = Risks from disturbances (e.g. trampling vegetation, disturbance to breeding activities, disturbance to rest sites, etc.)
- H = Risks from habitat alteration/destruction (e.g., long-term habitat alteration)

<u>Social/Historical Resources</u>

- Historical resources: buildings and artifacts
- Fisheries and tourism: recreational and commercial

<u>Issues to Consider</u>

- Impacts to recreation
- Impacts to historical features
- Impacts to commercial fisheries

Scoring Resources

- All resources were scored 0 to 3 for potential impacts ; biological resources were evaluated for toxicant risk, disturbance risk, and risk of habitat alteration.
  - 0 = Negligible or Not Applicable
  - 1 = Low
  - 2 = Medium
  - 3 = High

Operational Considerations

1. Efficacy
2. Legal availability of technique
3. Physical availability of technique
4. Time to register and trial for conservation on islands
5. Personnel safety
6. Logistical feasibility
7. Research needs

The following table is a breakdown of the valuation system for each operational consideration.

Value	Efficacy	Legal Availability	Physical Availability	Time to Register & Trial for Island Use	Personnel Safety	Logistical Feasibility	Research Needs
3	Ineffective	Illegal	No Known Source	5+ years	High Risk	Unfeasible	Exorbitant
2	Low	Not Legally Available	Needs a Redesign	3-5 years	Moderate Risk	Low	Extensive
1	Moderate	Legal for Other Purposes	Could be Manufactured	1-3 years	Low Risk	Moderate	Some Required
0	High	Legal	Sold Commercially	0-1 year	Negligible Risk	High	Little Required

Potential Mitigation Measures

To Reduce Toxicant Hazard

4. Carcass removal
5. Gull hazing – intended to reduce gull take to a minimal level
6. Raptor capture/hold/relocation
7. Captive holding of salamanders
8. Captive holding of camel crickets
9. Tarp drinking water catchment pad
10. Bait deflector

To Reduce Disturbance Risk

1. On the ground measures to reducing wildlife disturbance (e.g. crouching, walking slowly, etc.)
2. Helicopter controlled surveillance flight and slow approach to decrease disturbance to pinnipeds

- **Product 4 – Comparing Rodent Control versus Eradication Operations**

The net conservation gain achieved by rodent control (i.e. reducing and maintaining rodent populations at low levels) on an island is temporary, generally more expensive and less beneficial that the permanent restorative benefits of complete eradication. Sustained rodent control is immensely challenging on islands such as the Farallones where topography, climate, and disturbances to sensitive native wildlife make access difficult and in some areas impossible. The long-term risks to non-target wildlife from control operations are generally greater than the risks posed by island eradications because of the ongoing nature of a control operation. Eradications occur over a short timeframe and, if conducted properly and successfully, are single actions resulting in only short-term negative impacts.

On the Farallones, a hugely greater number of personnel hours would be needed on an annual basis in perpetuity to sustain a mouse control operation. Activities associated with a control program would result in repeated disturbances to sensitive breeding seabirds and marine mammals. If rodenticides were used as the control method, control operations would place non-target wildlife at an almost constant risk of exposure to toxicants. Should rodent control operations be interrupted or ineffective, mice are able to quickly reproduce and rapidly re-populate the island reaching former population sizes relatively quickly. An ongoing control effort, even if possible, would increase personnel safety risk, be more impactful to native species, would be less cost-effective, and would not result in permanent island-wide conservation and restoration benefits to the species of native animals and plants that exist on the Refuge.

Table 4.1 illustrates why eradication, and not control, is being considered for Farallon ecosystem restoration, a comparison of the differences between eradication and control operations is provided in the table below.

Table 4.1. Comparison of island eradication and mainland control operations for rodents.

Comparison of Island Eradication and Mainland Control Operations		
	Eradication on Islands	**Control on Mainland**
Location	Rodent eradications are primarily attempted on isolated islands where an invasive species is impacting the native species of plants, animals, and the island's natural ecological processes, and where rodents cannot recolonize the area from adjacent habitats.	Rodent control efforts are primarily attempted on the mainland in urban, residential or agricultural areas where rodents impact people or commercial endeavors.
Goal	Restoration of the island ecosystem by complete removal of the target species from an island. 100% removal of all individuals is required, as failure to remove every individual from an island will result in surviving individuals repopulating the island.	Reduction of the rodent population in a confined management area (agricultural zone or near residential areas/buildings). Generally, an eradication is impossible because rodents can easily recolonize from adjacent habitats..
Successful Methods	On all but the very smallest islets, the only invasive rodent eradication technique that has been successful on islands has involved distributing a lethal dose of rodenticide to every individual rodent on the island.	A variety of toxic, non-toxic, mechanical (traps) and biological (predator) methods are available for controlling rodents in mainland areas. It is not necessary for control operations to remove every single rodent.
History of Success	Rodent eradications have been successfully conducted on over 338 islands world-wide with many more awaiting confirmations. Successful eradications typically result in the recovery of native biota. Success rates have increased in recent years as techniques are refined. Success depends on a variety of factors including rodent species, techniques employed, and seasonal timing.	Many methods are used for controlling rodent numbers on the mainland with variable rates of success including toxic and non-toxic techniques.
Length of Operation	Eradications are typically one-time operations that usually take only a few days or weeks to conduct.	Depending on the nature of the infestation, control efforts must be continued for long periods or revisited periodically in perpetuity.
Extent of Positive Impact	The positive impacts to island ecosystems include measurable, dramatic, and often immediate benefits to the many native species, while other species take years to be restored.	The positive impacts are limited in extent, degree, and duration. Measurable benefits to mainland areas are generally small in size and temporary as immigration and repopulation can result in a return to former rodent population levels

		within months.
Extent of Negative Impact	While eradications have been known to have non-target effects, these unintentional impacts are usually one-time, short-term, and generally lack population-level impacts. A majority of impacts are avoided, minimized or mitigated. Most have a limited extent and are confined to a relatively closed island ecosystem.	Negative effects of chronic rodent control efforts have resulted in direct and indirect impacts to non-target species. Because of the open ecological system on the mainland, a toxicant can be distributed widely through a variety of pathways by a wider range of scavengers and predators. Repeated toxicant exposure in urban and agricultural settings extends the period of time in which toxicant impacts can occur. Most non-target species populations that are negatively impacted continue to repeatedly accumulate toxins for a period of many years, often with fatal results.
Risk of Failed Operation	Because of the generally high one-time cost and logistical complexity of conducting whole-island rodent eradications, there is a reduced likelihood of funding and organizing follow up attempts. The ecological benefits to sensitive island species and resources will not be realized and certain species may face extirpation or extinction as a result.	Rodent controls efforts are never completely successful because individuals repopulate the area from adjacent habitats. Because of their relative low short-term cost and low logistical complexity, unsuccessful rodent control efforts can be manipulated with additional techniques to increase success. Rodent control is typically on a local and relatively small scale and impacts of failure are similarly low level and localized. While short-term impacts to human health and economic endeavors may continue, long-term impacts are less likely. In the long-term, managing frequent infestations can incur large economic costs.
Extent of Regulatory Oversight	In the U.S., island eradications are permitted after extensive planning and a review of 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 is little oversight regarding application rates and methods of delivery for rodent control products used in the commercial and residential sectors. However, the use/misuse of toxicants for residential and commercial use is wide in extent and has resulted in the removal of several rodenticides from retail sale.

- **Product 5 – Assessment of Mouse vs. Rat Ecology**

Eradications of introduced rodent species have been successfully conducted on about 482 islands since 1971 (MacKay 2007). Success rates can vary depending on the species targeted, the methods attempted, as well as the geographic and ecological factors of each island (Howald 2007, MacKay 2011, Clapperton 2006, Parkes et al. 2011). The large majority, 89%, of rodent eradications have targeted one or more species of rat (*Rattus* spp.). In conjunction, most methods that have been developed for island rodent eradication have been focused on rats. In the relatively small number of attempts made (81 attempts), success rates for mouse eradications have historically been lower on average (35% success) than rat eradications partly because managers generally treated mice in the same way as rats. While there are some similarities between house mice and rats, there are several differences between them in behavior and physiology that are important to consider when designing island eradication projects. In some recent mouse eradications, managers have taken into consideration these differences, with resulting success.

Understanding how each introduced rodent species interacts with their environment allows conservation managers to direct resources and conduct rodent removal operations more effectively. While many of the aspects of a rodent eradication are the same regardless of the rodent species targeted, understanding the unique behavior and biology of the target species allows for greater likelihood of eradication success and minimization of impacts to non-target species. Eradication methods that might be effective for some rat species may not be as effective for house mice due to differences between mice and rats in their foraging ecology, home range, density, and physiology (Clapperton 2006).

The following discussion summarizes the relevant differences in foraging ecology, home range, density, and physiology between rats and mice to help inform the planning process for the removal of introduced house mice from the South Farallon Islands.

Foraging Ecology

All rodent species are opportunistic omnivores, readily consuming seeds, plants, invertebrates, and bird eggs and chicks (IUCN 2011, MacKay 2011). Mice tend to consume more invertebrates than rats (Shiels 2010). Mice are considered to be light and more intermittent feeders than rats (Crowcroft & Jeffers 1961), as rats are known to cache and store food more regularly. Rats need to consume approximately 1.5 oz (43 grams) of food per day (about 20% of their body weight), while house mice on average only need to consume approximately 0.1 ounces (3-4 grams) of food per day (about 13% of their body weight). Thus it can require more careful planning to ensure that each mouse ingests the required lethal dose of bait.

Home Range Size and Population Density

Home range size is a factor that can potentially affect the efficacy of eradication techniques for rats and mice. Rats generally have much larger home ranges than house mice. Average home range size for most rats is typically greater than one hectare and can be as large as 11 hectares (Shiels 2010). House mouse home ranges, however, are typically 0.25 hectares or less (Pickard 1984). Small home range size for mice accentuates the need for ensuring comprehensive bait coverage when targeting a mouse population to ensure that every individual mouse gets access to the required dose of bait or access to a removal device, with no gaps in coverage.

Densities of introduced rats on islands are typically much lower than densities of invasive mice. Rat densities on Pacific islands are typically in the 5-10 individuals per hectare range, while most reported house mouse densities fall into the 10-50 individuals per hectare range (Pearson 1963, MacKay 2011). Densities of more than 800 mice per hectare have been reported during periodic population eruptions (Pearson 1963). Estimated densities on islands can be an order of magnitude higher for mice than for rats. In a mark-recapture study on Southeast Farallon Island in 2010, mouse densities were calculated to be approximately 1,200 individuals per hectare (95% CI 799-1792). This density estimate is among the highest ever reported for this or any other rodent species (Grout, in prep). Mouse populations typically show cyclical changes in population density (Ruscoe and Murphy, 2005), especially in the northern latitudes when food or weather are variable (MacKay 2011). Mouse removal operations must be designed and timed to consider these cyclical population fluctuations.

Physiology

Adult house mice generally range from 0.5oz to 0.9oz (15g to 25g), while introduced rats species can be 80 times more massive (King 2005). House mice, however, are not simply small rats, as their physiology is much different, with higher metabolic rates, higher reproductive rates, and differences in behavior. House mice have a very high reproductive potential, which is a large part of their success as an invasive species. Female mice can breed for the first time at 3-6 weeks of age and can produce litters of 6-8 young every 4 weeks after that (Berry 1981). Such reproductive capabilities can lead to massive eruptions and subsequent population crashes for mice. In one study, 20 mice placed in an outdoor enclosure with abundant food and water became a population of 2,000 in only 8 months (Corrigan 2001).

Mice and rats also react to toxicants much differently. Resistance by mice to first generation toxicants such as warfarin and diphacinone has been recorded, and mice are known to have different levels of susceptibility to many toxicants. The LD_{50} (poison dose required to kill 50% of tested individuals) for 1st generation anticoagulants like Diphacinone is 1.75 mg/kg for the Norway rat while the same test determined that the LD_{50} for a laboratory mouse is over four times higher, 7.05 mg/kg (Erickson and Urban 2004). Another study lists the LD_{50} for diphacinone as much as 350 times higher for mice than for rats (O'Connor and Booth 2001). It seems apparent that the physiology of mice and rats are sufficiently different that it would be inadvisable to assume that a method or toxin that has proven effective for eradicating rats would necessarily be as effective for eradicating mice.

Mouse Eradication Success Rates

Many more island eradication operations have been undertaken for rats (>400) than for mice (81). Prior to 2007, reported operational failure rates were higher for mice (19-32%) than for rats (about 5-10%), but some of the mouse operations either only targeted (or primarily targeted) rats. Additionally, many of the mouse eradication attempts did not take into account the unique behavior and ecology of mice (Howald et al. 2007, MacKay 2007). Much has been learned from both the early mouse removal successes and failures, and since 2007 ten of the eleven (91%) mouse eradications attempted have been confirmed as successful. Mice have now been removed from islands as large as Rangitoto (2,311 ha) and Motutapu (3,854 ha) in New Zealand.

Of the 41 successful mouse eradications, all but one used brodifacoum, a second generation anticoagulant, or another closely related toxicant. Bait stations were used as the primary method in 30 of 60 mouse eradication attempts on 48 islands. Hand broadcasting was used in two attempts, and aerial broadcast was used in 25 attempts. A total of 29 mouse eradication attempts have been completed on islands where another pest mammal species was present, and 13 of these operations failed. Early mouse eradication failures may have been complicated by the presence of other species, and the eradication design may not have accounted for the presence of mice. Several operations that used bait stations used a spacing design appropriate for rats but not for the small home range sizes of mice.

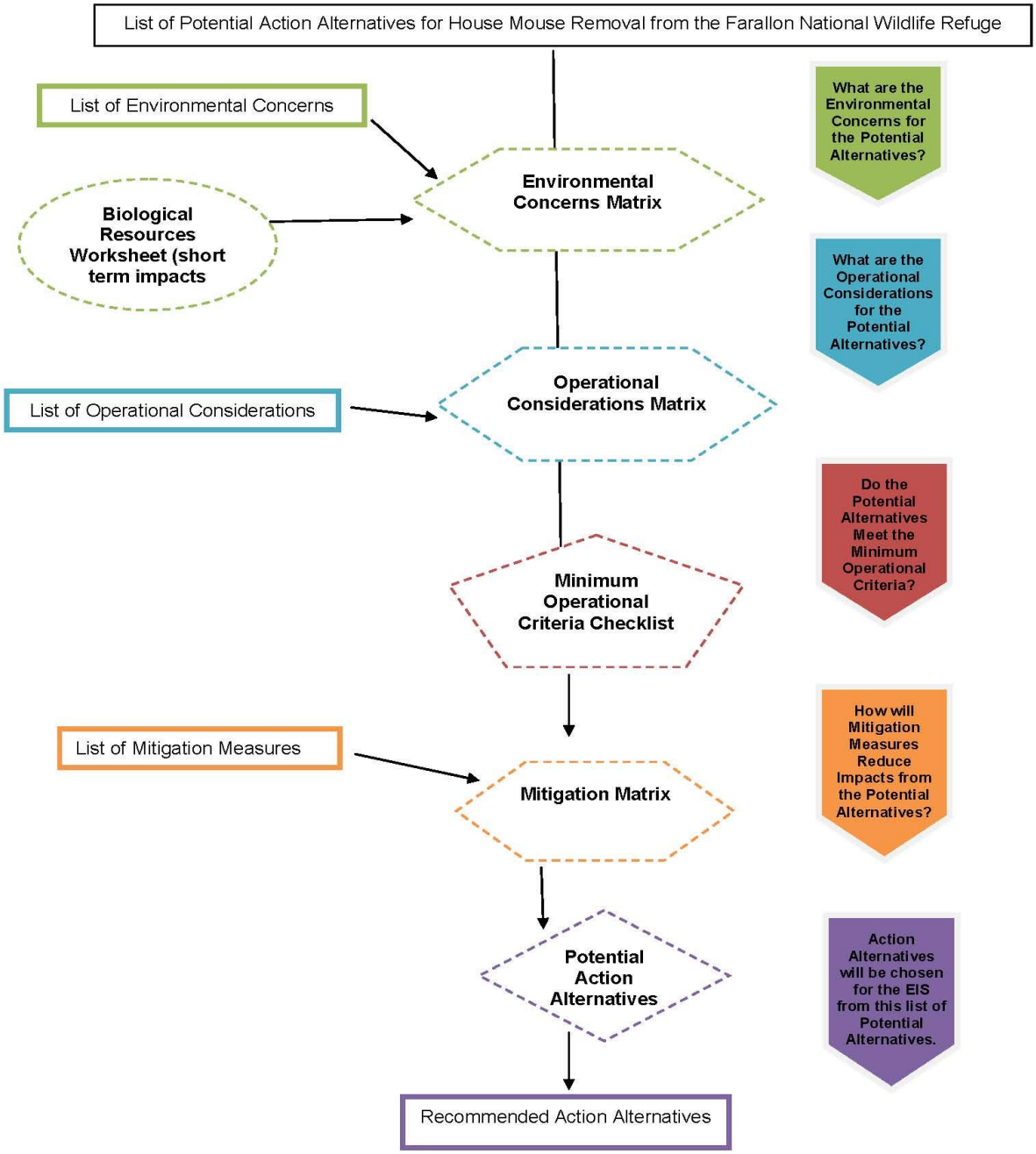
When mice are the only target species on the island, the eradication success rate is now over 90%. Table 5.1 summarizes the results of the attempted mouse eradications and corresponding success rates.

Table 5.1. Summary of house mouse (*Mus musculus*) eradication attempts with documented results and methods *(Keitt et al. 2011, Mackay et al. 2011).*

Toxicant used		**Eradication attempts**	**Successful**	**Failed**
1st Generation anticoagulant rodenticides	Diphacinone	1*	0	1
	Pindone	1	0	1
	Warfarin	1	1	0
2nd Generation anticoagulant rodenticides	Brodifacoum	50	35	15
	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

*At Buck Island in .U. Virgin Islands a successful rat eradication failed to eradicate house mice, although it is unclear if mice were eradication targets or not (Witmer 2007).

- **Product 6 – Conceptual Model of the Alternatives Selection Process**



Appendix B: Contributors

US Fish and Wildlife Service

- Gerry McChesney, Manager, Farallon National Wildlife Refuge: Gerry has a B.A. in Biology (focus, Marine Sciences) from the University of California, Santa Cruz and an M.S. in Biological Sciences (Conservation Biology) from Sacramento State University. He began his career as a seabird biologist in 1986 as an intern for Point Reyes Bird Observatory on Southeast Farallon Island. Gerry returned to Southeast Farallon in summer 1987 to conduct a study on population status and diet of ashy and Leach's storm-petrels. He completed his M.S. thesis work examining the breeding ecology of Brandt's Cormorants (*Phalacrocorax penicillatus*) on San Nicolas Island, California. Gerry now has over 25 years of experience studying seabirds in the California marine ecosystem. After working as a wildlife biologist at Humboldt State University for nearly 14 years, Gerry began managing a seabird restoration program at the Service's San Francisco Bay National Wildlife Refuge Complex in 2002 and since 2008 has also been the manager of the Farallon National Wildlife Refuge.

- Carolyn Marn, Fish and Wildlife Biologist: Carolyn has a Ph.D. in Wildlife Science from Oregon State University and an M.S. in Wildlife Management from Auburn University. She has over 20 years of experience with the U.S. Geological Survey and the U.S. Fish & Wildlife Service addressing the effects of environmental contaminants on wildlife. She has been working as a senior staff biologist with the Service's Natural Resource Damage Assessment and Restoration Branch in Sacramento since 2005.

PRBO Conservation Science

- Russ Bradley, Farallon Program Manager: Russ earned a B.S. in Biological Sciences and an M.S. in Wildlife Ecology from Simon Fraser University in British Columbia, Canada. He brings almost 15 years of conservation research experience from work in British Columbia, California, Hawaii, Nova Scotia, and the Pacific. Russ completed his Masters work on the breeding ecology of Marbled Murrelets, a threatened seabird breeding in old growth forests, on one of the largest conservation projects in Canada. Since 2002, he has worked on the Farallon Islands as a biologist for PRBO Conservation Science, and has managed their Farallon research program since 2005. He has spent over 1400 nights on the Farallon Islands and has extensive expertise and unique knowledge of their islands and their wildlife populations through scientific research and monitoring. Russ has authored over 20 scientific publications, and presented research findings at dozens of scientific conferences, management councils, and public meetings.

Island Conservation

- Gabrielle Feldman, Environmental Compliance Specialist: Gabrielle earned a BS in Zoology and an MS in Environmental Science and Regional Planning from Washington State University. She earned a Ph.D. in Natural Resources with an emphasis in Environmental Policy Analysis and Decision Science from the University of Idaho. Gabrielle has worked on a myriad of environmental planning projects in the United States and on the Black Sea with a focus on biodiversity conservation and sustainable development. Gabrielle brings over fifteen years of experience analyzing and writing state, national, and international environmental impact analyses, developing decision making tools for land managers, and building consensus between stakeholders. Gabrielle currently serves as the Environmental Compliance Specialist at Island Conservation. Under her guidance, Gabrielle has lead the compliance processes for the Palmyra

Atoll rat eradication, the Desecheo Island rat eradication, and is currently leading the compliance process for the Farallon Islands mouse eradication. In addition, Gabrielle has developed several decision tools (including the Alternatives Selection Model) designed to provide a framework for decision making that is comprehensive, transparent, and impartial.

- Dan Grout, Project Manager: Dan earned a B.S. with Honors in Wildlife Ecology from the University of Wisconsin-Madison. He has 30 years of endangered species conservation experience with a wide range of international, federal, state, university and private institutions throughout California, Hawaii, Mexico, Micronesia and the Pacific. Dan has worked as a Senior Wildlife Ecologist for California State Parks, the U.S. Fish & Wildlife Service, as a private consultant and as adjunct faculty with CSU-Monterey Bay and CalPoly University. Dan served as USFWS liaison to the Department of Defense and the CNMI in the Western Pacific and has coordinated with many international agencies and nonprofit organizations from many different countries overseas. His field research expertise focuses largely on endangered birds and small mammals, but he has over 25 years of experience conducting environmental impact assessments on a wide variety of wildlife species. Dan has written peer-reviewed articles and has presented his research on ecosystem restoration at dozens of scientific conferences and conservation community gatherings. His expertise is in designing and implementing endangered species research, recovery and management programs for endangered bird and mammals species, including invasive species control and removal operations on islands. He has been assisting the USFWS and PRBO in the planning efforts for the Farallon Island Restoration Project since August 2010, and his professional goal is to facilitate practical collaborative conservation and recovery actions for imperiled species based on sound science.

- Brad Keitt, Director of Conservation: Brad received an MS in Marine Sciences from the University of California, Santa Cruz and is a Switzer Foundation Conservation Fellow. His thesis work focused on the conservation and ecology of the Baja California endemic Black-vented Shearwater. He has conducted research on all of the Baja Pacific Islands, as well as islands in Alaska, Hawaii, California, Oregon, the tropical Pacific, and the Caribbean. Brad has published over 40 scientific articles on seabirds and the conservation of islands and has extensive involvement around policy issues related to the protection of island biodiversity and island ecosystems in the US and Mexico. Brad helped to create the Guadalupe Island Biosphere Reserve, leading to the protection of nearly a half million hectares of marine environment and the 26,000 hectares of terrestrial habitat on Guadalupe Island. Brad helped secure almost $4million US to implement much needed management actions on the “Islas del Pacifico” of Baja California, and he also petitioned to declare these islands an official protected area – an action that will protect 11 islands and almost 180,000 hectares of the surrounding marine environment. Brad currently serves as the Director of Conservation at Island Conservation where he oversees the implementation of island restoration projects. In his more than15 years with Island Conservation Brad has participated in the planning and implementation of over 70 eradications of invasive vertebrates from islands.

- Richard Griffiths, Project Director: Richard Griffiths gained his MS in Ecology at Lincoln University in 1996. Between 1998 and 2011, he worked for the New Zealand Department of

Conservation where he led species recovery and island restoration programs. Richard also served as a member of the Department's Island Eradication Advisory Group over a five year period. Some of his successes include the successful eradication of mice from Mokoia Island in 2000, Pacific rats from Little Barrier Island, the world's largest Pacific rat eradication, in 2004 and the removal of eight invasive mammals in one operation from Rangitoto and Motutapu in the Hauraki Gulf in 2009. With stoats, cats, hedgehogs, rabbits, mice and three species of rats spread across an area of 3854 ha, the latter project was the most challenging and complex island pest eradication the Department of Conservation had ever attempted and as a consequence the Department received the 2010 Parks Forum Environmental Award. Richard has a strong interest in the conservation of threatened species and led the stitchbird (*Notiomystis cincta*) recovery program between 2000 and 2007. During this period additional populations of the species were established including on the mainland after an absence of over 120 years. Richard now works for Island Conservation based in Santa Cruz, California where he manages a team of project managers and island restoration specialists whose focus is preventing extinctions on islands through the removal of invasive vertebrates. Two recent accomplishments by his team include working with USFWS to successfully implement the removal of rats from Palmyra and Desecheo National Wildlife Refuges.

- Gregg Howald, North American Regional Director: Gregg received an MS from the University of British Columbia's Department of Animal Science. He is one of the world's foremost experts in island restoration – he has participated in the restoration of 20 islands from the sub-Arctic to the deep tropics. Gregg has consulted on rodent removal and research programs in Hawai`i, Micronesia, Alaska, British Columbia, the California Channel Islands, and Mexico. Gregg works closely with multiple government agencies across North America in his capacity as the North America Regional Director. Gregg's technical expertise in ecotoxicology has been applied in multiple projects in which the use of rodenticides have been used for rodent eradication - both during the development of bait products and shepherding specific rodenticides through rigorous field trials for the regulatory process. He has applied his technical expertise in environmental compliance and project management. He published peer-reviewed articles, and has given over 50 presentations to the scientific and conservation communities regarding rodent eradications on islands. Gregg's wide range of skills, excellent diplomatic sense, and tri-national contact network make him a heavily-utilized resource in nearly all of IC's projects worldwide.

8.3 Appendix D – Bait Degredation Trial Report

Farallon Islands Restoration Project

Evaluating the duration of potential risk exposure to susceptible non-target species following the application of rodent bait.

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Executive Summary

Introduced mice pose a threat to the Ashy Storm-petrel and other native and endemic species of the Farallons National Wildlife Refuge. To provide for species and ecosystem recovery, the removal of mice from the Farallons has been proposed. Methods being considered for removing mice include the aerial application of one of two EPA-registered grain-based rodent baits; Diphacinone-50 Conservation or Brodifacoum-25D Conservation. These anticoagulant based products have been used successfully in past rodent eradications.

The fall has been proposed as the best timing for a mouse eradication attempt because most resident seabirds are absent from the islands at this time. However, risk of exposure to rodenticide exists for some non-target wildlife such as Western gulls. Individual western gulls would be at risk of consuming rodent bait until it has either been consumed or degraded to an unpalatable state. To better quantify this risk, develop mitigation measures for gulls and other non-target species, and inform the NEPA process, two trials were undertaken, the first beginning in 2011 and the second in 2012 to determine the length of time rodent bait would take to degrade and disappear on the South Farallon Islands.

In the first trial both Diphacinone-50 Conservation and Brodifacoum-25D Conservation bait degraded to a condition not considered available and palatable to Western gulls over a period of 101 days. However, trial results were confounded by a record-setting drought. A second trial was undertaken beginning in 2012 under wetter conditions. Degradation of Brodifacoum-25D Conservation in the second trial was rapid and bait degraded to an unpalatable state within seven days. For unknown reasons, Diphacinone-50 Conservation persisted in a palatable condition despite the higher rainfall until the conclusion of the second trial. Reasons for the difference between years for this bait type 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 testify to the impact of rainfall on the rate of bait degradation and data from our trial supported the inference 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 similar to the average over the last 30 years, it is anticipated that Brodifacoum-25D Conservation bait would remain available and palatable to Western gulls for a period of up to five weeks. Diphacinone-50 Conservation may pose a risk to non-target wildlife for a longer period, 15 weeks or longer.

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1. Introduction

Introduced House mice (*Mus musculus*) are impacting the IUCN-Endangered Ashy Storm-petrel (*Oceanodroma homochroa*) and other native and endemic species of the Farallon National Wildlife Refuge. To eliminate these impacts and allow species and ecosystem recovery, the USFWS is assessing the potential for removing mice from the Refuge. To inform the NEPA process, the planning for a possible eradication attempt and the development of potential mitigation measures to protect non-target wildlife from harm, a number of trials have been completed.

This report documents the findings of two trials that aimed to determine the length of time rodent bait might remain available and palatable to susceptible non-target species specifically Western gulls (*Larus occidentalis*) if consumption by the target species, in this case mice, was precluded. Although a wider suite of methods is under consideration, the trial focused on the use of rodent bait as the application of rodent baits containing rodenticides is the only method that has been used successfully to remove mice from islands (Keitt et al. 2011, Mackay et al. 2011). Non-toxic formulations of Diphacinone-50 Conservation and Brodifacoum-25D Conservation, two rodent bait types registered with the EPA for use in the U.S. to remove invasive rodents from island ecosystems, were used in the trial. Both bait types have been used successfully in past rodent eradications (Howald et al. 2007).

The use of rodent bait containing a rodenticide on the Farallones presents a temporary risk to susceptible non-target wildlife. Western gulls were identified as being particularly vulnerable to the use of rodent bait containing rodenticides because they are omnivorous scavengers and individuals of this species will be present during the time of year that a mouse eradication might be undertaken. The duration of potential exposure will depend on how quickly rodent bait is consumed by mice and invertebrates[1], but also the length of time that bait takes to degrade. Bait degradation for the purposes of our trials was only considered within the context of the risk posed to Western gulls and other bird species. The availability and palatability of rodent bait to mice was not considered within the scope of the trial.

Rates of bait disappearance were evaluated in 2010 with high rates of bait take recorded but degradation of remaining bait was not assessed (Appendix C). To determine the length of time that rodent bait, not consumed by mice, might persist on the South Farallon Islands, the breakdown of non-toxic Diphacinone-50 Conservation and Brodifacoum-25D Conservation rodent bait was monitored over the autumn and winter period beginning in 2011 and 2012. This report documents the methods used and the results of this monitoring. Differences between the two bait types and variability in bait degradation between sites, substrates and years are discussed. The influence of rainfall on bait degradation is evaluated and predictions made based on varying rainfall scenarios of the length of time that bait may remain palatable and available to non-target species.

[1] Because of their different physiology, most invertebrates are not susceptible to anticoagulants such as diphacinone and brodifacoum (Ogilvie et al. 1997).

2. Trial Objective

Assess the rate of degradation of rodent bait products currently registered for rodent eradication on the South Farallon Islands.

3. Methods

To determine the rate at which rodent bait would degrade after its application, non-toxic samples of two rodent baits (Table 1) were placed on Southeast Farallon Island (SEFI) and its fate monitored over subsequent months. Monitoring was undertaken from November because this is the time that a mouse eradication operation involving an application of rodent bait is most likely to occur. The first trial began on November 10, 2011 and extended to March 16, 2012 and the second trial began and ended on November 27, 2012 and March 12, 2013 respectively. Both rodent baits are registered with the EPA for rodent eradications on U.S. islands. Conservation 25D was developed by Bell Laboratories for dry temperate climatic conditions similar to the Farallones. Ramik® Green, produced by HACCO undergoes a hot extrusion process during manufacturing that makes it weather resistant without the use of wax.

Table 1 Rodent Baits Tested on Southeast Farallon Island

Bait Name	Pellet Weight	Condition	Manufacturer
Brodifacoum-25D Conservation	1g	Dry	Bell Laboratories
Diphacinone-50 Conservation	1g	Dry	Hacco®

Specially constructed exclusion cages (Figs. 1 & 2) were used to prevent bait take by birds or mice. Cages were uniquely labeled, their location and elevation recorded and the layout of baits and bait types within the cage documented for monitoring. Cages were anchored with a buried rock and wire or in the case of rock substrate, with masonry nails, to prevent disturbance by gulls and mice. Exact placement of the cages was coordinated with PRBO staff on island prior to their being secured and cages were placed on or near existing paths to minimize impacts to island resources, and to avoid impacts to other study plots.

Bait degradation rates can be affected by a range of factors (Craddock 2003), so cages were established at six different sites on the island representing a range of microclimates. Three bait cages were deployed at each site, one in each of the three significant substrate types found on the island; rock, bare soil, and vegetation. Soil substrate was not sampled in the second trial. Bait cages at each site were placed within 20 meters of each other.

Between four and eight pellets of each bait type were placed into each cage. The number of bait pellets remaining and the condition of each was then assessed weekly and degradation scored as per the scale developed by Craddock (2003) (Appendix 1). A photograph was taken during weekly inspections for later reference. If a pellet was obscured, the top of the cage was unscrewed to discern whether the pellet had

truly disintegrated or was simply hidden by vegetation growing inside the cage. Rainfall data were collected three times daily by Point Reyes Bird Observatory (PRBO) staff as part of a program for the National Weather Service.

Fig. 1 Photo of bait degradation cage with pellets. Wire mesh bottom on this cage not visible in picture.

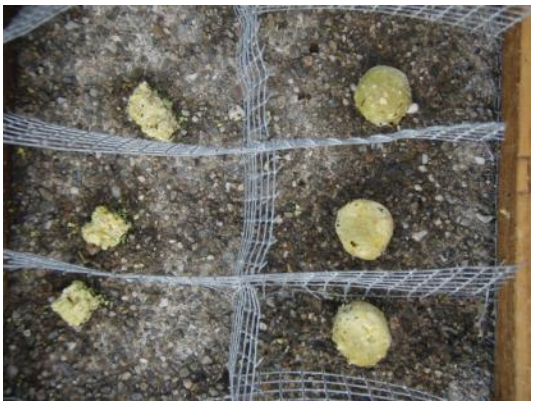

Fig. 2. Close up of the two bait types during the trial (Brodifacoum-25D Conservation on left and Diphacinone-50 Conservation on right)

To evaluate the relative availability and palatability of rodent bait over time and establish the duration of potential exposure to non-target species such as Western gulls, bait degradation scores determined after Craddock (2003) were converted to a degradation index (Table 2). A degradation index of 1 indicates that bait is intact and identical to fresh bait whereas a degradation index of 0 indicates that the bait has completely disintegrated or disappeared. An assumption made in analyzing the data set was that bait was no longer palatable or attractive to non-target species of concern on SFI when it reached a condition degradation index of 0.4. Availability and palatability of rodent bait to mice was not considered. Bait with a condition score of 0.4 is described by Craddock (2003) as a soft or moist pile of mush, 50% or more of which may be covered in mold. Bait in this condition, is considered to be less visible and not attractive to gulls and other bird species. It also cannot be readily manipulated or removed in one piece.

Table 2. Degradation indices used as a measure of bait availability and palatability to non-target species.

Bait degradation score after Craddock **(2003b)**	Degradation index used for analysis
1	1.0
2	0.8
3	0.6
4	0.4
5	0.2
6	0

To determine the effect of year, bait type and substrate on mean weekly bait degradation rate, and extent of bait degraded by week 15, we used a linear mixed model with Restricted Maximum Likelihood estimation, with sites specified as random effects. We included interactive effects of bait type x year, and bait type x substrate, but not year x substrate because one substrate type (soil) was only tested for one year. Bait degradation rate was expressed as an average for the site over one season. Models created within JMP v. 10.0, alpha was tested at 0.05 and diagnostics were checked using standard plots (Quinn and Keough 2002).

The influence of rainfall on bait degradation was explored by linear regression on the extent of weekly bait breakdown and total weekly rainfall. Degradation rates and rainfall data collected from SEFI were compared with data collected from Palmyra Atoll, Wake Atoll and Anacapa. Data from SEFI and Anacapa were then used to predict the length of time over which bait might remain available and palatable to non-target species on the South Farallon Islands under three

different rainfall scenarios. No index was available for invertebrate activity and only anecdotal data is reported.

4. Results and Discussion

Bait degradation cages were checked for 18 weeks in the first trial and for 15 weeks in the second. One cage in the second trial was crushed by an elephant seal at 12 weeks precluding further monitoring of this cage. All cages successfully excluded mice and gulls and may have reduced access by invertebrates. Weekly rainfall differed between the two trials, with almost twice as much rain falling by the 15th week in the second trial compared to the first (Fig. 3).

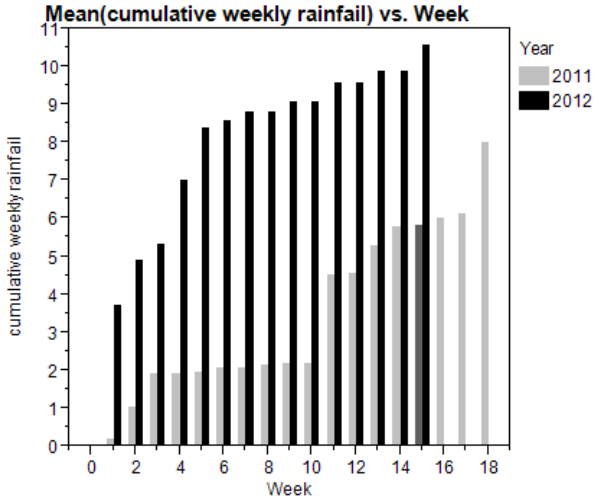

Fig. 3 Cumulative rainfall on SEFI during the two trials

During the unusually dry fall of 2011, 90% of Brodifacoum-25D Conservation baits degraded to a state considered unpalatable to gulls and other wildlife over a period of 17 weeks (Fig. 3). However, Brodifacoum-25D Conservation pellets degraded to a similar state within just three weeks in the second trial under what are considered to be normal rainfall conditions based on the last 30 years of rainfall data

(PRBO unpublished data). Ninety percent of Diphacinone-50 Conservation bait degraded to an unpalatable and unavailable state by 15 weeks in the first trial (Fig. 4). In contrast, more than 90% of Diphacinone-50 Conservation bait was still considered to be available at the conclusion of the second trial.

Rates of bait degradation during the first trial (Fig. 4) were considerably slower than anticipated and this is attributed to the unprecedented period of dry weather that ensued over the course of the trial. Monitoring in the first trial was undertaken during the driest December on record for the Farallones and for the Central California coast in general (Appendix 2). Degradation rates observed for Brodifacoum-25D Conservation during the second trial when more rainfall was experienced, were much closer to those expected and reinforce previous observations that degradation rates for cereal based rodent pellets are strongly influenced by rainfall (e.g. Merton 1987a, Howald et al. 2001).

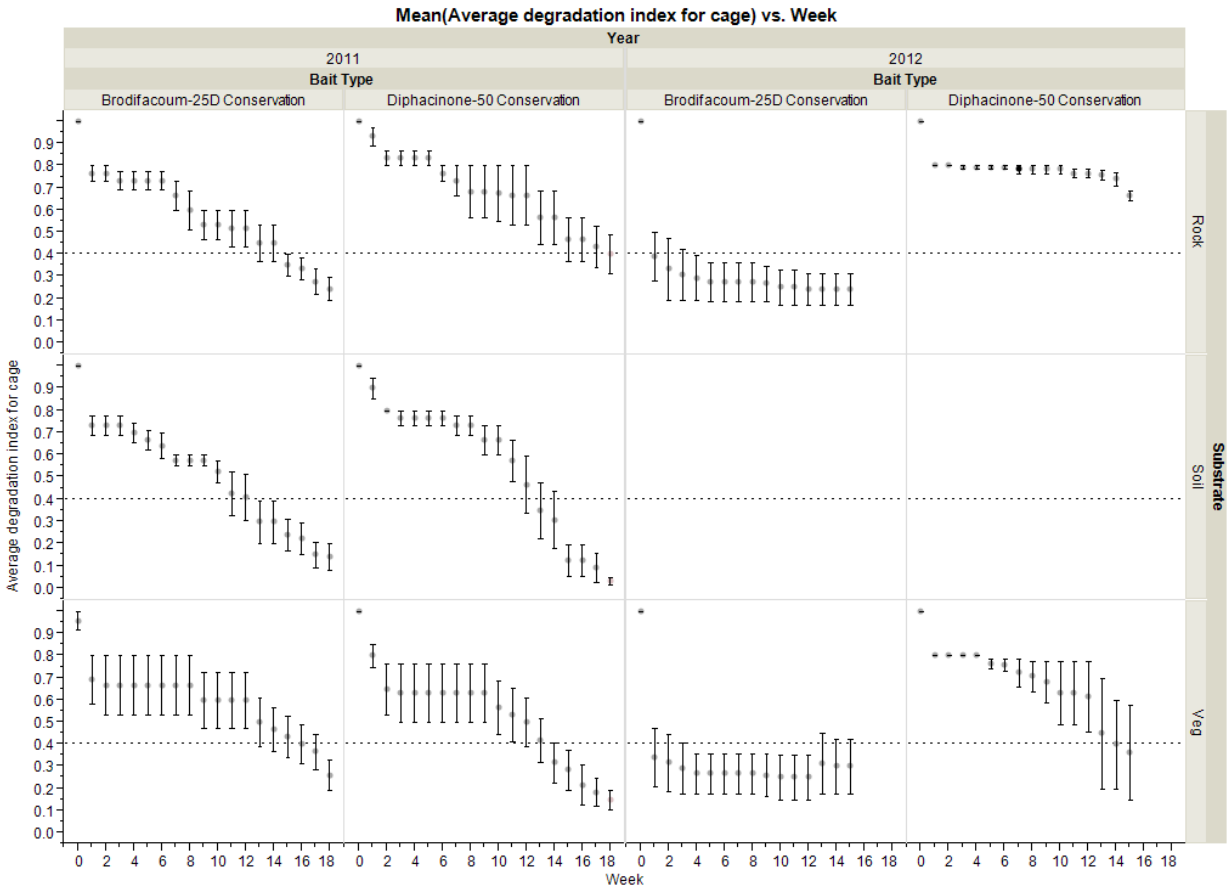

Fig. 4. Relative availability and palatability of non-toxic Brodifacoum-25D Conservation and Diphacinone-50 Conservation rodent bait protected from consumption by vertebrate consumers observed over time on rock, vegetation and soil substrates during two trials undertaken beginning in the fall of 2011 and 2012 on SEFI. Vertical bars represent standard error. Bait that has degraded to a relative bait availability and palatability index of below 0.4 is considered to no longer pose a risk to non-target species such as Western gulls for the reasons outlined above.

A significant difference in mean bait degradation rate was found between substrate type, and interactive effects of bait x substrate, and bait x year (Table 1). Adjusted R^2 for the model testing mean weekly bait degradation rate was 0.57, and 0.67 for extent of bait degraded by week 15, suggesting these variables explained 57% and 67% of the variation observed respectively. Of the three substrate types, baits broke down significantly faster on bare soil and in vegetation than they did on bare rock. It is thought that bait persisted longer on bare rock because it was able to dry out between periods of rainfall or dense fog. In contrast, bait degradation varied little between sites (Table 3).

Table 3: Fixed effects tests of year, bait and substrate on mean weekly bait degradation rate, and extent of bait degraded by week 15. Stars indicate statistical significance.

Parameter	Mean weekly bait degradation rate	Extent of degradation by week 15
year	F1,36.4=0.38, *p*=0.537	F1,38.0=0.26, *p*=0.613
bait	F1,32.5=0.46, *p*=0.504	F1,32.4=2.09, *p*=0.157
substrate	F2,32.5=8.98, *p*<0.001*	F2,32.5=11.38, *p*<0.001*
bait x substrate	F2,32.5=3.84, *p*=0.032*	F2,32.4=6.64, *p*=0.004*
year x bait	F2,32.5=16.74, *p*<0.001*	F2,32.4=8.11, *p*=0.008*

Linear regression found a loose but meaningful correlation between total weekly rainfall and the weekly extent of bait degradation for both Brodifacoum-25D Conservation ($R^2 = 0.4$, $F = 17.37$, $df = 26$) and Diphacinone-50 Conservation ($R^2 = 0.23$, $F = 7.68$, $df = 26$). Because repeated samples were taken, data on bait degradation rates were correlated over time violating the assumption of independent data points required for regression. However, based on our observations and similar conclusions about the influence of rainfall on bait degradation by other authors (e.g. Merton 1987a, Howald et al. 2001) we consider it reasonable to make an estimate of the length of time rodent bait might persist on the South Farallones Islands based on the degradation rates we observed.

It must also be noted that the sinusoidal pattern of bait degradation we observed for both bait types (Fig. 4) suggests that factors other than rainfall are also important in influencing the rate at which bait degrades. Bait formulation may possibly explain why the rate of degradation initially proceeds rapidly but then slows down and the presence and abundance of mold may also play a role. Pellets of both bait types remaining at the end of the first trial and pellets of Brodifacoum-25D Conservation at the conclusion of the second trial were all heavily molded, black in color and virtually impossible to see against a dark background.

Factors other than rainfall may have contributed to the higher bait degradation rate observed for Diphacinone-50 Conservation in the first trial including increased consumption by invertebrates. In the first trial, Diphacinone-50 Conservation pellets appeared to be exposed to a higher level of invertebrate consumption; slugs were detected in at least two cages and most bait pellets in these cages had disappeared within four weeks. However, as no indices of invertebrate activity were recorded, no definitive conclusions can be made. Diphacinone-50 Conservation baits were also observed to grow mold more quickly than Brodifacoum-25D Conservation.

Tables 4 and 5 below provide a comparison of the rate of breakdown observed during this trial for Brodifacoum-25D Conservation and Diphacinone-50 Conservation and the degradation rates for these bait types observed during trials conducted on Anacapa, Palmyra, Wake and Desecheo islands. As can be seen, rates of bait breakdown vary widely between islands. Because of the dissimilarities in climate between the tropical and temperate islands, it is considered that predictions of bait persistence on the South Farallon Islands should be extrapolated from SEFI trial data and information from Anacapa. Anacapa has a similar climate to the Farallones.

Table 4 Degradation of Brodifacoum-25D Conservation and rainfall amounts for five different sites.

Location	Monitoring period (days)	Average time to reach bait degradation index 0.4 (days)	Total rainfall to reach bait degradation index 0.4 (inches)	Rate of bait breakdown with rainfall (extent of breakdown/inch)
SEFI 2011	126	101	5.88	0.10
SEFI 2012	105	7	3.73	0.16
Anacapa	133	77[2]	4.51[3]	0.13
Wake	23	20[4]	2.36[5]	0.25

[2] Estimated based on qualitative information provided in Howald *et al.* (2001)

[3] Estimated based on average monthly rainfall data for Anacapa provided by the Western Regional Climate Center.

[4] Estimated based on qualitative information provided in Mosher *et al*. (2007)

[5] Estimated based on average monthly rainfall data for Wake provided by the Western Regional Climate Center.

Palmyra	5	3	4.94	0.12
Desecheo	21	7	1.24	0.48

Table 5 Degradation of Diphacinone-50 Conservation and rainfall amounts for three different sites.

Location	Monitoring period (days)	Average time to reach bait degradation index 0.4 (days)	Total rainfall to reach bait degradation index 0.4 (inches)	Rate of bait breakdown with rainfall (extent of breakdown/inch)
SEFI 2011	126	98	5.78	0.10
SEFI 2012	105	Trial ended before bait reached necessary degradation index	N/A	N/A
Wake	23	20[4]	2.36[5]	0.25
Palmyra	5	5	7.30	0.08

Although information is limited, we believe that the approximate length of time that Brodifacoum-25D Conservation bait would remain available and palatable to non-target species on the South Farallon Islands can be estimated for different rainfall scenarios by extrapolating from the rate at which bait degraded with rainfall during this trial and on Anacapa (Tables 4 & 5). Assuming a normal fall rainfall pattern on the South Farallon Islands, it is anticipated that Brodifacoum-25D Conservation would pose a risk to non-target species such as Western gulls for up to five weeks (Fig. 5). This period could be reduced if rainfall is higher than normal (Fig. 5) or, as was observed in the second trial, a significant rainfall event (>2 inches) occurs. Because of the disparity in results between years for Diphacinone-50 Conservation, predictions for this bait type is more difficult. Based on the results observed and the range of conditions experienced we conclude that this bait type could pose a hazard to susceptible non-target wildlife for a period of 15 weeks or longer.

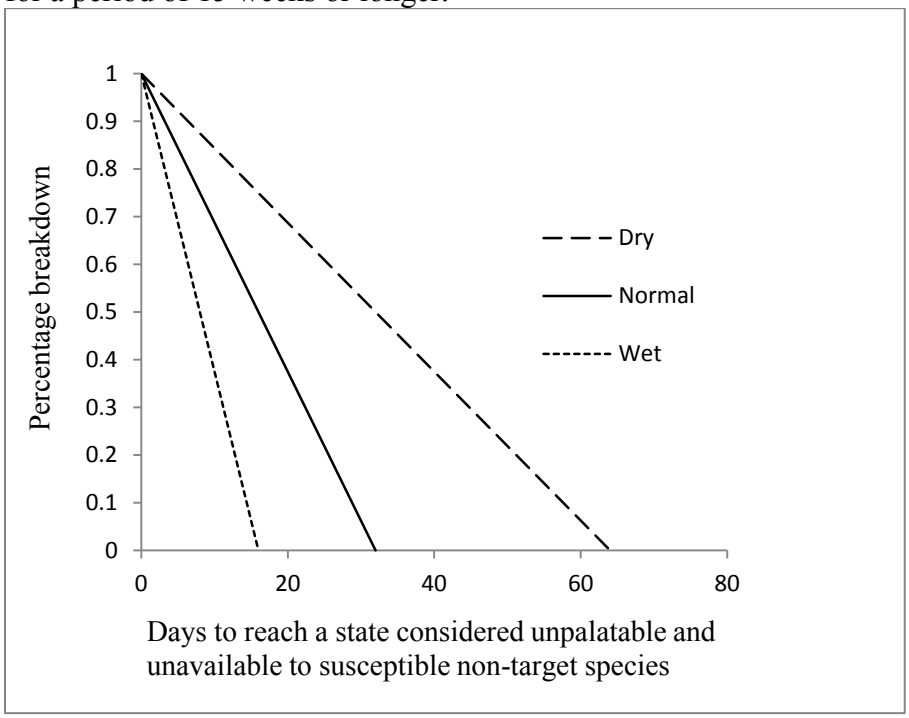

Fig. 5. Hypothetical bait degradation rates for Brodifacoum-25D Conservation under three projected rain scenarios for the South Farallon Islands as determined from data collected on SEFI and Anacapa. Rainfall for a wet year was estimated as twice the amount seen in a normal year and half the normal rainfall was used for a dry year.

There are several factors that we did not incorporate into our predictions of bait longevity but are likely to shorten the duration of bait availability and palatability. Growth of vegetation on the island after bait was applied during a recent gull hazing trial rendered most pellets invisible to the human eye even at close range. Consequently, bait in vegetated areas is likely to be obscured from non-target species such as Western gulls as a result of this growth. Bait availability could also be manually reduced by picking up

bait after the mouse eradication is deemed complete. Removing bait from rocky substrates where it is likely to persist the longest could reduce the time and effort required to mitigate non-target risks. Bait degradation cages are also considered to have inhibited bait uptake by invertebrates and it is likely that bait degradation rates would be higher if bait is unprotected.

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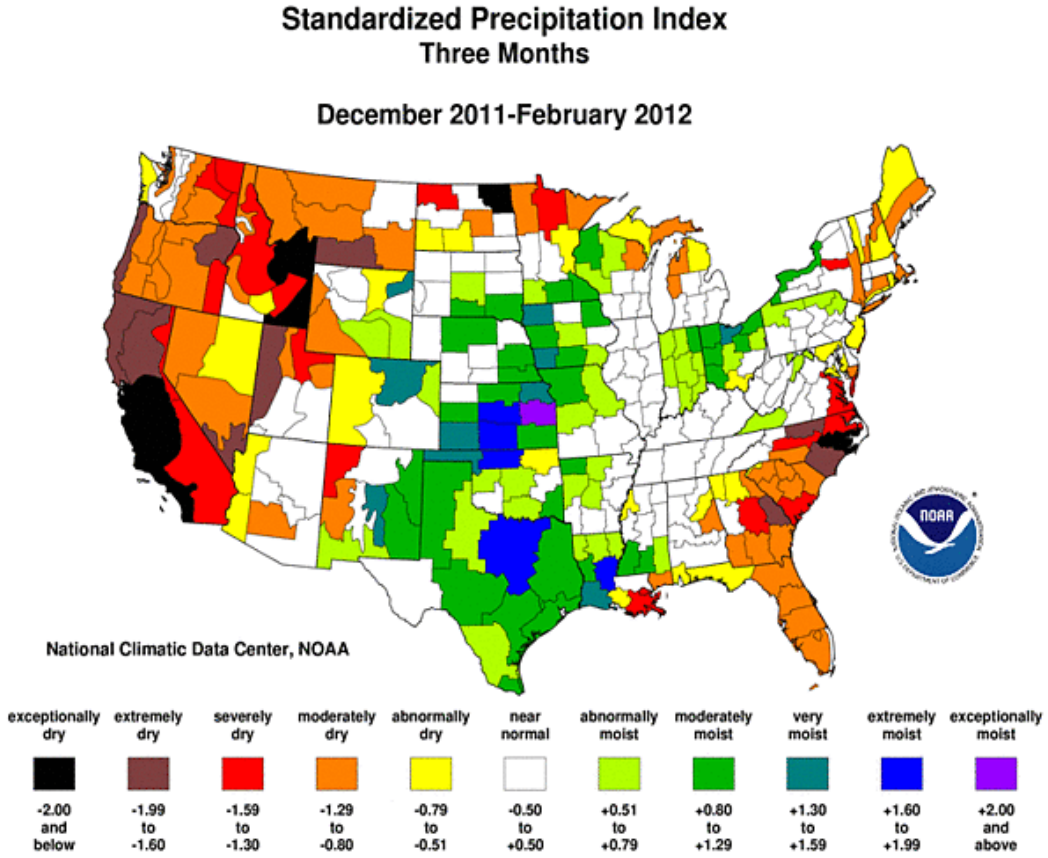
Appendix 1. Bait degradation scale used (Craddock 2004).

	Pellet matrix	Change in shape	Presence of mold	Loss of volume
Condition 1 ***Fresh pellets***	Identical to fresh bait	Identical to fresh bait	None	None
Condition 2 ***Soft pellets***	<50% pellet matrix is or has been soft/moist	Distinct cylinder still; smooth sides may have been lost	<50% bait pellets mold	Little or no volume lost
Condition 3 ***Mush pellets***	>50% bait matrix is or has been soft/moist	<50% pellet has lost distinct cylinder shape	>50% bait pellets have mold	Bait has lost some volume (<50%)
Condition 4 ***Pile of mush***	100% of bait matrix is or has been soft	Pellets lost distinct cylinder shape & resembles a pile of mush with some grain particles in matrix showing distinct separation from main pile	>50% bait pellets have mold	Bait has lost some volume (<50%)
Condition 5 ***Disintegrating Pile of mush***	100% of bait matrix is or has been soft	Pellet has completely lost distinct cylindrical shape and resembles a pile of mush with >50% of the grain particles in the bait matrix showing distinct separation from each other and the main pile	>50% bait pellets have mold	Bait has lost a significant amount of volume (>50%)
Condition 6 ***Bait gone***	Bait is gone or is recognizable as only a few separated particles of grain or powder.	Bait is gone or is recognizable as only a few separated particles of grain or powder.	Bait is gone or is recognizable as only a few separated particles of grain or powder.	Bait is gone or is recognizable as only a few separated particles of grain or powder.

Appendix 2 Map showing drought conditions extending over California during the 2011 trial.



8.4 Appendix E – 2012 Western Gull Hazing Trial Report

ISLAND CONSERVATION

Preventing Extinctions

Farallon Islands Restoration Project

Hazing Western Gulls on the South Farallon Islands

Prepared by

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April 12, 2013

EXECUTIVE SUMMARY

Introduced mice pose a threat to the Ashy Storm-petrel and other native and endemic species of the Farallons National Wildlife Refuge. To allow species and ecosystem recovery, the removal of mice from the Farallones has been proposed. Methods being considered for removing mice include the aerial application of rodent bait containing a rodenticide. The late fall has been proposed as the best time of year for conducting a mouse eradication because most resident seabirds are absent from the islands at this time. However, risk of exposure to rodenticide exists for some non-target wildlife such as Western Gulls.

Hazing of gulls has been recommended as a means of isolating gulls from rodent bait and mitigating potential risk of exposure. To evaluate the potential for hazing gulls from the South Farallon Islands a gull hazing trial was undertaken in November and December 2012. The hazing trial successfully demonstrated the ability to keep the majority of Western Gulls off the South Farallon Islands for a period of 12 days. The trial also successfully prevented gulls from accessing areas where rodent bait was available. Results from the trial provide a high degree of confidence that a well planned and executed hazing operation could reduce gull mortality to minimal levels during a mouse eradication.

The hazing trial caused minimal disturbance to non-target species. Some bird species were affected including Brandt's Cormorant, Common Murre, Brown Pelican, Black Oystercatcher and a handful of overwintering shorebirds but the impacts observed to these species were short lived. 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.

ACKNOWLEDGEMENTS

The Farallon Avian Hazing Trial was designed and conducted by the Farallon Restoration Project Partners (U.S. Fish and Wildlife Service, PRBO Conservation Science and Island Conservation) with the assistance of expert professional avian hazing staff from USDA-APHIS Wildlife Services, CDFG-OSPR, and the Oiled Wildlife Care Network Wildlife Health Center at UC-Davis.

The hazing trial was made possible due to support from the Luckenbach Trustee Council oil spill settlement funds, the National Fish and Wildlife Foundation Coastal California Restoration Settlement Funds Grant #8001.04.034554, and the California Department of Fish and Game's Oil Spill Response Trust Fund through the Oiled Wildlife Care Network (OWCN) at the Wildlife Health Center, School of Veterinary Medicine, University of California, Davis. Special thanks also go to Todd Weitzman of Bird Gard, LLC for the loan of seven BirdGard biosonic units for the duration of the trial.

Many agencies and individuals were involved in developing the trial plan. We are grateful for the support we received from Jonathan Shore (USFWS), Jim Tietz and Ryan Berger (PRBO), Paul Gorenzel (OWCN), Valerie Burton and Eric Covington (USDA-APHIS WS), and Tommy Hall (IC). We would also like to thank the volunteers who contributed to the trial effort including: John Warzybok, Sara Acosta, Holly Gellerman, Kyra Mills-Parker, Paul Steinberg, Liz Ames, and Lara White. Sansone Company and the U.S. Coast Guard provided invaluable support in transporting supplies and freight to the island.

All actions conducted during the trial complied with the specific permit and authorization requirements specified in the following Hazing Trial permits:

- **NOAA-NMFS: Section 7 Biological Opinion and Incidental Harassment Authorization (IHA)** (Addresses monitoring, avoidance and minimization of impacts to pinnipeds during the trial)
- **ATF:** Permit issued by the Bureau of Alcohol, Tobacco, and Firearms for the use and handling of explosive pest control devices (EPCD) issued on November 9, 2012.
- **USFWS**: Wilderness Determination to allow for access the Wilderness Areas of the Refuge.

Categorical Exemption issued by the USFWS Refuge Manager.

- **Gulf of the Farallones National Marine Sanctuary:** Permit allowing helicopter over flights.

INTRODUCTION

The South Farallon Islands of the Farallon National Wildlife Refuge lie 30 miles west of San Francisco, California, and harbor the largest island breeding seabird colony in the continental U.S (Ainley and Boekelheide 1990). The presence of invasive House mice (*Mus musculus*) is having a significant impact on the IUCN-Endangered Ashy Storm-petrel (*Oceanodroma homochroa*) and other native and endemic species of the Farallon Island ecosystem. The USFWS is proposing to remove all introduced mice as part of the Farallon Restoration Project (www.restorethefarallones.org). Proposed mouse removal methods include the aerial application of rodent bait containing a rodenticide.

The timing of an operation to eradicate mice would likely take place during the fall when most resident seabirds are not present on the Farallones. However, evidence from past eradication projects(e.g. Howald et al. 2005) and a trial completed in 2010 (Grout and Griffiths 2012b) indicate that Western Gulls (*Larus occidentalis*) would be at risk of rodenticide exposure. Western Gulls are distributed along the west coast of North America between British Columbia, Canada to Baja California, Mexico, are not considered threatened and are listed by the IUCN as Least Concern. Western Gulls are omnivorous and opportunistic feeders and individuals of this species are known to roost on the island in the fall and winter (non-breeding season).

Hazing, or dissuading gulls from remaining on the island, during the period that rodent bait remains available has been proposed as one potential method for minimizing the risk of rodenticide exposure to Western Gulls. Hazing gulls may also be necessary to ensure sufficient bait remains available to mice, a prerequisite to eradication success. Farallon Western Gulls do not breed until April (Ainley and Boekelheide 1990), so hazing gulls from the Refuge during late fall and winter when their populations are greatly reduced will likely have no significant impact on the population.

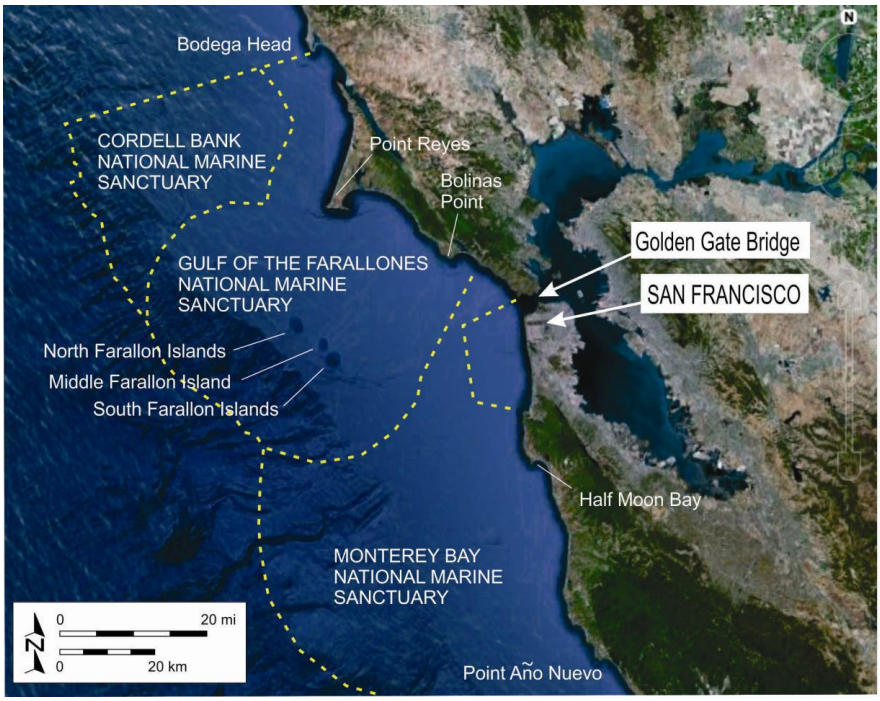
A number of hazing techniques were trialed during a pilot study in 2011 including those used successfully at airports, landfills and sensitive breeding areas on Refuges and other areas throughout California (Pott and Grout 2012). Based on recommendations from the 2011 trial, a second more comprehensive study was undertaken in 2012, during the time of year that a

proposed mouse removal operation might be conducted, deploying techniques shown to be effective along with several novel hazing methods on the South Farallon Islands (SFI). The 2012 trial aimed to evaluate the potential of hazing as a means of mitigating risk to Western Gulls and in accordance with the Marine Mammal Protection Act provide an assessment of the impact of hazing activities on the species of pinniped that haul out and breed on the South Farallon Islands: Northern elephant seal (*Mirounga angustirostris*), Harbor seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*), Northern fur seal (*Callorhinus ursinus*), and California sea lion (*Zalophus californianus*).

Although the relative effectiveness of hazing methods and the impact of each individual hazing technique on pinnipeds was assessed during the trial, results are only described qualitatively in this report. A quantitative analysis of the relative effectiveness and impact of individual hazing techniques is planned for subsequent reports.

The design and implementation of the avian hazing trial was conducted primarily by the Farallon Restoration Project Partners (U.S. Fish and Wildlife Service, PRBO Conservation Science and Island Conservation) with the assistance of expert professional avian hazing staff from USDA-APHIS Wildlife Services, CDFG-OSPR, and the Oiled Wildlife Care Network Wildlife Health Center at UC-Davis. This report documents the findings of the trial and discusses the ramifications of the study's results on the proposed mouse eradication attempt.

Fig. 1. Map showing the location of the South Farallon Islands, California.



OBJECTIVES

- Demonstrate the effectiveness of hazing methods to mitigate the risk of exposure by Western Gulls to rodent bait on the South Farallon Islands.
- Document the impacts of hazing activities on pinnipeds and other native species present on the South Farallon Islands.
- Determine the logistics and level of resourcing required to conduct an extended hazing program on the South Farallon islands prior to and during a mouse eradication.

METHODS

Trial timing and schedule

The trial took place between November 27 and December 15, 2012. This time period was selected to coincide with the likely timing of a mouse eradication operation involving an application of rodent bait, when overall marine bird numbers are at their lowest of the year and before the start of elephant seal breeding. This period also aimed to exploit a low-point in Western Gull presence prior to their return to the islands in increasing numbers. The trial was split into three distinct phases with each phase having its own specific objective (Table 1). Baseline numbers of gulls and pinnipeds were recorded prior to initiation of the hazing trial and post-trial monitoring of gulls and pinnipeds was undertaken to determine the rate at which gulls

resumed normal roosting patterns, and to document any lasting impact on pinnipeds. The impact of hazing activity and individual techniques on pinnipeds was assessed throughout the trial.

Phase 1 aimed to evaluate the relative efficacy of specific techniques for hazing gulls and determine the effective range of individual hazing tools. Results from Phase 1 were used to guide the deployment of hazing techniques during subsequent trial phases. However, results from Phase 1 have not yet been analyzed and are not presented within this report. Phase 2 aimed to evaluate the effectiveness of a gull hazing operation at reducing the number of gulls on the South Farallon Islands. Phase 2 simulated the likely hazing activity planned to take place prior to and during a mouse eradication. Hazing techniques and combinations of techniques were deployed as required during Phase 2 with the intention of reducing gull numbers to minimal levels. Hazing activities were continued in Phase 3 but only from SEFI and only by personnel on foot. Due to the greater limitations on access during this phase, gulls were allowed to roost on a few specific islets. Phase 3 aimed to demonstrate that even a scaled back hazing operation could prevent gulls from settling in those areas of the island where bait would be applied during an eradication effort.

Table 1. Trial Phases.

Phase	Scope	Scope	Duration	Dates
1	• Assessing the effectiveness of individual hazing methods on gulls on the South Farallon Islands	SEFI and small areas of WE	5 days	November 28 – December 2, 2012
2	• Assessing the effectiveness of a hazing operation to reduce gull numbers across the South Farallon Islands	Island-wide	9 Days	December 3 – 11, 2012
3	• Assessing the effectiveness of hazing from SEFI to reduce gull numbers across the South Farallon Islands	SEFI and most of WE	3 days	December 11-13, 2012

[1]Although the relative efficacy of hazing techniques was tested during the trial, analysis and interpretation of the results obtained from Phase 1 is not a subject of this report.

Gull hazing

A total of 19 different avian hazing techniques were deployed on the South Farallon Islands during the trial. A short description of each tool and how it was used in the trial is presented in Appendix 1. More detailed information on the tools and methods used can be found in (Pott and Grout 2012). Tools were often used together in a variety of combinations to increase effect.

During Phase 1 of the trial, a number of the avian hazing tools listed in Appendix 1 were tested individually on various areas of Southeast Farallon Island where gulls were present. Each hazing tool tested was trialed up to five times to determine an effective range for hazing gulls and to assess how far from pinnipeds it could be used without creating significant disturbance.

Phase 2 of the trial aimed to haze all gulls off the South Farallon Islands. All methods and method combinations listed in Appendix 1 were utilized to prevent gulls from landing or roosting on the islands. A Robinson 22 helicopter allowed team members and equipment to be transported to and stationed at West End (WE) allowing more comprehensive hazing coverage. Hazing techniques were generally deployed as needed rather than all at once and were used in a sequence from least to most aggressive.

Following the departure of several staff and the helicopter on December 11, personnel and hazing equipment were withdrawn from WE. Hazing of most areas of SEFI and portions of WE could still be undertaken so the aim of Phase 3 was to determine if both main islands could still be hazed effectively using only ground-based personnel on SEFI. With the exception of the helicopter, the same hazing tools and hazing tool combinations were used during this portion of the trial. During this time, gulls were allowed to roost in limited locations where bait may not be applied during a mouse eradication operation, including several small off-shore islets and tidally submerged roosts.

Methods such as trained dogs and raptors to deter gulls and lethal removal were not used in the trial. Trained dogs and raptors were not used because of cost limitations and lethal removal was considered unnecessary for the purposes of a trial. Experimentation with unmanned aerial vehicles (UAVs) to monitor gulls and other wildlife and haze gulls on the Farallones was planned. However, permission from the FAA to use UAV's on the South Farallon Islands was not able to be gained in time.

Gull distribution and abundance and behavioral responses to hazing

Dawn gull counts were conducted on a daily basis by experienced ground based observers on the South Farallon Islands between November and March in 2010 and 2011 to establish a baseline population estimate for gulls on the island during the fall and winter. To evaluate the impact of hazing on the islands' gull population, these counts were continued during the 2012 fall/winter

season prior to, during and after the hazing trial. To allow a more detailed assessment of the impact of specific hazing techniques used during the trial, the island was divided into 49 discrete sectors (Fig. 3). During all phases of the trial, gull numbers and their location in each sector were recorded multiple times per day at regular intervals, as well as immediately prior to and after deployment of hazing techniques. The helicopter was used to assist with counts of sectors that were partially obscured to ground based observers on South East Farallon Island (SEFI) and WE.

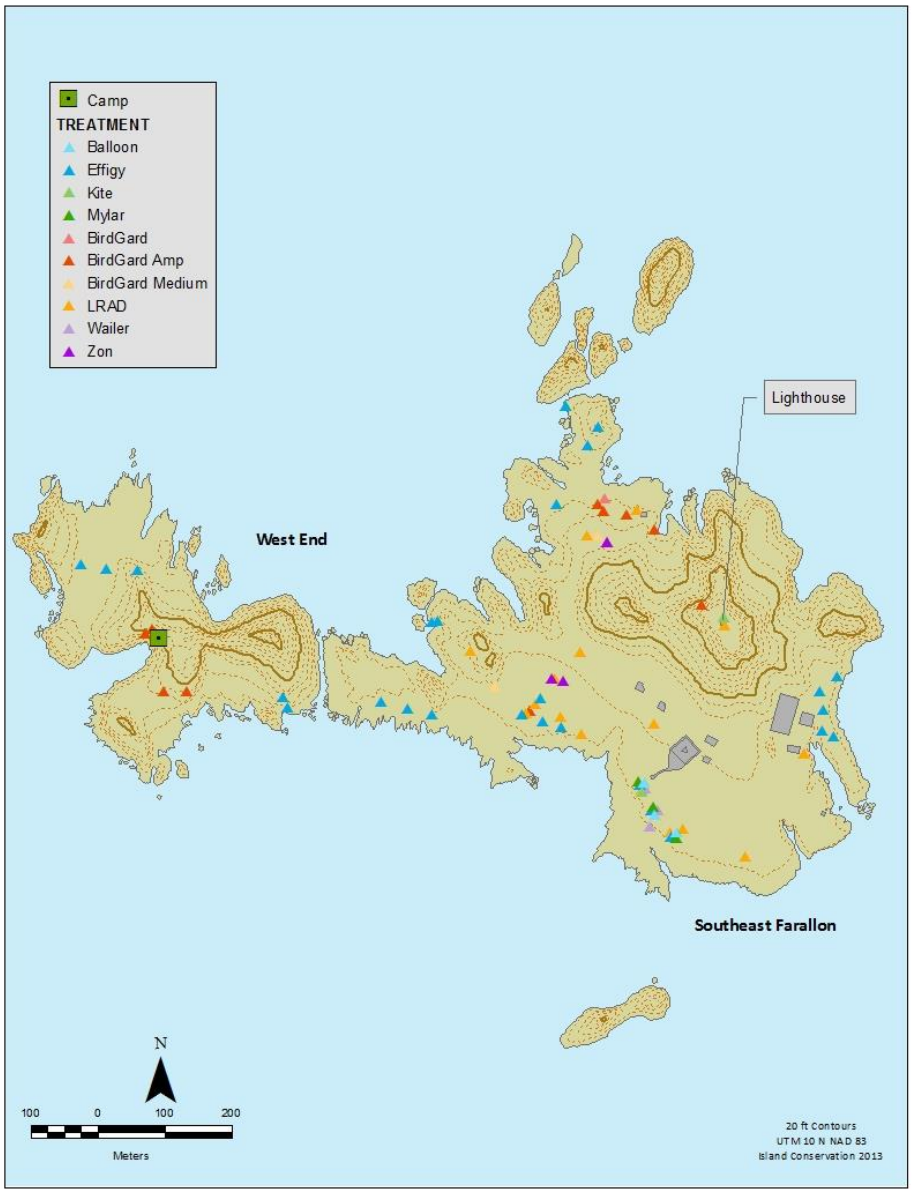


Fig. 2 Location of hazing tools used during a 2012 gull hazing trial on the South Farallon Islands.

A complete count of the targeted area was completed prior to any hazing activity and the level of response by gulls was determined from the percentage of the original number remaining after the conclusion of hazing activity. Responses of gulls to a hazing activity were categorized into one of two possible behaviors: 1) no response and; 2) flushed. If a gull's response fell into the 'flushed' category then it was noted what percentage of those gulls 1) immediately departed the area or 2) immediately circled and returned to the same site. Any sign of gull habituation as defined by Bejder et al (2009) was noted, including the following:

- Gulls not responding to hazing and continuing to roost in target area
- Gulls becoming less responsive to hazing and returning to roost more quickly
- Decreasing range of effectiveness of hazing techniques
- Decreasing percentage of gulls responsive to hazing tools
- If the use of pyrotechnics had to be more frequent to maintain roosts free of gulls

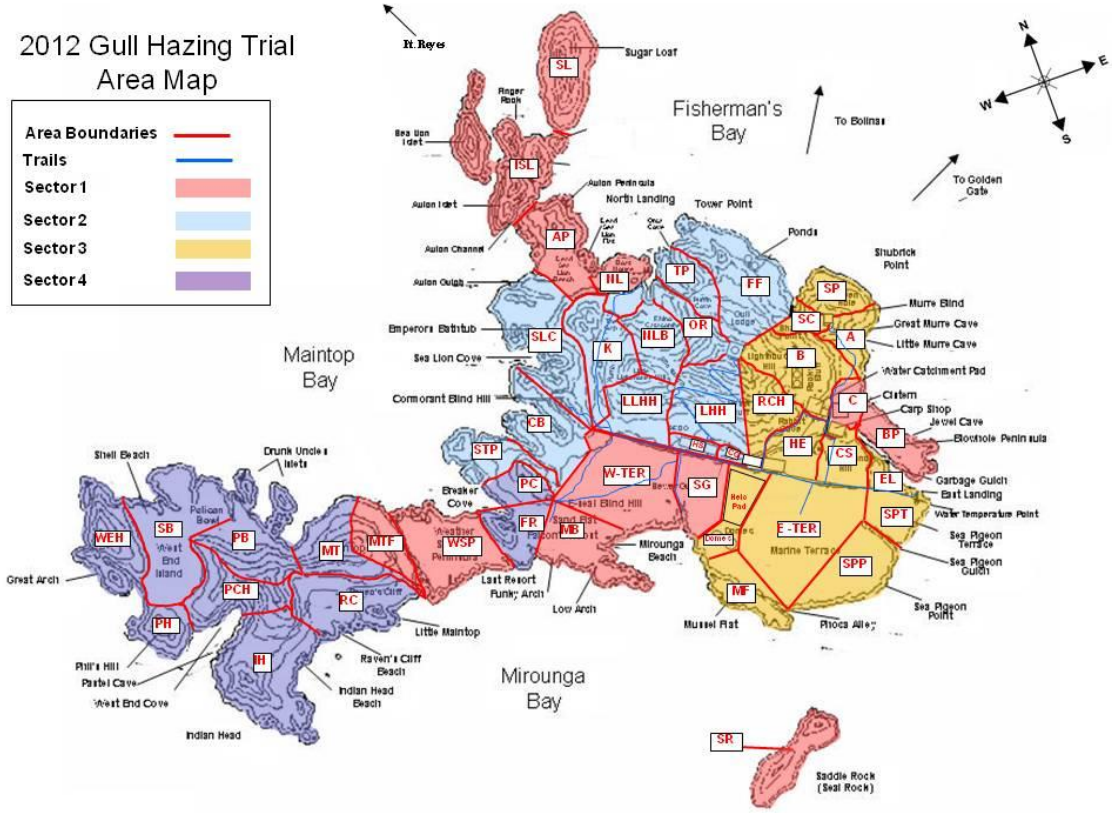


Fig. 3. Sectors used for monitoring gull numbers and behavior during a hazing trial conducted on the South Farallon Islands in 2012.

Gull monitoring generally required at least two individuals for each of SEFI and WE. At least one observer was stationed at the lighthouse and the other on the ground closer to where hazing activity was conducted. Each observer was responsible for tracking the behavior, location and movement of gulls. Hazing staff and observers worked together, so that all hazing impacts were accurately monitored. In the evening, after gull hazing activities had ceased, periodic nighttime patrols were conducted to confirm no roosting gulls were present on the island. Patrols consisted of surveying the island from the lighthouse.

The impact of hazing activity on inter-annual gull population abundance was evaluated by comparing averaged weekly counts made between the last week of November and the first week of January in 2010 and 2011 with those conducted prior to, during and after the hazing trial. We also examined the overall effectiveness of the hazing effort in reducing the number of gulls roosting on the island. We did this by comparing the number of gulls present in the 10 day period immediately prior to hazing activity with 1) the number of gulls present during the Phase 2 of the trial, and 2) a 10 day period in early January. We expected that by early January gulls would have re-acclimated to the island after cessation of hazing. We used the daily maximum number of gulls present at dawn in the period prior to, during and after the hazing trial for all comparisons. Daily morning surveys were conducted for two weeks prior to the initiation of hazing activities and again for several weeks after the conclusion of hazing. During the hazing trial, maximum dawn numbers were determined by summing gull counts made during the earliest period of hazing activity in each area on each day.

Finally, we determined effective daily hazing rates by calculating the percent difference between the daily maximum gull count and the daily minimum gull count (as determined by the hourly surveys). By this method, days on which we were able to clear all gulls off the island were considered to be an effective hazing rate of 100%. It is acknowledged that daily counts of gulls prior to and during the trial are not independent i.e. counts are likely influenced by size of the gull population present the previous day. However, this was an unavoidable constraint of the trial design. Paired *t-tests* were used to evaluate the difference in gull numbers between time periods to counter this lack of independence between samples.

We originally intended to evaluate changes in the proportion of gulls roosting within breeding territories during the trial period relative to those observed in intertidal areas and on small wave

washed off-shore islets. The aim was to demonstrate that a hazing operation could prevent gulls from settling in those areas of the island where bait would be applied during an eradication effort. However, no territorial gulls were detected during the trial period (presumably because of hazing activity) so we were not able to evaluate the effectiveness of keeping them off territories.

Quantitative analysis of the behavioral response by gulls to hazing was considered beyond the scope of this report but general patterns of the behaviors observed are reported. Similarly, spatial changes in gull distribution observed during the trial are displayed graphically rather than analytically.

Bait consumption by gulls

In an attempt to recreate conditions that would be present during a mouse eradication operation, two different types of non-toxic (placebo) rodent bait were applied in different areas on SEFI and bait consumption by gulls recorded. Rodent bait was applied at application rates proposed for mouse eradication (Grout and Griffiths 2012b) at four sites on SEFI (Fig. 4). Plots were selected because they were accessible, easily monitored and either in or near active gull roosting sites. The total area treated was approximately 3 ha. Two plots were baited at 18kg/ha with non-toxic Brodifacoum-25D Conservation (Bell Laboratories Inc.) rodent bait and two plots at 42kg/ha with non-toxic Diphacinone-50 Conservation (HACCO Inc.) rodent bait. Bait remained in all four plots at close to the original application rate for the duration of the trial. Plots were monitored continuously each day and during the night throughout the hazing trial for signs of gull foraging activity. Boundaries of baited areas were clearly marked with PVC poles and flags so observers could monitor the areas from the Lighthouse. Observers tracked any gull activity within plots during regularly-scheduled surveys.

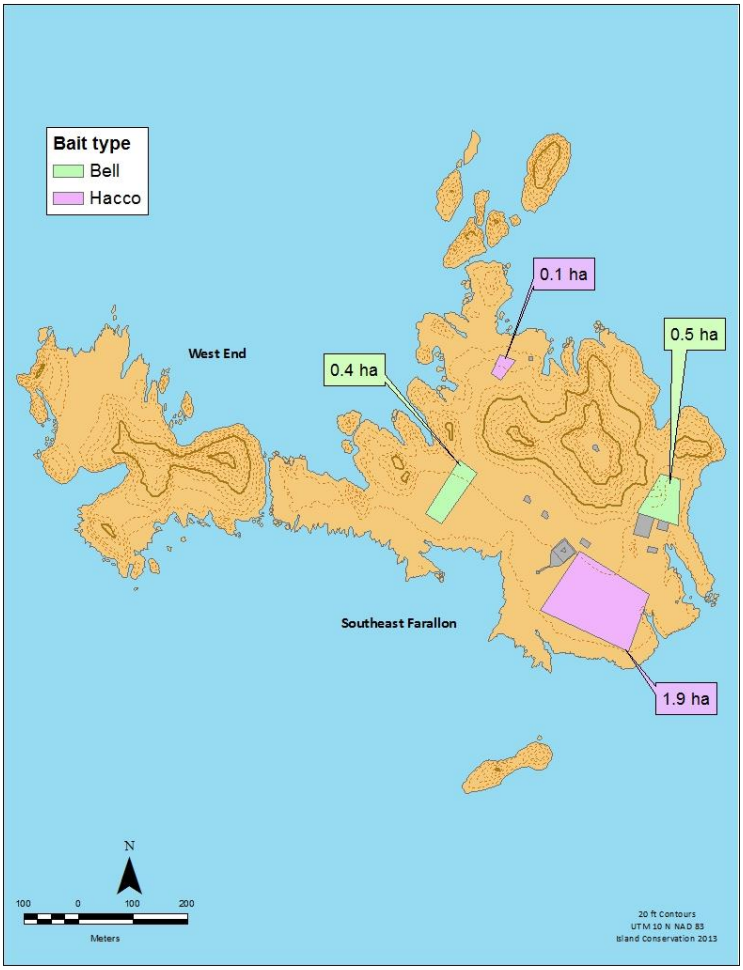


Fig. 4 Areas broadcast with non-toxic rodent bait during a gull hazing trial on the South Farallon Islands. All plots were monitored for signs of any gull presence or foraging.

Monitoring of impacts to non-target species

As part of an ongoing research program, weekly surveys of all pinnipeds present on land at the South Farallones are conducted throughout the year. Data from the last five years (2007-2011) were averaged to determine 'historical' attendance patterns. To evaluate the impact of gull hazing on pinniped abundance and distribution, we compared these historical numbers with pinniped counts prior to and after the hazing trial. We tested for a significant effect of hazing on overall numbers by comparing the 2012 pre and post hazing trial counts (after controlling for seasonal trends) as well as comparing the 2012 counts with the historical mean (Figs 10-12). Comparisons were made separately for each of the five pinniped species present on the island. We did not conduct the standard weekly surveys during the active hazing period because any response to hazing activities would have biased counts.

Behavioral responses of pinnipeds during the hazing trial were documented by counting all animals present in the target area (area targeted for hazing treatment) immediately prior to the initiation of any hazing technique and recording the proportion of the animals that reacted. Responses of pinnipeds were categorized into four possible behaviors: 1) no response; 2) alert (animal raised head, looked around or shuffled position); 3) moved (moved > 1m from initial location); and 4) flushed (animal moved to the water). Hazers worked closely with designated observers to track and record all pinniped responses to hazing activities. Additional observers were occasionally required to record responses.

During Phase 1 of the trial, a range finder was used to gauge the tolerance as defined by Bejder et al (2009) of pinnipeds to biosonic and pyrotechnic hazing tools from varying distances. Hazers deployed these hazing tools at decreasing distances from pinnipeds while an observer assessed the response of the closest animals. Pyrotechnics and biosonics were only used when it was possible to observe pinniped behavior. Data collected on the response of pinnipeds to particular hazing techniques will be presented in later reports.

The impact of the trial on other non-target species present on the South Farallones Islands was recorded as part of other long term monitoring programs and anecdotal observations. Species of interest included Common Murre, Brandt's Cormorant, Brown Pelican, Black Oystercatcher, other shorebirds and raptors.

Trial staffing and organization

Staffing for the hazing trial was provided primarily by the core Farallon Restoration Project Partners (Island Conservation, USFWS, and PRBO conservation Science), with supplemental expert hazing professionals provided by the Oiled Wildlife Care Network, CDFG-OSPR and USDA-APHIS Widlife Services. Generally between 10 and 12 people were deployed each day to conduct all monitoring and hazing activities. PRBO staff stationed on the Farallones maintained daily gull and weekly pinniped monitoring from December 15, 2012 until February 28, 2013.

To ensure that the field trial actions were well coordinated, an Incident Command Structure (ICS) was utilized for the duration of the trial. The ICS allowed for the controlled flow of information and supervision up and down the command structure.

RESULTS

Gull hazing

The gull hazing trial was completed as planned from December 3 - 13, 2012. Based on the number of gulls responding, the most effective hazing techniques appeared to be the use of lasers at night, at dawn and at dusk, effigies, pyrotechnics, biosonics, helicopters and a combination of these same tools. Kites appeared only mildly effective and were heavily dependent on wind conditions. Zons were also less effective and were hampered by the damp conditions present on the Farallones. Placement of tools varied between and within days, but Fig. 2 shows where most stationary tools were deployed. More mobile devices like pyrotechnics, lasers, LRAD and helicopter were used from many different locations at many different times.

Hazing effectiveness was sustained through Phase 3 and the efficacy of SEFI based hazing remained high (Fig. 6), even though the majority of WE was only hazed at dawn and dusk using lasers from the Lighthouse. Those islets where gulls were allowed to roost included Sea Lion Islet, Saddle Rock and Sugarloaf (Fig. 8). The presence of small numbers of gulls roosting in these refugia did not appear to attract other gulls, so allowing some roosting refugia may be an option in areas where bait application is not planned during an operation.

Gull distribution and abundance and behavioral responses to hazing

Overall gull numbers before the hazing trial were intermediate between the previous two years (Fig 5). The average number of gulls on the South Farallon Islands during the 10 days immediately prior to the hazing trial (Nov. 19-28) was 3,716 birds in 2012. This is approximately 32% lower than the same period in 2011, but more than three times greater than 2010.

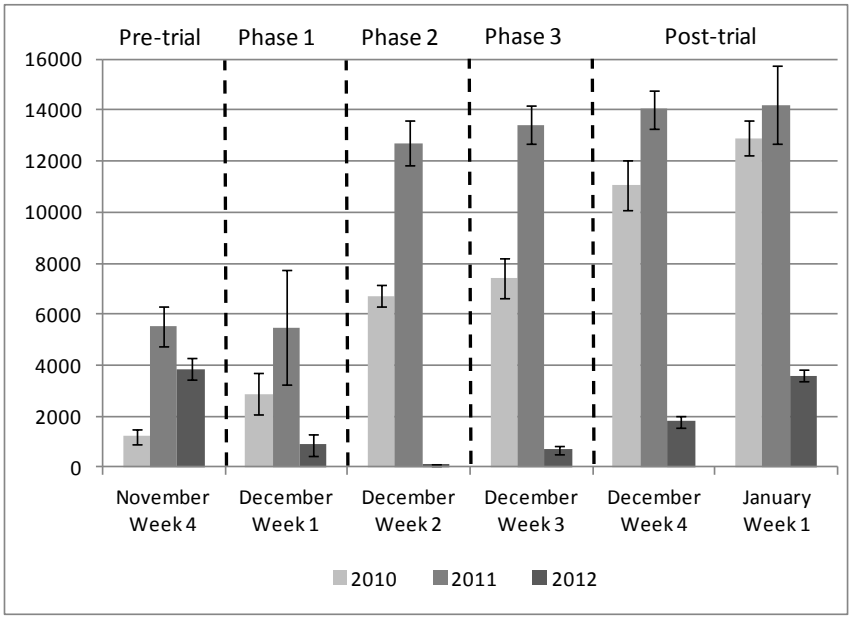


Fig. 5. Mean number of gulls present on the South Farallon Islands during the 2010, 2011 and 2012 fall/winter seasons. Active gull hazing was conducted during the first two weeks of December.

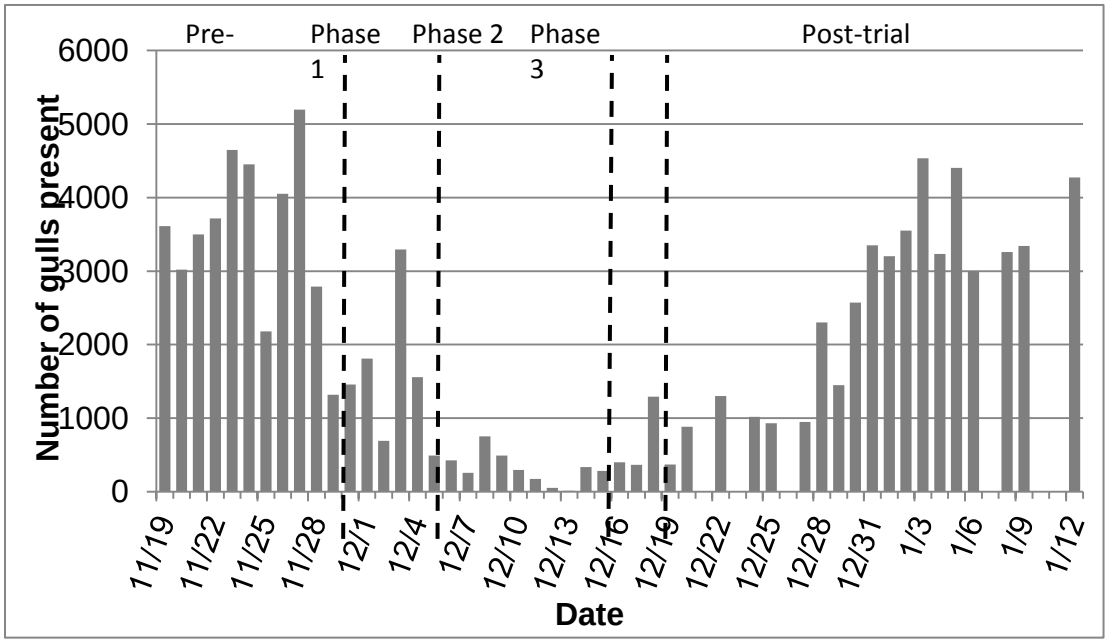


Fig. 6. The maximum number of gulls present at dawn throughout the course of the gull hazing trial. The dashed vertical lines delineate the different phases of the trial (see Table 1). Full island active hazing efforts occurred during Phase 2.

Hazing activity during Phase 2 of the trial significantly reduced gull numbers when compared to the 10 day period immediately preceding hazing activity (t=10.8225, p<0.01, df=17; Fig 6). During the ten day period of island-wide hazing, the average size of the gull population was only

327 as opposed to 3,700 over the ten days prior. Gull numbers increased throughout this period in other years gulls were monitored.

The average number of gulls present on the island during the same ten day period was 4795 in 2010 and 9102 in 2011. This represents a 93% to 96% reduction in the number of gulls present when compared to previous years (Fig. 7) and is significantly different from both previous seasons (2010 t=6.1246, p<0.01, df=9; 2011 t=6.5316, p<0.01, df=9).

The daily hazing success rate was estimated by comparing the daily maximum gull counts to the daily minimum count for each day of hazing activity (December 1 - 14; Fig 7). The number of gulls hazed off the islands was calculated from the difference between these two figures. The daily hazing success rate for Phase 2 (full-island hazing effort) and Phase 3 (hazing from SEFI only) of the trial was between 92% and 100% and averaged 98%. In other words, hazing efforts were 98% effective at keeping gulls off the island and away from areas that would potentially be baited during an eradication effort.

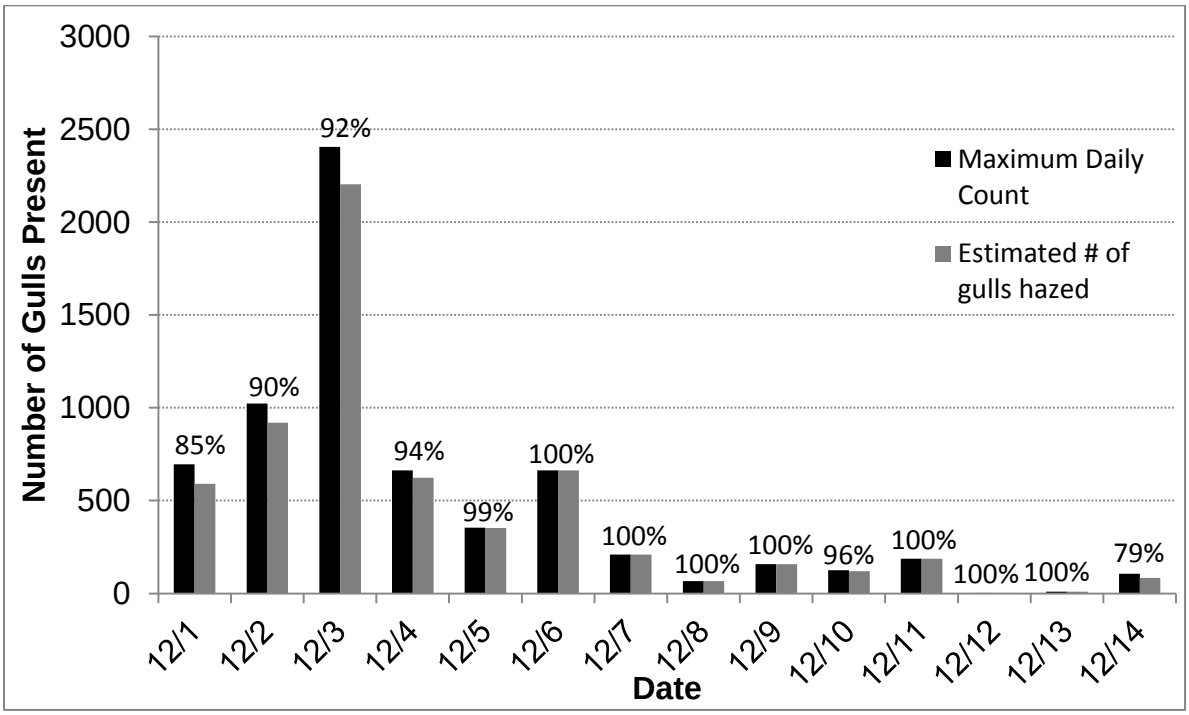


Fig. 7. The maximum number of gulls present on the South Farallon Islands at any given time (based on 1/2 hourly gull counts) and the estimated number that were successfully hazed during a gull hazing trial completed in December 2012. Percentages represent the daily hazing effectiveness. Hazing efforts were reduced on December 14 due to departure of staff.

Gull numbers remained low during Phase 3 when hazing was undertaken solely by ground based personnel on SEFI (Fig. 6.) and hazing efficacy appeared to remain high, even though the majority of WE was only hazed at dawn and dusk using lasers from the Lighthouse. Islets where gulls were allowed to roost included Sea Lion Islet, Saddle Rock and Sugarloaf (Fig. 8.) and these birds did not appear to attract other gulls. During Phase 3, gulls were completely kept off of Blowhole Peninsula and greatly reduced in both numbers and extent in other areas around the island. Remaining gulls were generally restricted to smaller flocks, farther out in intertidal areas (Fig. 8).

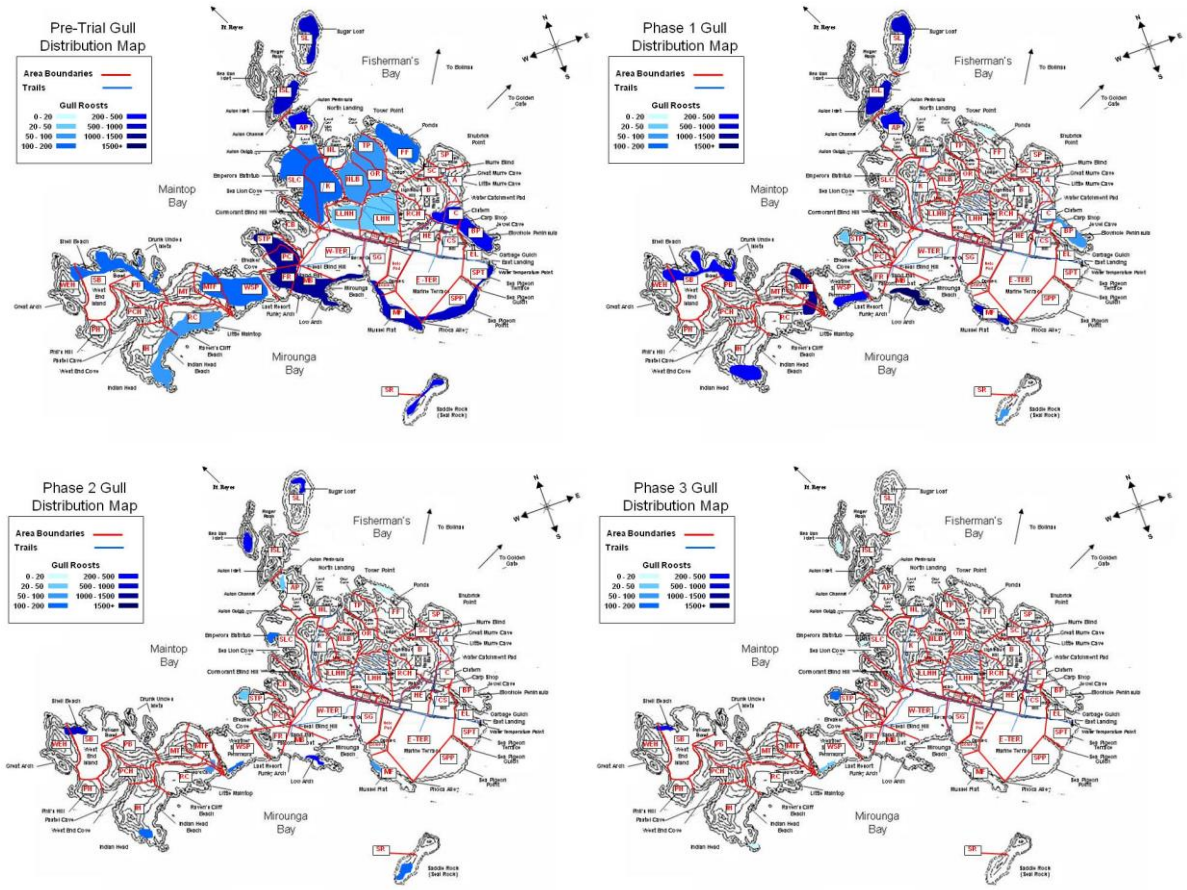


Fig. 8. Location of the main gull roosting sites prior to and during a gull hazing trial completed on the South Farallon Islands. Monitoring began on November 28, 2012.

Following the trial Western Gulls were slow to resume roosting on the South Farallon Islands and average weekly gull counts did not reach their pre-hazing trial level until approximately three weeks after hazing ceased (Fig. 6). In addition to overall reduced gull abundance, spatial

changes in gull distribution were observed during the trial. In general, gulls were kept off of the marine terrace and other upland territorial areas throughout the trial period. The highest concentrations of gulls at the initiation of hazing activities (Phase 2) were on WE (primarily Shell Beach, Indian Head and Maintop), the Islets, Mussel Flat and Mirounga Beach. There were also large concentrations on Blowhole, Aulon, Weather Service and Study Point Peninsulas (Fig. 8).

Bait consumption by gulls

Although gulls were observed consuming non-toxic rodent bait in previous trials, no gulls were detected eating bait during the hazing trial. Due to the continuous hazing activity, gulls were never observed in the baited area and did not have access to rodent bait.

Monitoring of impacts to non-target species

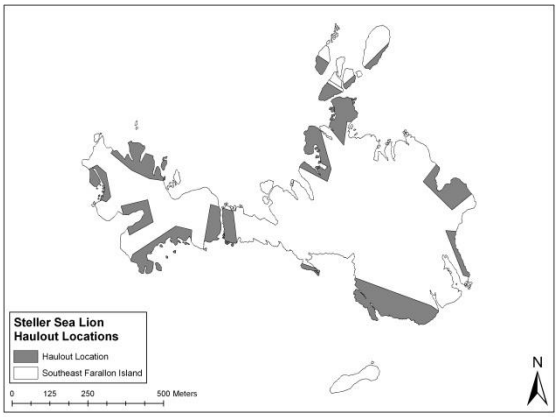
There was very little impact on non-target birds as a result of the hazing activity. The hazing trial was designed to be conducted during the time of year when the majority of seabirds are not present on the island. Overall numbers of non-target species were not determined as part of this trial. We simply noted the presence of and any disturbance to non-target species and made a general estimate of the number of birds affected. 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 3 and 4 of the trial, only 37 caused disturbance to non-target birds (~7%). Of those, there were 22 which disturbed roosting cormorants, 10 events which disturbed Common Murre, six events which disturbed roosting Brown Pelican and six events which flushed shorebirds from intertidal roosts. 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.

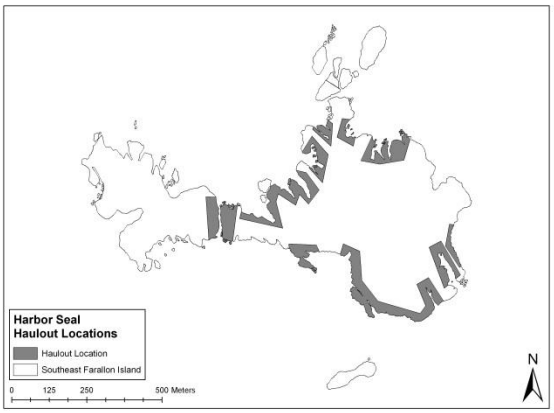
Similarly, the impact of gull hazing activities on overall pinniped abundance was minimal. Pre-trial counts for all species were statistically similar (two tailed tests - Northern Elephant Seal: $t = 1.686$, $p = 0.106$, $df = 22$, Harbor Seal: $t = 0.347$, $p = 0.732$, $df = 22$, California Sea Lion: $t = 1.068$, $p = 0.297$, $df = 22$) or higher (Steller Sea Lion: $t = 3.751$, $p = 0.001$, $df = 22$, Northern Fur Seal: $t = 4.125$ $p < 0.001$, $df = 22$) to numbers observed during the same period in the previous five years

(Figs 10 & 12). 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 (t = 1.198, p = 0.270, df=7), Steller Sea Lions (t = 1.306, p = 0.233,df=7), and California Sea Lions (t = 1.096, p = 0.309, df=7) (Figs 11 & 12). The other two species showed significant declines: Northern Elephant Seals (t = 6.328, p < 0.001, df=7) and Northern Fur Seals (t = 3.721, p = 0.008, df=7) (Fig 11). However, these declines are consistent with regularly observed seasonal declines as juvenile elephant seals and most fur seals depart the island 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 past five years (Northern Elephant Seals: t = 0.193, p = 0.849, df=24,Northern Fur Seal: t = 1.136, p = 0.267, df=24). Thus we conclude that there were no major impacts to pinniped abundance from the trial.

A map of pinniped haul-out areas on the Farallones Islands can be found below in Fig. 9. No major changes in the spatial distribution of pinnipeds were noted.





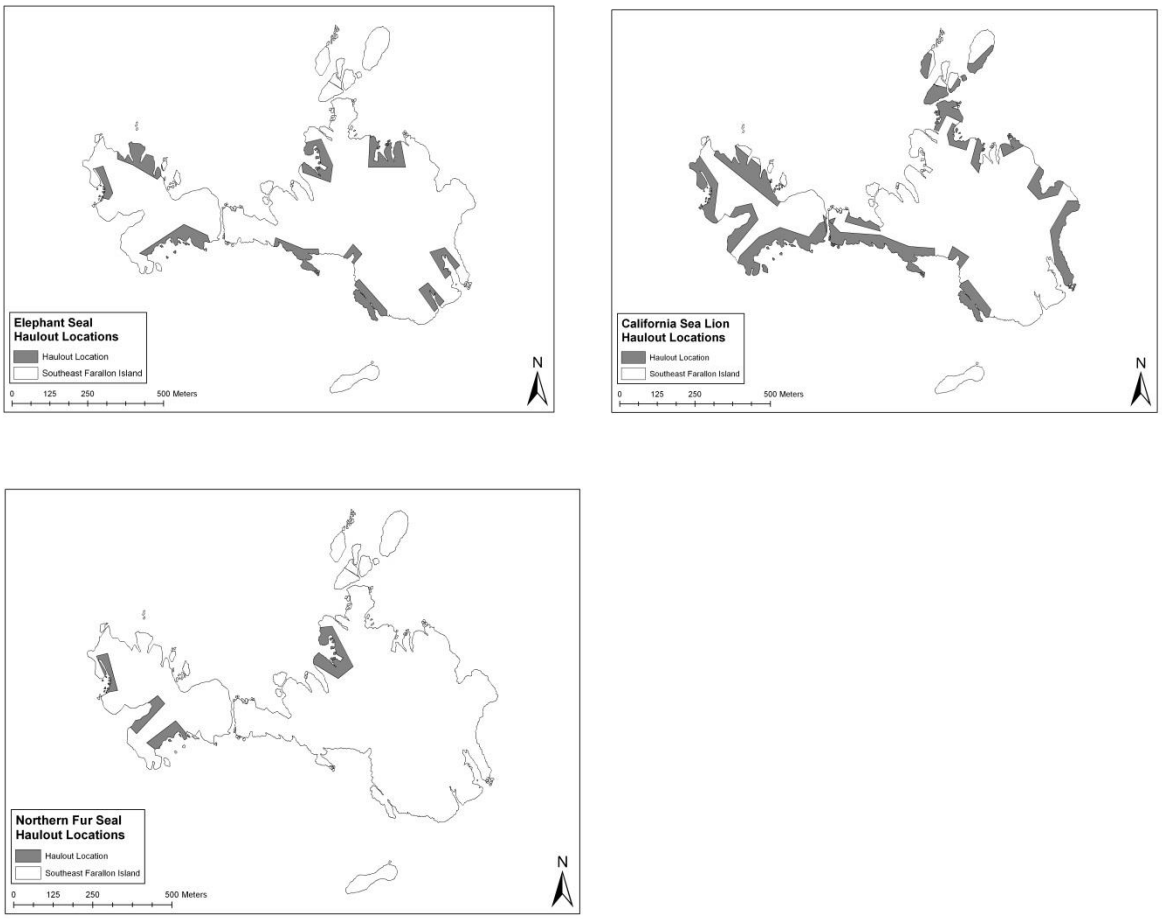


Fig. 9. Pinniped haul-out sites on the South Farallon Islands.

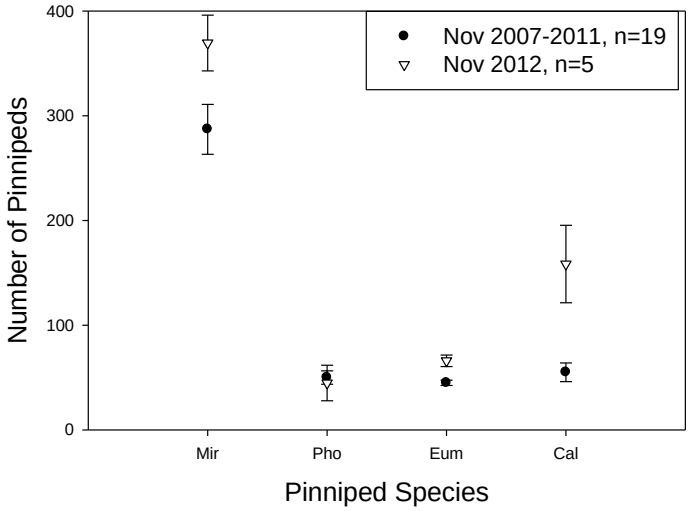


Fig. 10. Pretrial Farallon Pinniped numbers for November. Historic data (2007-2011) compared with pre-trial data from 2012. Mean monthly values with standard errors are plotted. Species

shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal)

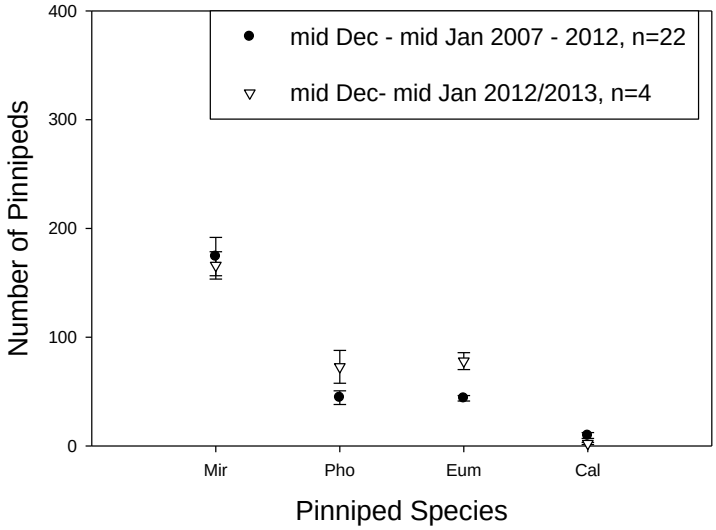


Fig. 11. Post-trial Farallon Pinniped numbers for mid-December to mid-January. Historic data (2007-2011/2) compared with pre-trial data from 2012/2013. Mean monthly values with standard errors are plotted. Species shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal)

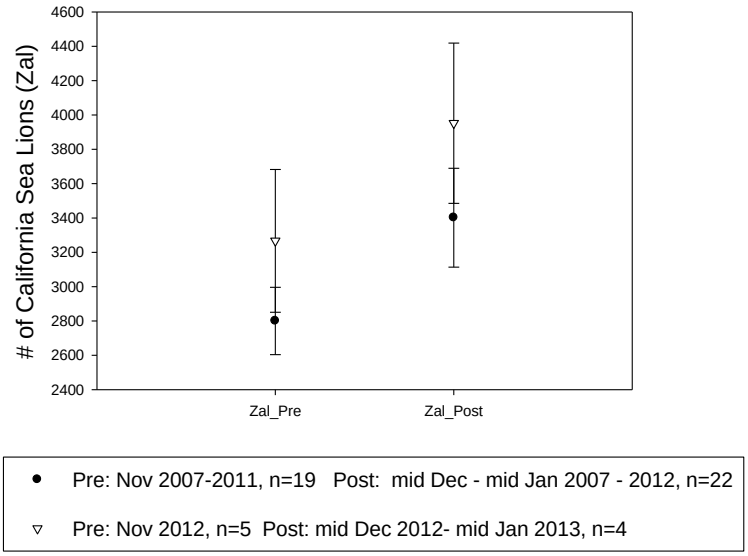


Fig. 12. Pre and Post Trial Farallon California Sea Lion numbers. Historic data (2007-2011/2) compared with trial data from 2012/2013. Mean monthly values with standard errors are plotted.

Bioacoustic hazing methods showed little effects on pinniped behavior, with no responses of animals moving greater than >1m or flushing for elephant seals and harbor seals, and mean

response for the other species for both behaviors at less than 3% of the time they were present in hazing target areas (Figs 13 and 14).

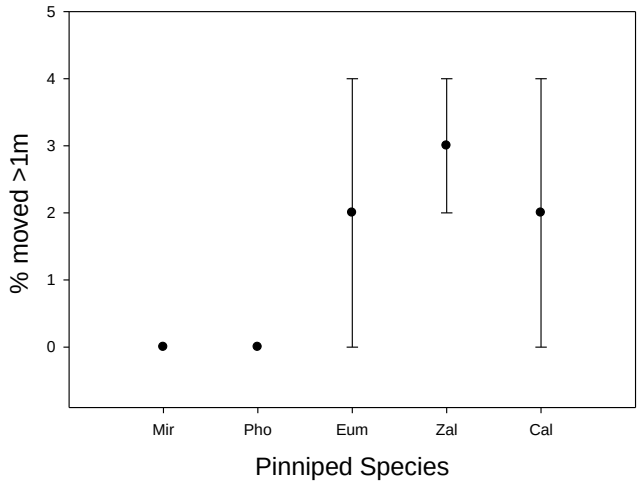


Fig. 13. Bioacoustic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=103). Methods used include Bird Gard, Wailer, LRAD, and LRAD from Helicopter. Percentage of pinnipeds moved >1m and standard error shown, for treatments with animals present . Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

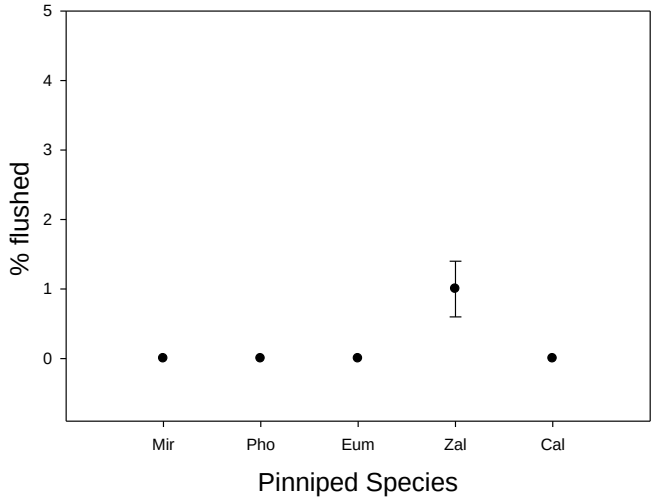


Fig. 14. Bioacoustic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=103). Methods used include Bird Gard, Wailer, LRAD, and LRAD from Helicopter. Percentage of pinnipeds flushed and standard error shown, for treatments with animals present . Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

Pyrotechnic hazing methods elicited greater responses from marine mammals. However, Elephant seal and fur seal response was effectively nil. The localized nature and low numbers of fur seals in December prevented them from exposure to a lot of these techniques. California Sea Lions were the only species with over 10% mean response for movement >1m (Fig. 15). Harbor seal flushing rates were high, over 20% mean value (Fig. 16). This response was primarily driven by the loudest of the pyrotechnic devices, the CAPA rocket.

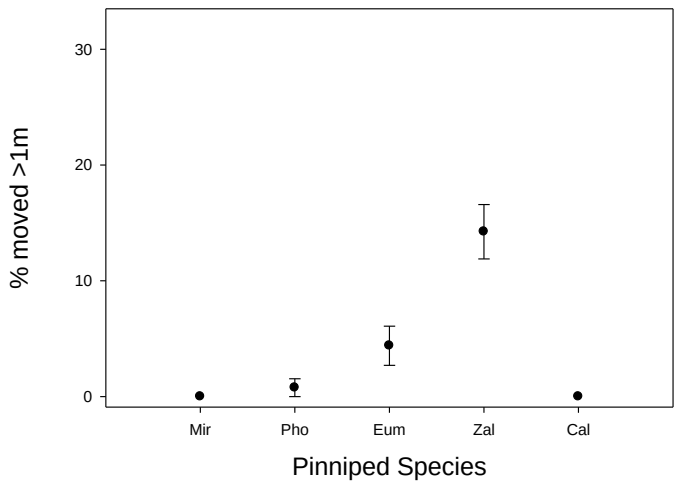


Fig. 15. Pyrotechnic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=91). Methods used include screamers, bangers, and CAPA rockets. Percentage of pinnipeds moved > 1m and standard error shown, for treatments with animals present. Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

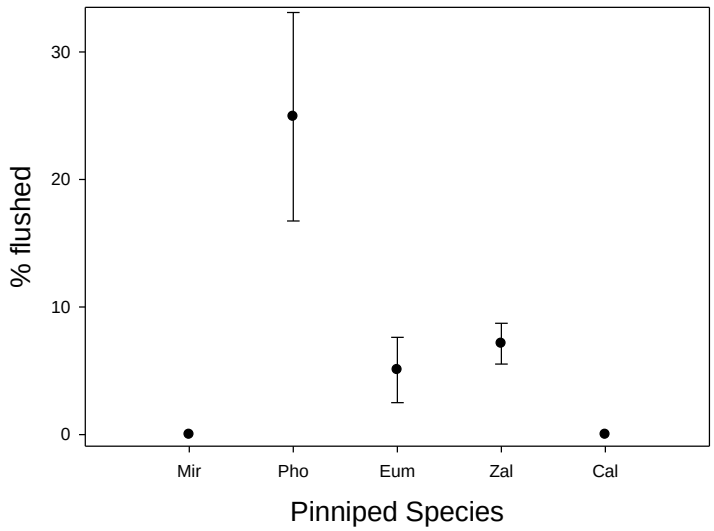


Fig. 16. Pyrotechnic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=91). Methods used include screamers, bangers, and CAPA rockets. Percentage of pinnipeds flushed and standard error shown for treatments with animals present. Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

DISCUSSION

The hazing trial tested many different techniques and tools and at the same time demonstrated that it is possible to keep the majority of Western Gulls off the South Farallon Islands for an extended period of time. The trial also successfully prevented gulls accessing areas where rodent bait was available. Results from the trial provide a high degree of confidence that a well planned and executed hazing operation implemented during and after the application of rodent bait for mouse eradication could reduce gull mortality to minimal levels and well below levels that might affect current population trends.

Gull numbers were effectively reduced from an average of approximately 3,700 present on the island prior to the trial to none present for the majority of each day by the end of the hazing period. Individual gulls often moved from one roost location to another on the island and coordinated efforts were required to prevent birds from returning to roost after they had been initially hazed. Gull numbers on and around the island were greatest during the morning and evening periods when they would be observed flying in from the sea to roost and a near-constant effort was required to keep all birds off the islands.

In all we tested 19 different hazing tools and multiple combinations of these tools throughout the trial period. In general, tools that involved both sound and motion were more effective than stationary tools, with the exception of effigies. The least useful tools tested were mylar, balloons and kites. These were difficult to use in the high wind conditions prevalent, often broke down, and seemed to have little impact on gulls. Zons were effective at flushing gulls at relatively close ranges, but their use was hindered by the need to protect them from moisture and, when placed close to tidal flats, the need to minimize disturbance to pinnipeds. The most effective hazing methods were effigies, lasers, pyrotechnics, amplified biosonics and LRAD, helicopters and a combination of these same tools. Effigies were particularly effective at dissuading birds from

roosting but were only effective over a relatively small area. Lasers were highly effective over long line-of-sight distances at dawn and dusk, before it became too bright to use them. They were successful at clearing roosting gulls and also discouraging them from landing. Lasers also had the added benefit of causing no disturbance to pinnipeds and less disturbance to other bird species. Biosonic devices which play predator and distress calls were successful in clearing large areas with relatively little effort and often little to no impact on pinnipeds. The biosonic devices could also be automated to produce a call at random varying intervals to keep an area gull free for extended periods.

The LRAD (Long Range Acoustic Device) offered the ability to directionally project sounds toward distant gull roosts while preventing disturbance to pinnipeds. This device was particularly effective when played from the helicopter attempting to haze difficult to access roost sites on offshore islets and other remote locations. Pyrotechnics were also effective at hazing birds in difficult to reach areas or driving off birds that had already been flushed into the air using another tool. The effectiveness of pyrotechnics depended greatly on the type of pyrotechnic chosen and the target distance. Screamers and CAPA (which cover a greater distance) typically had a greater effect than bangers or cracker shells. Pyrotechnics do have the drawback of causing a greater amount of pinniped disturbance, particularly to Harbor Seals.

The number of Western Gulls on the South Farallon Islands is variable, both seasonally and between years (Ainley and Boekelheide 1990). Immediately prior to the trial, the gull population was intermediate in size relative to the same time of year in 2010 and 2011 and there were particularly low numbers present within breeding territories. The data suggest that there are significant inter-annual differences in the total number of gulls roosting on the island during the fall, but the 2012 population was well within the normal variation expected. Data from the previous two seasons also indicate that gull numbers typically increase between late November and early January as more birds return to roost on the island. It is clear from the count data that the hazing activity altered this pattern during 2012 and that overall gull numbers were significantly reduced during this period. Although we believe that the hazing methods tested here would continue to be effective even if the gull population was larger, it is likely that the effort required would be proportionately greater given a larger starting population.

By the end of the hazing trial, gulls were confined to just a few small isolated pockets in difficult to reach areas of the intertidal zone or on offshore islets. For mouse eradication rodent bait would not be applied to intertidal areas and wave washed rock stacks, thus the gulls roosting in many of these location would not be at risk. Gulls roosting in these areas did not appear to attract other gulls so allowing some roosting refugia may be an option during an eradication operation.

We did not have the opportunity to demonstrate the effect of hazing activities on territorial gulls because the trial began before gulls had established territories and no territories were established during the trial. However, hazing activity likely postponed the formation of territories and the same outcome is expected to occur if a hazing operation is implemented prior to and during a mouse eradication. Hazing activities associated with an eradication operation would likely commence in early November or earlier.

In general, the hazing trial caused minimal disturbance to non-target species. The timing of the trial (and the planned timing of the proposed eradication) ensured that all seabird populations were at their annual minimums. Other than gulls, the only bird species affected by the trial were Brandt's Cormorants, Common Murres, Brown Pelicans, Black Oystercatcher and a handful of overwintering shorebirds. These species were sensitive to disturbance, and most hazing methods, effective on gulls, would also cause some disturbance to these species. As such, from a non-target disturbance perspective, it is desirable that any eradication of mice be conducted during the late fall/early winter.

The hazing trial also had a proportionately low impact on pinnipeds (seals and sea-lions) hauled out at the island. When disturbance was observed, the vast majority of them were animals alerting (i.e. rising up or looking around) and few resulted in animals abandoning their haul-out areas and flushing to the water. Responses of pinnipeds varied depending on the hazing tool employed and the species present. Generally speaking, pyrotechnics, helicopter activity and human approach were the most disruptive. Of the five species present on the island, Harbor Seals were the most sensitive to all hazing methods and the most likely to flush. Elephant seals, in contrast, exhibited almost no response to any of the hazing methods employed.

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APPENDIX 1 Hazing Methods used in a 2012 Gull Hazing Trial on the South Farallon Islands.

Description	Use	Location
Human Movement		
Movement of people on foot across the island	Monitoring and setting up hazing equipment occasionally flushed gulls from roost sites	Various locations
Effigies		
Effigies are models of animals or human forms (scarecrows) used with the intent of scaring birds.	Effigies consisting of dead Western Gulls (beach wrecked carcasses) were attached to 8ft poles by nylon fishing line. Approximately 15 effigies were used during Phase 3 of the trial.	Various locations at persistent gull roosts (See Fig. 2)
Mylar Tape		
Mylar is a reflective plastic ribbon colored on one side. It is often tied to poles or suspended from overhanging lines, where its motion in the wind creates a humming or crackling sound and it reflects sunlight.	Mylar tape was deployed at a few locations to discourage gulls from roosting.	Mussel Flat and Blowhole Peninsula (See Fig. 2)
Kites		
Kites (traditional and inflatable) in the shape of predators or painted with predators can be used to deter birds.	Two types of kites were deployed, a standard kite (Kite) and a helium-filled balloon (balloon) ("eye in the sky"). Both kite designs aimed to mimic aerial predators to frighten and disperse birds.	These were flown or positioned as close to intertidal gull roost areas as possible, usually on the Marine Terrace or Aulon Peninsula. See Fig. 2.
Lasers		
Lasers are concentrated light beams used in low lighting conditions to disperse or deter birds.	Three different lasers of varying power and intensity were used during the trial, a small 5mW green penlight, a red Avian Dissuader™ (Sea Technology, Inc., Albuquerque, NM), and a green Aries Phaser. Lasers were generally used in the early morning and the evening when light levels were low. Lasers were known to be less effective during daylight hours except at close range (Pott and Grout 2012), so limited testing of this tool during the day was undertaken. On moonless nights, spotlights were sometimes used to estimate numbers of gulls prior to flushing them with a laser.	Lasers were used primarily from Lighthouse Hill and West End locations. See Fig. 2.
Zon guns (Zons)		
Propane cannons, also called gas exploders, produce a loud, directional blast similar to that emitted by a 12-gauge shotgun.	Due to issues associated with moisture and sound levels, Zons were only occasionally used during the trial. Zons were triggered on command to flush gulls that were roosting or returning to roost areas.	Zons were established in three locations on the island See Fig. 2.
Biosonics – Birdgard Units		
Biosonics, or bioacoustics, as a hazing method, involves using animal alarm or distress calls to alter the behavior of a target species.	Three different Birdgard biosonic units were tested, a small unit with four small speakers, a medium unit, and a larger Super Pro-Amp with amplified speakers on a tower. Each unit was pre-programmed with a combination of recorded gull distress calls and hawk, peregrine falcon, and eagle calls, and were triggered on command or randomly to flush	Birdgard units were established at 19 locations. See Fig. 2.

	gulls or deter them from returning.	
Biosonics - Marine Wailer		
The Marine Wailer is designed to prevent birds from alighting on the water and typically used to discourage birds from landing on oil slicks.	The sound-emitting component of the Wailer was removed from its marine floats and played pre-recorded distress and predator calls.	The Wailer was positioned predominantly within the Marine Terrace area above Mussel Flat. (See Fig. 2)
Biosonics - Long Range Acoustic Device		
A powerful but portable directional speaker which can be made to play pre-recorded sounds.	Predator and distress calls were played both from the ground and later from a helicopter, to flush gulls from roost sites and deter them from resettling.	Used at several locations across the island (see Fig. 2) and from the air.
Pyrotechnics		
Pyrotechnics describe a wide variety of tools that can be used to haze birds. Pyrotechnics are primarily an auditory stimulus, creating a loud bang or report, but many charges also produce bright flashes, spiraling light, and smoke.	Pyrotechnics of varying types (Bangers, Screamers, Whistlers, Cracker Shells and Capa Rockets) were tested. Quieter or less disturbing charges were used first when near or close to pinnipeds, to minimize any unnecessary disturbance, to gauge the range of these devices and evaluate whether habituation by pinnipeds to their use was possible. Pyrotechnics were often used in conjunction with other hazing methods to disperse birds that were already in the air.	Various locations around the island
Helicopter		
Helicopters present both an auditory and visual stimulus that can be used to flush roosting birds or dissuade them from landing.	A small Robinson 22 helicopter was used principally for monitoring the presence of gulls and pinnipeds on the islands, as well as to transport personnel and equipment to West End. It was also later used as a tool for hazing gulls in less accessible locations.	

Method Combinations
Biosonics – Birdguard and Pyrotechnics
Birdguard units were used in combination with pyrotechnics during Phase 3 of the trial.
Biosonics – LRAD and Pyrotechnics
The LRAD unit was used in combination with pyrotechnics during Phase 3 of the trial.
Biosonics – LRAD and Helicopter
The LRAD unit was used from the helicopter to haze gulls from less accessible locations during Phase 3 of the trial.
Laser and helicopter
Lasers were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again (Phase 3 only).
Pyrotechnics and helicopter
Pyrotechnics were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again (Phase 3 only).

8.5 Appendix F - Western Gull Risk Assessment

Avian Risk Assessment for South Farallon Islands, California

RISK ASSESSMENT FOR WESTERN GULL EXPOSURE TO THE RODENTICIDES BRODIFACOUM OR DIPHACINONE ON THE SOUTH FARALLON ISLANDS

10 December 2012

Avian Risk Assessment for South Farallon Islands, California:

RISK ASSESSMENT FOR WESTERN GULL EXPOSURE TO THE RODENTICIDES BRODIFACOUM OR DIPHACINONE ON THE SOUTH FARALLON ISLANDS

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EXECUTIVE SUMMARY

The application of bait pellets containing either brodifacoum or diphacinone is being considered along with a range of other techniques to eradicate non-native house mice (*Mus musculus*) from South Farallon Islands (SFI), California. Of concern is the risk that these rodenticide products could have to western gulls (*Larus occidentalis*) that occur on the islands. Because western gulls are gregarious omnivores, they could be at risk of exposure by ingestion of baits or exposed mice should the gulls be present on the island when the bait is present. Given this concern, we undertook a probabilistic assessment of the risks posed by the application of bait containing either brodifacoum or diphacinone to western gulls on SFI.

There are three primary techniques for the application of rodent bait on islands for eradication of rodents, bait stations, hand broadcast and aerial broadcast application of bait pellets. The latter is the approach proposed for the South Farallon Islands.

Given the diet and behavior of western gulls and the fate of brodifacoum and diphacinone following bait application, there are two major routes of exposure to gulls: ingestion of rodenticide pellets (primary uptake), and ingestion of rodenticide-contaminated mice (secondary uptake). We used a probabilistic model known as the western gull risk model to estimate the effects of applications of brodifacoum and diphacinone to western gulls at SFI. The exposure portion of the western gull risk model includes both the primary and secondary routes of dietary exposure. The model estimates 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 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 third 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, a combination of weathering and consumption by gulls should have removed all or very nearly all rodenticide pellets 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 peak number of gulls expected on the South FI during the November to March timeframe. Each simulation of the model determines the fate of a western gull. At the outset of a simulation, the characteristics of the gull are randomly chosen (i.e., sex, body weight, life stage). At the same time, the model determines whether the gull will be present on SFI to forage on pellets and/or mice. As a mitigation measure, gull hazing would be implemented as part of the rat eradication to reduce the number of gulls on SFI 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 SFI.

Most gulls will not be present on SFI if initial application occurs in early to mid-November. Thus, for each gull, a starting date for its appearance on the island is determined by the model. Once a gull appears on SFI, it remains in the area until at least mid-February though only unhazed gulls are 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 SFI 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 are determined by the model based on the energetic requirements of western gulls and 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 is used for secondary exposure.

The availabilities of pellets and mice change over time in the western gull risk model. Subsequent time steps account for the relative availabilities 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 availabilities 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 which causes the pellets to break down over the next couple of 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 assumes 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 is 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 searches 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 is 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 exceeds the randomly chosen effects dose, the bird is considered dead. Otherwise, the bird is assumed to have survived the rodenticide applications. The model then proceeds to simulate the next gull. The process repeats for the number of model simulations selected by the user. The net

result over many simulations is that the entire dose-response curve is sampled thus capturing the expected range of sensitivities in the gull population at SFI. Thus, the analysis is not biased conservative, as would be the case with selecting a no observed effect level or low percentile on the dose-response curve (e.g., LD5), nor are potential effects to sensitive birds missed, as would be the case with relying on the LD50.

Model runs were conducted to determine how different application options (e.g., different application dates, differing rates of hazing success, etc.) for brodifacoum and diphacinone affected predictions regarding mortality of western gulls. An analysis conducted by Nur et al. (2012) for western gulls on SFI indicated that a one-time mortality event of 1700 individual gulls would not result in a detectably significant change in the population trend of the western gull on the Farallones over a 20-year period. We compared our model predictions to this benchmark.

It was clear from the modeling analyses that brodifacoum poses a higher risk to non-target western gulls than does diphacinone. The modeling analyses further indicated 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% or higher, neither rodenticide is likely to cause a population level impact as defined by a gull population viability analysis (PVA). The modeling analyses also demonstrated that the primary route of exposure was, by far, the most important route of exposure for western gulls for both rodenticides. Consequently, to minimize gull mortality, it is recommended that an effective gull hazing program, an early start date, and other measures to reduce gull exposure to bait are investigated.

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INTRODUCTION

The natural balance and ecology of the South Farallon Islands has been altered due to human presence and the introduction of pest species. Disruption of native biological resources, such as predation of seabirds, has occurred as a result of infestation by non-native house mice (*Mus musculus*). Along with other methods, application of one of two rodenticides, brodifacoum or diphacinone, is being considered to eradicate mice from the South Farallon Islands.

The goals of this assessment were to determine the relative risks of brodifacoum and diphacinone to western gulls (*Larus occidentalis*) and, for each rodenticide, to assist in determining what mitigation measures would be the most effective at reducing risk. Western gulls were the focal species of this risk assessment because it is one of the only resident seabird species of the Farallones that could be present during the proposed mouse eradication period that is not strictly piscivorous. As an omnivore, some western gulls could be at risk of exposure by ingestion of pellets or mice if any gulls are on the island when rodenticide bait is present. The remainder of this chapter provides background information on the South Farallon Islands, the bird species found there, and on the proposed mouse eradication project.

DESCRIPTION OF THE FARALLON ISLANDS

The Farallon Islands is a group of islands located 28 miles west of San Francisco in the Pacific Ocean. As a declared National Wildlife Refuge, the Farallon Islands are under the jurisdiction of the United States Fish and Wildlife Service (FWS). The surrounding waters are a National Marine Sanctuary and are under the jurisdiction of the National Oceanographic Atmospheric Administration (NOAA). The Farallon Islands, as a group, are also called the "Farallones" which means "rocks out of the sea".

Southeast Farallon Island (SFI) is the largest island in the Farallones group, having an area of 0.31 km² or 310,406 m². The island is pyramidal in shape and is approximately 109 meters above sea level at its peak. SFI is the only inhabited island of the group. The public is no longer allowed access to the islands.

THE WESTERN GULL (*LARUS OCCIDENTALIS*)

The western gull (*Larus occidentalis*) is a white-headed, medium-sized gull. Like most gulls, the western gull is sexually dimorphic in body size. Adult males measure 60-66 cm in total length, with body mass ranging from 1050-1250 g. Adult females are about 20 percent smaller with a total length of 56-62 cm, and mass of 800-980 g (Pierotti 1981; Pierotti and Annett, 1995). Like most gulls, the western gull is an opportunistic feeder that often forages on live prey (e.g., marine invertebrates, fish, eggs and chicks of other seabird species), scavenges carrion and refuse, and steals food from others.

The western gull is a familiar and well-known species on the Pacific Coast. However, the range and distribution of the species is limited (Pierotti and Annett, 1995). The total worldwide

population of western gulls is about 40,000 pairs with 30 percent or more nesting on SFI (Sowls et al., 1980; Penniman et al., 1990). PRBO Conservation Science has been monitoring western gulls and other seabirds and wildlife on the South Farallon Islands daily for over 45 years and this set of data and knowledge, along with that of the USFWS Refuge biologists, has helped inform many of the parameter estimates of this model.

PROJECT BACKGROUND

Female mice reach sexual maturity at about 6 weeks and males at about 8 weeks, but both can breed as early as 5 weeks. The reproductive potential of mice is staggering. They have a short gestation period of about 19-21 days. Females can produce 5-10 litters per year ranging in size from 3-12 pups per litter. Thus, a single female can produce between 15 and 168 pups in a single year (Musser and Carleton, 2005). Mice are relatively short-lived with a lifespan of usually less than 1 year in the wild. This short lifespan is often the result of predation and/or harsh environmental conditions.

Rodenticide application is being considered as a potential technique(s) for mouse eradication on SFI. Two registered rodenticides are being proposed for the eradication of mice from the Farallones: brodifacoum and diphacinone. There are three primary techniques of application, bait stations, hand broadcast and aerial broadcast application of bait pellets. The latter is the approach proposed for SFI. Aerial broadcast application would be conducted by helicopter, which is currently the most frequently used bait delivery technique for rodent eradications on large islands (Howald et al., 2007; Parkes et al., 2011). For additional background information on the use of rodenticides to eliminate rodents on islands, see Howald et al. (2007), Witmer et al. (2007), Mackay et al. (2007), Keitt et al. (2011), and Parkes et al. (2011).

As one of the proposed methods of eradication includes the use of a vertebrate toxin additional assessment is required to determine the degree to which non-target biota could be affected by exposure to brodifacoum or diphacinone.

The risks posed by exposure to brodifacoum are expected to be limited for nearly all non-target species (FWS, 2012). Because marine birds and pinnipeds typically feed exclusively on marine organisms and do not feed while on land, exposure to rodenticides in pellets is unlikely. The likelihood of secondary exposure through consumption of contaminated prey is also expected to be negligible.

Western gulls would likely be at risk from exposure to rodenticide due to their omnivorous and aggressive foraging habits. Risks to gulls from exposure to diphacinone are expected to be lower than for brodifacoum because the former is less toxic to birds (Erickson and Urban, 2004). The purpose of this assessment is to assist in estimating the likelihood and magnitude of western gull mortalities arising from aerial application of either brodifacoum or diphacinone pellets on SFI. This report is organized to follow the standard paradigm for ecological risk assessment: problem formulation, exposure assessment, effects assessment, and risk characterization.

PROBLEM FORMULATION

For this report, the timing of the aerial broadcast of rodenticide was forecast to occur in the late fall or early winter (i.e., November or December). This time of year is when the lowest numbers of non-target species are present on the island. Timing the operation for this period would provide the least risk to the island's native biota. The months of November and December occur after the summer breeding season for seabirds, sea lions, and fur seals and before female northern elephant seals have started giving birth in the early winter (PRBO unpublished data).

There are two general groups of anticoagulants used as rodenticides: the hydroxycoumarins (e.g., warfarin) and the indandiones (e.g., pindone, valone, diphacinone, and chlorophacinone). The second generation anticoagulants (e.g., bromadiolone, brodifacoum, and difethialone) are closely akin to the hydroxycoumarin group (ICWDM, 2005). Second generation anticoagulant rodenticides (SGARs) are much more potent than are first generation anticoagulants, making them effective for rodent eradications (ICWDM, 2005). When formulated at their current concentrations, they have the ability to kill a high percentage of individuals after a single feed. The effects of these compounds are also cumulative and often result in death after several feedings of even small amounts. These properties make SGARs effective primary rodenticides and they have become extremely important for rodent control worldwide (e.g., in New Zealand: Taylor and Thomas, 1989, 1993, Imber et al., 2000; in Canada: Howald, 1997; in the United States: Ebbert et al., 2007, Howald et al., 2009; in Antigua: Daltry, 2006; in Mexico: Samaniego-Herrera et al., 2009). Of the rodenticides, brodifacoum has been the most extensively used for rodent eradication from islands (Howald et al., 2007). Indeed, Parkes et al. (2011) reported that brodifacoum was used in 396 of 546 rodent eradication efforts that were attempted worldwide from 1971 to 2011. Diphacinone was used in 50 of those eradication efforts.

In this chapter, the environmental fate and toxicity of the two rodenticides under consideration, brodifacoum and diphacinone, are briefly reviewed. We then review the foraging behavior and diet of the focal species for this assessment, the western gull, to determine potential routes of exposure. The remainder of the problem formulation describes the assessment and measurement endpoints and analysis plan for the assessment.

BRODIFACOUM

Brodifacoum elicits acute toxicity by inhibiting the synthesis of vitamin K, which leads to increased coagulation times, followed by lethal internal hemorrhage (Erickson and Urban, 2004). A lethal dose is generally achieved after a single feeding, but mortality is usually delayed for 5 or more days (Erickson and Urban, 2004). Given that, vitamin K also plays a role in bone metabolism (Weber, 2001). Studies have been conducted to assess the hypothesis that exposure of non-target species to sub-lethal concentrations of SGARs may exhibit decreased bone density and bone strength. Such effects place non-target species at risk of bone fractures (Mineau et al., 2005; Knopper et al., 2007) in addition to hemorrhaging.

The high acute toxicity of SGARs and persistence in tissues create the potential for secondary exposure in predatory birds and mammals that feed upon exposed rodents. Erickson and Urban (2004) stated that brodifacoum poses a greater risk to birds and non-target mammals than diphacinone. Mortality incidents have been documented for many non-target predators exposed to brodifacoum (Stone et al., 1999; Howald et al., 1999; Eason et al., 2002; Erickson and Urban, 2004).

Following application, brodifacoum pellets are either consumed or break down as a result of rainfall, humidity, mechanical grinding and other factors. Once in soil, brodifacoum degrades at rates that vary with soil type (EPA, 1998a). The mechanisms and pathways of brodifacoum degradation in soil are not well described but appear related to moisture, temperature and soil type (Fisher, 2010). The half-life of brodifacoum in soil ranges from 12-25 weeks (EPA, 1998a). In leaching studies, only 2% of brodifacoum added to the soil leached more than 2 cm from its source in the four soil types tested (World Health Organization, 1995; soil type was not defined).

Brodifacoum is highly insoluble in water (Ogilvie et al., 1997). In field studies, freshwater samples were collected and brodifacoum concentrations determined after aerial applications of cereal pellet bait containing 20 mg ai/kg bait. The field studies were conducted at Red Mercury Island (Morgan and Wright, 1996), Lady Alice Island (Ogilvie et al., 1997), Maungatautari, Little Barrier Island and Rangitoto/Motutapu Islands (Fisher et al., in press). No detectable concentrations of brodifacoum in water were found in any of the studies.

DIPHACINONE

Diphacinone was first registered for use in the United States in 1960 (EPA, 1998a). It is a first generation indandione anticoagulant, a group that includes other pesticides such as pindone, calone, and chlorophacinone. As a first generation rodenticide, diphacinone is less acutely toxic to birds than are second generation rodenticides such as brodifacoum (EPA, 1998a; Erickson and Urban, 2004; Rattner et al., 2010). Control of rodent populations requires multiple feedings (Ashton et al., 1987). As a result, there is a higher risk of eradication efforts failing with diphacinone than is the case with brodifacoum (Parkes et al., 2011).

Diphacinone is quickly absorbed through the gut of animals, inhibits vitamin K, and uncouples oxidative phosphorylation (EPA, 2011). Studies with birds and mammals have documented increased blood coagulation time, external bleeding, and mortality following consumption of as few as one diphacinone-exposed prey item per day for 3 days (Erickson and Urban, 2004).

Diphacinone pellets or bait blocks can be broken down by rainfall, humidity, weather, mechanical grinding, and other factors. Diphacinone has a low solubility in water of 0.3 mg/L (EPA, 1998a). It has a low potential for volatilization, with a Henry's Law constant of 2×10^{-10} atm-m^3/mol. The potential for leaching is low, but diphacinone is expected to be moderately mobile in soil (EPA, 2011). The half-life of diphacinone in soil is 30 days (EPA, 2011).

FOCAL SPECIES

The western gull is found predominantly on coastal islands, including major offshore islands, rocky islets, abandoned piers, channel markers, and dikes in commercial salt flats (Pierotti and Annett, 1995). On SFI, gull nests tend to be found in the greatest density on the rocky marine terraces (Pierotti, 1976, 1981). Roosting western gulls can be found on SFI nearly year round, as well as in adjacent offshore waters, but the greatest concentrations occur during the spring breeding season (which begins in April) with fewest gulls present in late summer/fall. They are monogamous seabirds with bi-parental care, site and mate fidelity, and a maximum lifespan of 25 years (Pierotti and Annett, 1995). Highest breeding success of western gull pairs is achieved in either rocky or vegetated areas with adequate cover from both weather and predation for semi-precocial young (Pierotti, 1976, 1981). Studies have shown that reproductive success is sensitive to changes in pelagic fish abundance

Like most gulls, the western gull is an opportunistic scavenger on fish, carrion, and human refuse, and a generalist predator, capturing its own live prey, as well as stealing food from seals and other gulls (Hunt and Butler, 1980; Pierotti, 1976; Annett and Pierotti, 1989; Ainley et al., 1990). They capture food near the water's surface and on shore.

EXPOSURE ROUTES

Given the diet and behavior of western gulls and the fates of brodifacoum and diphacinone following application, there are two major routes of exposure: ingestion of rodenticide pellets (primary poisoning), and ingestion of rodenticide-contaminated mice (secondary poisoning) (Eason et al., 2002; Erickson and Urban, 2004; Bowie and Ross, 2006). The low solubility of brodifacoum and diphacinone in water precludes significant exposure via drinking water. Dermal exposure will be minimal for western gulls given the non-liquid nature of the pellet formulation, and infrequency of contact (except for ingestion). The nature of the formulation (i.e., pellets) and low vapor pressures for both compounds preclude inhalation exposure.

PROTECTION GOAL AND ASSESSMENT ENDPOINT

Protection goals are defined by scientific knowledge and societal values, describe the overall aim of a risk-based decision making and are used as the basis for defining assessment endpoints. The protection goal for the SFI mouse eradication project is the long-term maintenance of non-target wildlife species.

Assessment endpoints are ecological characteristics that are deemed important to evaluate and protect. They guide the assessment by providing a basis for assessing potential risks to receptors. Factors considered in selecting assessment endpoints include mode of action, potential exposure pathways, and sensitivity of ecological receptors. Assessment endpoints can be general (e.g., maintenance of bird populations) or specific (e.g., survival of western gulls) but must be relevant to the ecosystem they represent and susceptible to the stressors of concern (Suter et al., 1993).

The assessment endpoint for this analysis is the survival of juvenile and adult western gulls following application of rodenticide pelletized bait on SFI.

MEASUREMENT ENDPOINTS AND ANALYSIS PLAN

Measurement endpoints are the attributes used to quantify potential risks to an assessment endpoint (Suter et al., 1993). The challenge for risk assessors is to select measurement endpoints that will provide sufficient information to evaluate potential risks to the assessment endpoint. EPA (1998b) groups measurement endpoints into three categories. Measures of effect are measurable changes in an attribute of the assessment endpoint, or a surrogate, in response to the stressor (e.g., results of oral gavage studies on birds). Measures of exposure (e.g., daily dose, tissue residues) account for the presence and movement of the stressor in the environment and co-occurrence with the assessment endpoint. Measures of ecosystem and receptor characteristics consider the influence that the environment (e.g., rainfall events), and organism behavior and life history (e.g., diet, timing of nesting) will have on exposure and response to the stressor (EPA, 1998b).

A probabilistic model known as the western gull risk model was used to generate estimates of total intake of rodenticide by western gulls following the applications on SFI. The model included exposure from consumption of pellets and consumption of mice that have consumed pellets. The corresponding measures of effect are dose-response curves for bird species that have been tested for sensitivity to brodifacoum and diphacinone in laboratory exposure tests. The model is described in detail in chapters 3 and 4 of this report.

EXPOSURE MODEL

We used a probabilistic model known as the western gull risk model to estimate the effects of applications of brodifacoum and diphacinone to western gulls at SFI. The following sections provide an overview of the model, followed by a detailed description of the model inputs and components.

OVERVIEW OF EXPOSURE MODEL

The exposure portion of the western gull risk model includes both the primary and secondary routes of dietary exposure (Figure 3-1). Once ingested, brodifacoum and diphacinone accumulate and are persistent in tissues of birds, particularly the liver (Erickson and Urban, 2004; Fisher, 2009). The western gull risk model estimates daily intake of rodenticide from ingestion of pellets and mice for each of 90 days following initial application. The whole body tissue concentration on any given day is the total daily intake for that day plus the tissue concentration remaining from the previous day,

$$C_{gull,dayi} = TDI_i + C_{gull,dayi-1} \times RME$$

where C_{gull} is the whole body tissue concentration in mg/kg body weight (bw), *TDI* is total daily intake of rodenticide (mg/kg bw/day), and *RME* is the daily rate of metabolism and elimination (d^{-1}). The model runs for a total of 90 days to account for the possibility of two or three applications with an interval of up to several weeks apart. The second and third 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, the combination of weathering and consumption by gulls should have removed all or very nearly all rodenticide pellets from the environment (Howald et al., 2001). The exposure metric chosen by the model for comparison to the effects metric is the maximum $C_{gull,\ day\ i}$ estimated during the 90-day simulation. In practice, concentrations in gull tissues stop increasing a few days after the first significant rain event following the last application of rodenticide.

The number of western gulls simulated by the model is selected by the user. In the assessment described herein, the number of western gulls included in each simulation was 11,000 gulls which is the peak number of gulls expected on SFI during the November to March timeframe. See section 3.2.4 for details on how this number was determined. The results are used to determine percent mortality. To determine expected number of dead gulls from applications of rodenticide, percent mortality is multiplied by the maximum number of gulls on SFI in the November to March timeframe, assuming an initial application in the month of November or December).

Each simulation of the model determines the fate of a western gull (Figure 3-1). At the outset of a simulation, the characteristics of the gull are randomly chosen (i.e., sex, body weight, life stage). At the same time, the model determines whether the gull will be present on SFI to forage on pellets and/or mice, based on the expected number of gulls each day over time. As a mitigation measure, gull hazing would be implemented as part of the mouse eradication to reduce the number of gulls on SFI immediately following bait application. Thus, the probability of a gull being present was determined based on the selected value for expected hazing success. The probability of hazing success is entered in a binomial distribution with a sample size of one to determine if the gull will be present to forage by random chance. The model assumes that hazing will occur each day and that gulls responsive to hazing will be absent throughout the 90-day exposure duration. Gulls not responsive to hazing will be present each day to forage on SFI.

Few gulls would be present on SFI if the initial application occurs in early to mid-November, based on PRBO data. Thus, for each gull, a starting date for its appearance on the island must be determined. This is done by randomly selecting from a binomial distribution for each week that has been parameterized with a probability equal to the fraction of the maximum number of gulls present during that time step. Once a gull appears on SFI by random chance, it remains in the area until at least mid-February, though the model assumes that hazed gulls will not forage on the island. The probability of the gull leaving after mid-February is a function of the overall population remaining relative to the maximum number of gulls present on SFI in the fall and winter.

At time zero (day of initial application), pellet availability in the environment is a function of the initial application rate. If a lag time is specified before unhazed gulls begin consuming pellets (data collected at SFI indicate that pellet consumption by gulls is a behavior learned over time), then no consumption takes place on day zero. Similarly, mice are not consumed on day zero because they are not normally part of the western gull diet and are only likely to be consumed once they become easy to capture because of rodenticide intoxication. For brodifacoum and diphacinone, there is a lag time of several days before mice exhibit signs of intoxication (Erickson and Urban, 2004; Fisher et al., 2009). Consumption of pellets and mice can begin at the time steps at which the lag times for the primary and secondary routes of exposure expire assuming that the gull has appeared on SFI (otherwise, there can be no consumption). The number of pellets consumed by an unhazed western gull at the initial time step following expiration of the lag time is a function of availability of pellets and probability of the gull consuming pellets. Availability of 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 according to the application rate plus pellets remaining from previous applications. The probability of an unhazed gull consuming pellets is a function of observational data from SFI in 2010 in which the proportion of gulls consuming non-toxic pellets was determined (Grout 2012). The observed proportion of unhazed gulls consuming pellets is entered in a binomial distribution with a sample size of one to determine by random chance whether that particular gull consumes pellets on the day at which the lag time for consuming pellets expires. An analogous methodology is used to determine whether the unhazed gull will consume mice following expiration of the lag time for consuming mice. If by random chance pellets and/or mice are consumed at a time step, then the numbers of pellets and/or mice consumed must be determined for the gull of interest. Observational data indicate that once an unhazed gull learns to consume pellets, it may consume many pellets. To determine number of pellets consumed at a given time step, a value is randomly chosen from a Poisson distribution that has been parameterized to ensure that the maximum number of pellets consumed does not exceed the daily energetics requirements of a western gull. Primary exposure for that time step is then a function of the number of pellets randomly selected multiplied by rodenticide concentration in each pellet. A similar approach is used for secondary exposure except that the number of mice consumed cannot exceed the daily energetic requirements of a western gull given the number of pellets already consumed (i.e., model assumes that pellets are a preferred dietary choice over mice). Secondary exposure for that time step is then a function of the number of mice randomly selected multiplied by rodenticide concentration in each mouse. The latter is a randomly chosen value from a lognormal distribution parameterized with measured data from field studies conducted elsewhere. Primary and secondary exposures are summed for each time step to determine total daily intake. As noted above, the tissue concentration in the unhazed gull on any given day is the total daily intake for that day plus the tissue concentration remaining from the previous day.

The availabilities of pellets and mice change over time in the western gull risk model. Subsequent time steps account for the relative availabilities of pellets and mice by assuming that

consumption rates are linearly related to availabilities. 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, which causes the pellets to break down over the next couple of 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.

Once the lag times have expired for consumption of pellets and/or mice, the model assumes 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 and vice versa. The same is true for mice. As before, a binomial distribution with a sample size of one is used to determine whether a dietary item is consumed in subsequent time steps. However, the probability entered into the binomial distribution is updated to reflect the conditional probability coefficient. If a dietary item is consumed in a time step, the number of dietary items consumed is randomly selected from a Poisson distribution as before. However, the randomly chosen value from the Poisson distribution is multiplied by relative availability to account for changing availability over time for each dietary item.

At each daily time step in the model, a tissue concentration is calculated for the gull of interest. The model then searches 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 is compared with a randomly chosen gavage dose (in units of mg ai/kg bw 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 exceeds the randomly chosen effects dose, the bird is considered dead. Otherwise, the bird is assumed to have survived the rodenticide applications. The model then proceeds to simulate the next gull. The process repeats for the number of model simulations selected by the user.

The input values and distributions for the brodifacoum and diphacinone models are summarized in Table 3-1 and discussed in detail in the subsequent section.

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
Application date	User choice of Nov 1, Nov 8, Nov 15, Nov 22, Nov 29, Dec 6, Dec 13 or Dec 20			
1st application rate (brodifacoum)	18	kg bait/ha	EPA, 2008	Maximum recommended application rates on label.
2nd application rate (brodifacoum)	9			
Number of applications	2		EPA, 2008	Label recommends 2 applications to

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
(brodifacoum)				ensure efficacy.
Applications interval (brodifacoum)	12	days	R. Griffiths, pers. comm.	Based on preliminary assessments and previous eradications, interval would likely be 10-14 days.
Brodifacoum concentration	25	mg ai/kg pellet	EPA, 2008	Label states 0.0025% active ingredient in pellet formulation.
Application rate (diphacinone)[1]	48	kg bait/ha	R. Griffiths, pers. comm., based on average rate of bait uptake during 2010 bait trial (Grout, 2012)	Because an uninterrupted supply of this rodent bait is required for up to 21 days to ensure mortality in rats, more applications and a shorter interval between applications will be required to minimize the risk of bait being unavailable to mice.
Number of applications (diphacinone)	3			
Applications interval (diphacinone)	7	days		
Diphacinone concentration	50	mg ai/kg pellet	Ramik Green Label	Label states 0.005% active ingredient in pellet formulation.
Pellet weight	1.1	g ww	Island Conservation, unpubl. data (Grout 2012)	Mean pellet weight determined from a sample of 100 placebo 3/8-inch diameter pellets.
Pellet half life (1st application)	1	day	Island Conservation, unpubl. data (Grout 2012)	Nov 2010 trials showed that most pellets from 1st application had disappeared after 5 days. Assuming a half-life of 1 day leaves 3.13% of pellets after 5 days.
Time to significant rainfall event following 2nd application	4, 28 or 117	days	1972-2010 rainfall dataset for SEFI (PRBO)	Time to median significant rainfall (≥2" in 3 d) is 28 days. Best case scenario is 4 days and 95th percentile is 117 days.
Time to removal of bait following significant rainfall event	4.5	days	Mosher et al., 2007; Howald et al. 2001, 2004; Gregg Howald, pers. obs.	Pellets generally degrade within 2-7 days of a significant rainfall event. Model assumes average value.
Mean brodifacoum concentration in mice	4.9	mg/kg ww	Howald et al., 1999, 2001	Mean of 2.71 mg/kg cited in Howald et al. (2001). Mice were exposed for 4-9 days to 25 mg ai/kg bait. Howald et al. (1999), found mean concentration of 4.9 mg/kg in mice. Assumed underlying lognormal distribution in model.
Standard deviation for brodifacoum concentration in mice	1.26			
Mean diphacinone concentration in mice	51.5	mg/kg ww	Pitt et al., 2011	Tables 1-3 list bait consumption and weights of mice killed by diphacinone-treated pellets (50 mg/kg). Upper bound residue concentrations were calculated for each mouse and a mean and standard deviation determined. Assumed underlying lognormal distribution in model.
Standard deviation (SD) for diphacinone concentration in mice	13.0			
Proportion of gulls removed by hazing	User choice. In this assessment, model runs were conducted for hazing success rates of 75-98%			
Proportion western gull females	0.5		Pierotti and Annett, 1995	In the south California Bight, sex ratios have been near equity since 1970s and 1980s.
Proportion western gull juveniles	0.46		Nur et al., 2012	There are ~32,200 individuals of which 46% are subadults and non-breeding adults.

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
Mean western gull adult body weight (BW) - female	879	g	Pierotti, 1981	Measurements taken on SEFI with sample sizes of 21 and 15 for males and females, respectively. Model assumes underlying normal distribution.
SD of western gull adult BW - female	78			
Mean western gull adult BW - male	1,136			
SD of western gull adult BW - male	47			
Juvenile western gull BW relative to adult body weight	0.875		Penniman et al., 1990	See Table 7.5 in source. Model assumes underlying normal distribution.
Daily probability of gull consuming mice (unhazed gulls)	0.125		Proportion of gulls consuming dead/dosed mice is estimated to vary between 0.01-0.25 (model assumes 0.125) assuming 100% mice availability for unhazed gulls.	
Daily probability of gull consuming pellets (unhazed gulls)	0.25		2010 SEFI field study	Observational and fecal count data indicated an average of 22-25% of unhazed gulls had foraged on pellets. Initial daily rates are much lower, ranging from 0 to 29% during first five days and thus this analysis was conservative.
Conditional probability for consuming mice	0.9		Once birds learn to consume pellets, they will be more likely to consume pellets on subsequent days. No data are available, however, to quantify this behavior.	
Conditional probability for consuming pellets	0.9		Once birds learn to consume pellets, they will be more likely to consume pellets on subsequent days. No data are available, however, to quantify this behavior.	
If mice consumed, Poisson rate	0.2		This value is used as a rate in a Poisson distribution. By adding 1 to the Poisson randomly generated value with a rate of 0.2 suggests an upper limit of 3 mice/gull, which is approximately the maximum value suggested by daily energetic requirements.	
If pellets consumed, Poisson rate	15		A Poisson rate of 15 suggests an upper limit of 30 pellets/gull, which is approximately the maximum value suggested by daily energetic requirements. Western gulls foraging on pellets are highly unlikely to eat just one. A rate of 15 would make this outcome unlikely.	
Lag time for consuming mice	5	days	Fisher, 2009 (Trial 3 data)	Mice are not normally part of the gull diet on SFI. However, once symptoms of exposure begin (5 days), mice are easier prey.
Lag time for consuming pellets	1	day	Grout, 2012	Trial showed no consumption on day of application but consumption began 1 day later.
Proportion intoxicated mice below ground - brodifacoum	0.87		Taylor, 1993; Howald, 1997; Buckalew et al., 2008	Mice generally retreat to burrows following onset of symptoms stemming from exposure to brodifacoum.
Proportion intoxicated mice below ground – diphacinone[2]	0			No information was available for diphacinone..
Gull LD50 for brodifacoum	0.588	mg/kg	Wildlife	Values generated from probit

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
Probit slope for brodifacoum	2.32	bw	International, 1979a,b	regression conducted on raw data for laughing gulls in the reports. Laughing gull should be a reasonable surrogate for western gulls.
Gull LD50 for diphacinone	97.0	mg/kg bw	Rattner et al., 2010	Values generated from log-probit regression conducted by study authors for most sensitive species tested to date, the American kestrel.
Probit slope for diphacinone	6.69			
Half-life for elimination from gull- brodifacoum	217	days	Erickson and Urban, 2004	Calculated mean retention time in the liver from available studies.
Half-life for elimination from gull - diphacinone	90	days		

[1] The application rate for diphacinone was revised upward after the contract was awarded for this project.

[2] A different value could be used for this input parameter in future model simulations. The results of the sensitivity analyses described in Section 5.4 of this report, however, indicate that the value assumed for this input parameter has a negligible influence on predicted mortality of western gulls.

DETAILED DESCRIPTION OF EXPOSURE MODEL INPUTS AND COMPONENTS

There are a large number of input parameters in the western gull risk model. In general, variables of minor importance and/or that have little uncertainty and variability are treated as deterministic variables (i.e., one value per variable). Those variables that are variable or have high uncertainty are either treated as distributions or considered in the sensitivity analysis to determine their importance to model predictions. Each of the model input parameters for the western gull risk model are discussed below (also see Table 3-1).

Application of Rodenticide

For brodifacoum, the model assumes two applications on SFI in November-December. The first application rate will likely be 18 kg bait/ha, the maximum rate allowed on the Brodifacoum 25-D label (EPA, 2008). The second application will likely be at a rate of 9 kg bait/ha, which is also the maximum rate allowed on the label (EPA, 2008). The Brodifacoum 25-D formulation consists of grain-based pellets that weigh 1.1 g on average and have a target brodifacoum concentration of 25 mg ai/kg pellet (i.e., 0.0025% active ingredient in the formulation). The interval between applications was assumed to be 12 days.

For diphacinone, the model assumes three applications on SFI in November-December, with an application rate for each application of 32 kg bait/ha. The diphacinone formulation consists of grain-based pellets that weigh 1.1 g on average and have a target diphacinone concentration of 50 mg ai/kg pellet (i.e., 0.005% active ingredient in the formulation). The planned interval between applications is 7 days.

Date of Initial Application

Bird counts in previous years on SFI indicate that western gulls occur in low numbers in early November and increase gradually to peak winter numbers in early to mid-December. The number of gulls on SFI declines slightly beginning in February. Given this information, date of

initial application could influence the number of affected gulls because fewer gulls will be present for the initial application if it takes place in early November. To explore the influence of date of initial application, separate model runs were conducted for each rodenticide assuming initial application dates of November 1, 8, 15, 22 and 29, and December 6, 13 and 20.

Removal of Pellets

Generally, cereal-based pellets disappear rapidly from the environment due to degradation from rainfall, humidity, etc. and from consumption by target organisms, i.e., mice in the case of SFI (Buckelew et al., 2005). Trials conducted at SFI in November 2010 demonstrated that non-toxic pellets (i.e., pellets without rodenticide) disappeared in 3-5 days after the first application (Grout, 2012). Such a range suggests a pellet half-life following the first application of 1 day. Near total removal of pellets within a few days has also been observed on other islands with high densities of rodents (e.g., Round Island, Merton, 1987; Anacapa Island, Howald et al., 2001; Gough Island, Wanless et al., 2009). Thus, a half-life of 1 day for removal of pellets following initial application was assumed in this assessment.

Mice are not expected to be present in significant numbers at the time of the second application of brodifacoum or third application of diphacinone. As a result, the likely major removal mechanism for pellets from the SFI environment following the final rodenticide applications will be disintegration following a significant rainfall event (Howald et al., 2001; Gregg Howald, pers. comm.). A significant rainfall event is one sufficient to initiate pellet degradation, which according to manufacturer and applicator experience, was defined as at least 2 inches (5 cm) of rain occurring over a period of 1-3 days. Merton (1987) previously observed that pellet effectiveness is eliminated with rainfall events of 4 cm (1.6 in) or greater. Daily rainfall data have been collected at SFI since 1972. We isolated the rainfall data for the months of November and December for each year that data had been compiled (1972-2010). We then calculated 3-day running averages and determined the probability of a significant rainfall event for any 3-day period at SFI in November and December. The probability of such an event is 2.58%. Based on information provided from preliminary planning, application of brodifacoum would only occur if little or no precipitation was forecast for at least 4 days. Thus, the best case scenario is for rain to occur 4 days after the final application of rodenticide. Assuming a 2.58% probability of a significant rainfall event for any given 3-day period and an underlying binomial distribution, the resulting median (i.e., most likely) estimate of time to first significant rainfall event is 28 days. The worst case value was assumed to be the corresponding 95th percentile which is 117 days (i.e., rainfall event does not occur within 90-day model simulation). In this assessment, model runs were conducted assuming a first significant rainfall event after the final application of 4, 28 and 117 days[6]. The 117 day data point likely overestimates the risk associated with bait being present for this duration because rainfall probabilities increase considerably in the months of January and February.

[6] Future model simulations may consider January-February rainfall patterns and additional periods of time to the first significant rainfall event - as January-February rainfall historically encompasses the majority of the annual winter rainfall on the island.

A significant rainfall event will not lead to immediate disintegration of rodenticide pellets. Based on observations of pellets during the SEFI trials in November 2010, Dan Grout of Island Conservation cited a range of 2-7 days for removal of pellets via disintegration following a significant rainfall event (see also Moser et al., 2007; Howald et al., 2001, 2004). Howald et al. (2004) showed that 2 g brodifacoum pellets (dry formulation) were disintegrating within 3 days when there was 1 inch of rain per day. Even with small rainfall events, much of the annual vegetation growth on SFI likely would obscure many if not most bait pellets, which would further limit rodenticide exposure for gulls. In our analyses, we used the average value of the 2-7 day range observed on SFI (i.e., 4.5 days) for time to removal of pellets following a significant rainfall event.

Number, Sex and Life Stage of Western Gulls on SFI

The western gull has a total worldwide breeding population of approximately 40,000 pairs of which more than 30% occur on SFI (Penniman et al., 1990; Pierotti and Annett, 1995). Ainley and Lewis (1974) similarly estimated that there are 25,000 individuals present on SFI, of which about 20,000-22,000 of these birds are breeders. The remaining gulls are excess adults because of a lack of nesting areas. Numbers are lowest, perhaps a few thousand birds, during early fall. The numbers increase during November and reach peak numbers in the spring (Ainley and Lewis, 1974).

The number of western gulls on SFI is variable, both seasonally and between years. Observational data collected in November to March 2010-11 and 2011-12 were used to estimate numbers of western gulls on SFI on a weekly basis (Table 3-2). For the western gull model, the two years of data were combined and approximate values generated for each two week period from November to March. These data were used to determine probabilities of a given bird being present (i.e., Model Assigned Value in Table 3-2/Maximum Possible Value of 11,000 birds) for each week through November to March assuming that once a bird appears on SFI in November or December, it does not leave until mid-February at the earliest. A bird can be present but not foraging on SFI, as would be the case with birds that are successfully hazed each day. The general pattern indicates that the probability of a given bird being present in early November is relatively low and then increases to a probability of 1 by mid-December (Table 3-3). The probability of the bird being present on SFI begins to decline in mid-February (Table 3-3).

Table 3-2. Western gull counts on SFI in 2010-11 and 2011-12.

Month	Day	Mean Gull Count		Two-Year Mean	Two-Week Average	Model Assigned Value
		2010-11	2011-12			
Nov	0	2080.25		2080	2333	2300
	6	2584.75		2585		
	13	1265.14		1265	2317	
	20	1206.5	5530	3368		
Dec	27	2873	5486.67	4180	6948	7000
	34	6716.67	12,716.25	9716		
	41	7402.43	13410	10,406	11,480	11,000

Table 3-2. Western gull counts on SFI in 2010-11 and 2011-12.

Month	Day	Mean Gull Count		Two-Year Mean	Two-Week Average	Model Assigned Value
		2010-11	2011-12			
	48	11,074.38	14,034.29	12,554		
Jan	55	12,914.5	14198	13,556	12,114	
	62	10,669.2	10,673.33	10,671		
	69	10,960	8546.67	9753	10,448	
	76	12,500.67	9782.86	11,142		
Feb	83	12,420	8182.857	10,301	10,391	
	90	10,070.29	10,890.5	10,480		
	97	7405.67	4770	6088	5441	8500
	104	6818.67	2770	4794		
Mar	111	8787.75	5224	7006	7852	
	118	10,566.17	6830	8698		
	125	12,620.6		12621	12,344	
	132	12,067		12,067		

Table 3-3. Probability of an individual western gull being present on SFI according to initial application date and simulation day.

Day	Initial Application Date							
	Nov 1	Nov 8	Nov 15	Nov 22	Nov 29	Dec 6	Dec 13	Dec 20
0	0.209	0.209	0.209	0.209	0.636	0.636	1	1
7	0.209	0.209	0.209	0.636	0.636	1	1	1
14	0.209	0.209	0.636	0.636	1	1	1	1
21	0.209	0.636	0.636	1	1	1	1	1
28	0.636	0.636	1	1	1	1	1	1
35	0.636	1	1	1	1	1	1	1
42	1	1	1	1	1	1	1	1
49	1	1	1	1	1	1	1	0.773
56	1	1	1	1	1	1	0.773	0.773
63	1	1	1	1	1	0.773	0.773	0.773
70	1	1	1	1	0.773	0.773	0.773	0.773
77	1	1	1	0.773	0.773	0.773	0.773	0.773
84	1	1	0.773	0.773	0.773	0.773	0.773	0.773

No information was found on the numbers of females and males present on SFI in November and December. In the Southern California Bight, sex ratios have been near equity since chemical companies stopped disposing waste to the Bight in the 1970s and 1980s (Pierotti and Annett, 1995). On SFI, the sex ratio may be skewed slightly in favor of females during the breeding season (Spear, 1988; Pierotti and Annett, 1995). Given the available information and minor importance of the sex ratio variable we assumed a ratio of males to females on SFI in November and December of 50:50.

According to Nur et al. (2012.), the total SFI population of western gulls of all age classes is about 32,200 birds. Of the 32,200 western gulls, about 17,400 are breeding individuals and about 14,800 are immatures and non-breeding adults. Assuming the latter to be immatures, 46% of the western gulls are immatures. No information was available to determine how the percentage of immature gulls varies seasonally. Thus, in the absence of other information, we assumed that 46% of western gulls present on SFI during November to March are immatures.

Size of Western Gulls

Based on measurements taken at SFI, the mean body weight of female western gulls is 879 g (standard deviation=78, n=15) (Pierotti, 1981). The corresponding mean body weight for males is 1,136 g (standard deviation=47, n=21) (Pierotti, 1981). In the western gull risk model, these values were used to parameterize normal distributions for males and females. Immature males and females were assumed to weigh 87.5% of their respective adult counterparts based upon data presented in Table 7.5 of Penniman et al. (1990).

Hazing Success

A number of studies have shown that gull species (i.e., *Larus* sp.) can be prevented from foraging and loafing in areas where their presence is not desired (e.g., airports, landfills) (Curtis et al., 1995; Slate et al., 2000; Chipman et al., 2004). The most common technique is to use non-lethal pyrotechnics (Chipman et al., 2004). This technique can be quite effective and has been observed to remove all or nearly all gulls if used on a daily basis. As such, daily hazing is being considered as a management technique on SFI to reduce the number of gulls exposed to the rodenticide following application. Although daily hazing has been an effective management tool at airports and landfills, it's effectiveness as a tool on SFI is unknown at this time. Thus, in this assessment we conducted model runs for each rodenticide for a range of possible hazing successes, i.e., 75%, 90%, 95% and 98%. Hazing trials conducted in January, 2011 confirmed that gulls could be effectively hazed from Southeast Farallon using standard avian hazing methods (Pott and Grout, 2012). A more extensive and longer gull hazing trial is being planned for the fall of 2012 at SFI to confirm and quantify the expected hazing effectiveness rates for western gulls on the island and to determine which hazing techniques are most effective at dispersing gulls.

Primary Exposure Route Variables

Cereal grains such as those found in the rodenticide pellet formulation are not found on SFI and thus are not normally part of the diet of western gulls. In general, western gulls are predators that forage on pelagic and intertidal marine fishes and invertebrates (Hunt and Hunt, 1976; Hunt and Butler, 1980; Pierotti, 1980; Ainley et al., 1990; Pierotti and Annett, 1995; Snellen et al., 2007). However, western gulls are opportunistic and will forage on other items that are readily available (Pierotti and Annett, 1995). During the SEFI trials in November, 2010, western gulls were observed feeding on non-toxic pellets. Pellet consumption was infrequent immediately after first application but increased as more gulls became aware of the food source (IC, 2011). Data from the SEFI trials indicated that 22% of unhazed gulls in the bait zone were observed or suspected of foraging on grain pellets. Further, approximately 25% of gull fecal pellets had a green dye that

had been incorporated in the pellets. To be conservative, we assumed a 25% daily probability of an unhazed gull consuming at least one pellet when pellets are readily available (i.e., shortly after application). A binomial distribution was assumed for this variable for each day of the model simulation.

In the western gull risk model, consumption of pellets was assumed to decline in direct relation to the decline in availability of pellets relative to the day of initial application. Thus, the daily probability of consuming pellets is adjusted to account for the availability of pellets. For example, if the daily probability of an unhazed gull consuming pellets on day zero is 25% and the availability of pellets on the surface compared to day of initial application is 3.1% on day 5 (the case when the pellet half-life is 1 day), then the daily probability of an unhazed gull consuming pellets on day 5 is 0.73%. Pellet availability increases with subsequent applications of rodenticide.

Observational data at SEFI suggest that once gulls learn of the pellet food source, they are more likely to return to that food source in successive days. We incorporated a conditional probability for daily probability of consuming pellets to account for this learned behavior. Quantitative data to parameterize the conditional probability, however, are lacking. A value of 90% was assigned to this variable. Although we assumed that most gulls, once they ate bait, would eat it again the next day, we assumed a 10% daily turnover rate of western gulls in the fall (a very conservative estimate). Thus, the probability of a gull consuming pellets on day 1 doing so on day 2 is thus ~90%. The conditional probability essentially adjusts the daily probability of an unhazed gull consuming pellets given the result from the previous day. Thus, consumption of one or more pellets the previous day increases the probability of consuming one or more pellets the following day (i.e., to 90%). If a gull does not consume any pellets on the previous day, it will be less likely to consume pellets the following day. The higher the conditional probability, the more likely that there will be long strings of days with pellet consumption and long strings of days without pellet consumption. There are no scientific data available from the Farallones or elsewhere upon which to base this 90% input parameter, but it was considered best to conservatively assume a relatively high likelihood of a gull consuming bait on a day subsequent to initial bait consumption. A rate of 90% was considered to be a high end estimate, given the high rate of learned foraging behavior observed in Farallon western gulls. In addition, the daily return rate of western gulls on the Farallones may not be 100%. It is likely a relatively high value, due to lack of extreme daily migratory behavior observed in western gulls, as well as observed movement of banded birds from this population.

In addition to determining whether an unhazed gull feeds on pellets in each day of the model simulation, we need to determine the number of pellets consumed on days when consumption occurs. Observations during the SEFI trials in November, 2010 indicated that when pellets are readily available, unhazed gulls are unlikely to consume just one pellet once consumption begins. To determine the daily maximum number of pellets that could be consumed, we determined the number of pellets required to meet the metabolic needs of adult gulls. The metabolizeable energy in cereal grain baits consumed by birds is 14.0 kJ/g dw bait (Nagy, 1987). Assuming a moisture content of 14% (Nagy, 1987) and a pellet mass of 1.1 g as determined in

SEFI field measurements of 100 placebo pellets, the metabolizeable energy in each pellet is 13 kJ/pellet ww. Adult western gulls require approximately 12 (females) to 14 (males) kJ/hour for normal maintenance during the non-breeding season (Pierotti and Annett, 1995). Thus, daily energy requirements are 288 and 336 kJ/day for female and male western gulls, respectively, similar to the values estimated for herring gulls (Pierotti and Annett, 1991; EPA, 1993). The upper bound for pellets consumed per day to meet daily energetic requirements for male western gulls would be 26 (336/13 = 26). We rounded this figure to 30 pellets/day to be conservative and because gulls may consume more food than required to meet typical daily energetic requirements on some days. A Poisson distribution with a rate of 15 for daily number of pellets consumed results in a distribution for which low (e.g., 1-3 pellets/day) and high values (i.e., 28-30 pellets/day) are rare events, but values in between are more common.

Finally, the western gull risk model assumes a 1 day lag time for consuming pellets because the SFI trials in November demonstrated that pellet consumption did not begin until the day after application.

Secondary Exposure Route Variables

Birds have the potential to consume live rodents or carrion containing brodifacoum or diphacinone residues (Eason et al., 2002; Erickson and Urban, 2004; Bowie and Ross, 2006). As with consumption of pellets, the western gull risk model estimated daily probability of consuming mice and, should consumption occur, the number of mice consumed per day.

Few data are available to determine the daily probability of consuming mice by western gulls. Stomach contents analyses show that consumption of rodents by gulls is low and typically in the range of 0-2% (Ainley et al., 1990; Pierotti and Annett, 1995). However, unhazed gulls are expected to change their behavior following rodenticide application on SFI because intoxicated or dead mice are easier to capture. Scavenging of trapped mice was observed during the SFI trials in November, 2010, with a maximum estimated scavenging rate of 25%, although most of this scavenging was likely done by other mice. Some of the mouse carcasses could have been scavenged by gulls, however, though it is also possible that none of the mouse carcasses were scavenged by gulls (Grout, 2012; Pott and Grout, 2012). Given the range of 0-25% of rodents in the diet of unhazed gulls, we selected an average probability of 12.5% for daily probability of consuming mice when they are intoxicated and readily available. A binomial distribution was assumed for this variable for each day of the model simulation.

The availability of mice for consumption by western gulls declines following exposure to brodifacoum. In a study by Fisher (2009), rats exposed to brodifacoum in their diet showed few symptoms for the first 5 days following initial exposure after which symptoms began to appear. All rats died 6-13 days following initial exposure. Eighty-seven to 100% of rodents generally retreated to burrows to succumb following onset of symptoms stemming from exposure to brodifacoum (Taylor, 1993; Howald, 1997; Buckalew et al., 2008). These mice would not be available for consumption by unhazed western gulls on SFI. We used the Trial 3 data from Fisher (2009) and the worst case value of 87% for mice retreating to burrows to estimate the proportion of the mouse population available for consumption on SFI as a fraction of pre-

exposure abundance. Based on data from Fisher (2009), symptoms were assumed to precede death by 2 days. The fitted regression model for the worst case scenario is shown in Figure 3-2. In the western gull risk model, once mice are dead, they are no longer available. Intoxicated mice on the surface, however, are available for consumption. The regression model for the worst case scenario is:

$$y = 0.0116x^2 - 0.215x + 1 \ (worst\,case)$$

Model fit for the worst case scenario was excellent with a correlation coefficient of 0.99. Thus, we have high confidence in the parameterization of the regression model. In the western gull risk model, consumption of mice was assumed to decline in direct relation to the decline in availability of mice relative to pre-application conditions. Thus, the daily probability of an unhazed gull consuming mice is adjusted to account for the availability of mice compared to pre-exposure. For example, if the daily probability of an unhazed gull consuming mice on day zero is 12.5% and the availability of mice on the surface compared to pre-exposure is 79.7% on day 5, then the daily probability of consuming mice on day 5 is 9.96% (i.e., 12.5% x 79.7% = 9.96%).

The availability of mice following application of diphacinone is not as well understood as is the case with brodifacoum. EPA (1998) noted that mice may experience severe symptoms as early as 3 days after exposure to diphacinone and are generally all dead following 9 days of continuous exposure. For this assessment, we assumed that an equal percentage of mice died on each day from day 3 to day 9. Because there were no data on the percentage of intoxicated and dead mice that remain above ground, we assumed the worst case scenario that all mice remained above ground following exposure to diphacinone. Assuming that all intoxicated and dead mice remain above ground means that they are available for consumption, which is not the case with mice that are below ground.

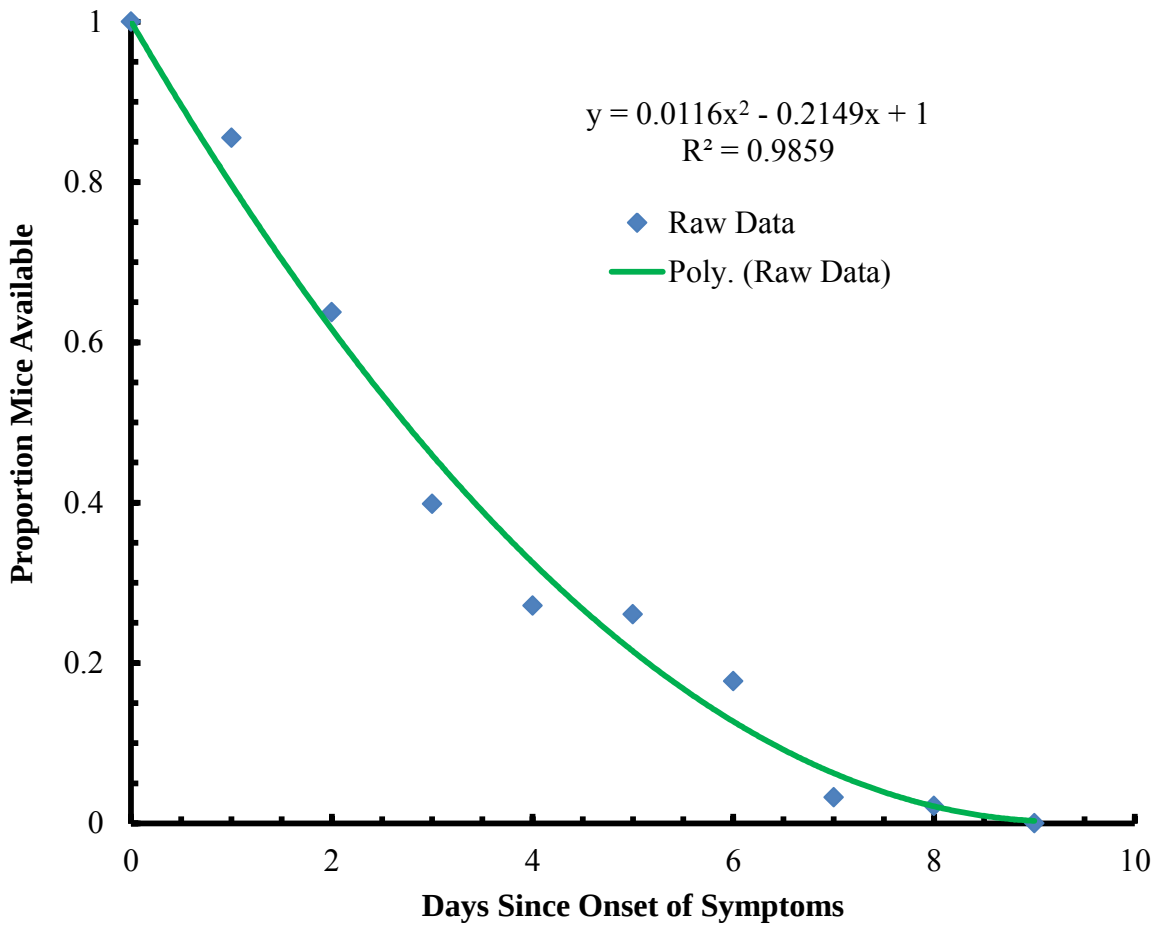

Figure 3-2. Proportion of mice available for consumption by western gulls following application of brodifacoum on SFI. Raw data are from Fisher (2009). The fitted model is a 2nd order polynomial model. Symptoms begin 5 days after initial application with death following 2 days after onset of symptoms.

As with pellets, once unhazed western gulls are aware of intoxicated mice as an easy food source, they are more likely to return to that food source on successive days. We incorporated a conditional probability for daily probability of consuming mice to account for this learned behavior. Quantitative data to parameterize the conditional probability, however, are lacking. As with pellets, we assumed a conditional probability of 90% for mice based on discussions with Dan Grout from Island Conservation. The conditional probability essentially adjusts the daily probability of an unhazed gull consuming mice given the result from the previous day.

In addition to determining whether an unhazed gull feeds on mice in each day of the model simulation, we need to determine the number of mice consumed on days when consumption occurs. We determined the number of mice required to meet the metabolic needs of adult gulls. The gross energy of mice is 8.4 kJ/g ww and they are assimilated by birds with an efficiency of 78% (EPA, 1993). Thus, the metabolizeable energy of mice is 6.55 kJ/g ww. Assuming an average body weight of 15.5 g for the house mouse (calculated from 278 samples during 2010 SFI field trials), the metabolizeable energy of each mouse is 102 kJ/mouse. Adult western gulls

require approximately 288 and 336 kJ/day for female and male western gulls, respectively (Pierotti and Annett, 1991; EPA, 1993). Thus, the upper bound for mice consumed per day to meet daily energetic requirements for male western gulls would be 3 (336/102 ≈ 3). By adding 1 to a value drawn randomly from a Poisson distribution with a rate of 0.2 generates an upper bound of 3 mice/gull/day. It is possible for gulls to exceed their daily energetic requirements on any given day but such a situation is not possible, on average, over many days.

Unhazed gulls could conceivably ingest both pellets and mice on the same day. To ensure that the model does not allow for exceedance of daily energetic requirements, the number of mice that could be consumed daily was limited to 0 if number of pellets consumed daily was >25, 1 if number of pellets consumed daily was >15-25, 2 if number of pellets consumed daily was >5-15, and 3 if number of pellets consumed daily was 5 or less.

To determine rodenticide concentration in unhazed gulls via consumption of mice requires data on expected concentration in mice. For brodifacoum, Howald et al. (2001) cite a mean concentration in mice exposed for 4-9 days to 25 mg ai/kg bait (i.e., same concentration as Brodifacoum-25D) of 2.71 mg ai/kg ww (standard deviation=0.7). Howald et al. (1999), however, cite a mean concentration of 4.9 mg ai/kg ww in exposed mice. We selected the worst case mean concentration in mice of 4.9 mg ai/kg ww. The coefficient of variation (CV) determined in the Howald et al. (2001) study (CV = 0.7/2.71 x 100 = 25.8%) was used to derive the standard deviation of 1.26 for the worst case scenario. Concentrations in mice were assumed not to change over time given the persistence of brodifacoum in tissues (Erickson and Urban, 2004) and the short period of time that mice remain after initial rodenticide application. For each mouse consumed in the brodifacoum model, a value was randomly chosen from a lognormal distribution parameterized with the mean concentration and associated standard deviation.

Little information is available on concentrations of diphacinone in mice following exposure to bait. Pitt et al. (2011) exposed mice to diphacinone in pellets at the same concentration as proposed for SFI (i.e., 50 mg ai/kg bait). Although the authors did not measure the resulting concentrations of diphacinone, they did determine mouse body weights and pellet ingestion rates in six mice that died during the course of the study (see Tables 1-3 in Pitt et al., 2011). Assuming that the mice did not metabolize or eliminate any of the ingested diphacinone, a worst case assumption, the resulting mean concentration in mice was 51.5 mg ai/kg bw. The corresponding standard deviation was 13.0. As with brodifacoum, diphacinone concentrations in mice were assumed not to change over time given the persistence of this pesticide in tissues (Erickson and Urban, 2004) and the short period of time that mice remain after rodenticide application. For each mouse consumed in the diphacinone model, a value was randomly chosen from a lognormal distribution parameterized with the mean concentration and associated standard deviation.

The western gull risk model assumes a 5 day lag time for consuming brodifacoum-contaminated mice because this is the length of time required for mice to become intoxicated and thus easily captured (Fisher, 2009). The corresponding value for diphacinone is 3 days (EPA, 1998).

Although the rates of metabolism and elimination of brodifacoum and diphacinone are slow in birds, we incorporated this variable in the western gull model because of the length of the model

runs (i.e., 90 days following initial application). Erickson and Urban (2004) reviewed the available literature for birds and determined a tissue half-life of 217 days for brodifacoum and 90 days for diphacinone. Assuming first-order kinetics, the resulting fractions of brodifacoum and diphacinone retained in gull tissues on a daily basis are 0.997 and 0.992, respectively.

EFFECTS CHARACTERIZATION

In this chapter, we derive effects metrics (i.e., dose-response curves) for gulls or surrogate species exposed to brodifacoum and diphacinone. The chapter concludes with a discussion of the pros and cons of using effects metrics from oral gavage studies versus dietary studies because the latter are much more available for rodenticides but are generally considered to be of low relevance in avian risk assessments for pesticides.

EFFECTS METRICS FOR BRODIFACOUM

The available information on the acute toxicity of brodifacoum to various bird species is summarized in Table 4-1. Avian LD50s range over nearly two orders of magnitude from 0.26 mg ai/kg bw for the mallard (*Anas platyrhynchos*) to 20 mg ai/kg bw for the Paradise shelduck (*Tadorna variegata*). By comparison, Erickson and Urban (2004) noted that the warfarin LD50 for the mallard is 620 mg ai/kg bw.

Table 4-1. Acute toxicity of brodifacoum to avian species (modified from Erickson and Urban, 2004; Godfrey, 1985; Eason et al., 2002; Bowie and Ross, 2006).

Species	LD50 (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, 1985
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
Australasian harrier	10	
Paradise shelduck	>20[b]	Eason et al., 2002

[a] the lowest concentration tested

Table 4-1. Acute toxicity of brodifacoum to avian species (modified from Erickson and Urban, 2004; Godfrey, 1985; Eason et al., 2002; Bowie and Ross, 2006).

Species	LD50 (mg ai/kg bw)	Reference

[b] the highest concentration tested

Because this assessment focused on consumption of pellets and mice over a long period of time, the preferred effects metric would be from a dietary exposure study. The dietary route of exposure is preferred over oral gavage exposures (i.e., acute oral tests) because gavage exposures are generally relevant to situations where active ingredients are ingested rapidly and in large doses (e.g., consumption of pesticide granules) (ECOFRAM, 1999; EPA, 2004).

In our assessment, we assumed that sensitivity of western gulls to brodifacoum exposure was in the range demonstrated for other gull species. Based on reviews conducted by Godfrey (1985), Eason et al. (2002), Erickson and Urban (2004) and Bowie and Ross (2006), LD50s for gull species ranged from <0.75 mg ai/kg bw for the southern black-backed gull (*Larus dominicanus*) to <5 mg ai/kg bw for the black-billed gull (*Larus bulleri*). For both species, however, the lowest dose tested caused greater than 50% mortality. Thus, there were insufficient data for deriving dose-response curves. Although not included in the above reviews, dietary toxicity data of sufficient quality were available to derive a dose-response curve for the laughing gull (*Larus atricilla*). The toxicity data were from two studies conducted by Wildlife International (1979a,b). Birds were acclimated for two weeks at which point they were randomly assigned to either a control diet consisting of toxicant-free masticated rodent tissue or one of ten treatment diets (both studies combined) consisting of spiked masticated rodent tissue. Five birds were placed in each dietary treatment. Exposure continued for 5 days followed by an additional 5-week exposure period in which all birds were maintained on a diet of Southern States cat food.

1.0 For the statistical analysis, daily treatment dose was calculated by multiplying treatment concentration by the corresponding average measured food intake rate. The daily treatment doses were then normalized to average gull body weight (average of 5 gulls/treatment on days 0 and 6). Finally, the doses were summed across the 5 days of exposure. The latter step assumes that metabolism and elimination of brodifacoum during the 5-day exposure period would have been minimal, an assumption that has been verified elsewhere (Fisher, 2009; see also Erickson and Urban, 2004). The statistical analysis was carried out in SAS using PROC PROBIT with dose log10 transformed. The fitted LD50 was 0.588 mg ai/kg bw and the probit slope was 2.32 (Figure 4-1). The LD50 of 0.588 mg ai/kg bw derived for laughing gulls is the lowest bounded LD50 reported for gull species (or indeed any bird species) exposed to brodifacoum.

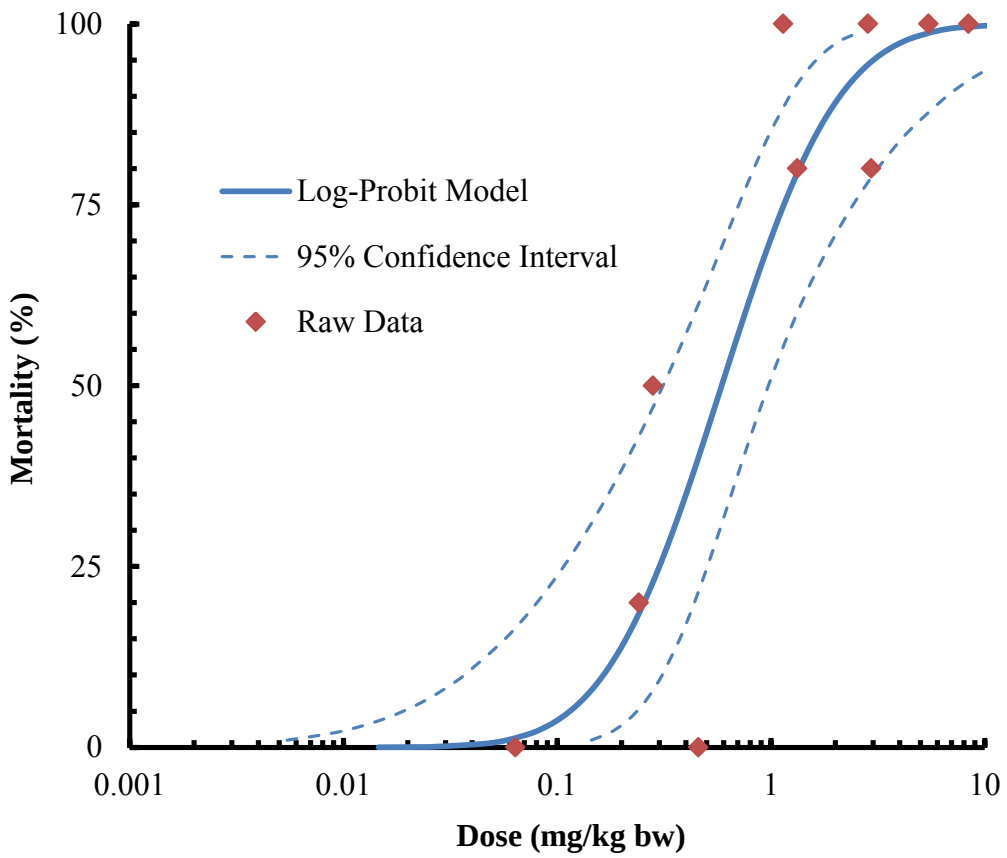

Figure 4-1. Dose-response relationship for effects of brodifacoum on laughing gulls.

EFFECTS METRICS FOR DIPHACINONE

Relatively few avian toxicity studies have been conducted for diphacinone and none have involved gull species (EPA, 1998a; Erickson and Urban, 2004; Rattner et al., 2010). A reliable LD50 for northern bobwhite (*Colinus virginianus*) could not be estimated by Campbell et al. (1991) because dosages were separated by a factor of 5. EPA (1998a), however, suggested that the LD50 for northern bobwhite fell between 400 and 2000 mg ai/kg bw. A subsequent study by Rattner et al. (2010) estimated an LD50 of 2014 mg ai/kg bw for northern bobwhite which is close to the upper bound estimated by EPA (1998) and reasonably close to the LD50 of 3158 mg ai/kg bw reported for mallards (*Anas platyrhynchos*) (Erickson and Urban 2004). Based upon data from avian species commonly used in pesticide registration tests (i.e., northern bobwhite, mallards), diphacinone appears to be far less toxic to captive birds than is brodifacoum (see Table 4-1). However, a recent diphacinone acute toxicity test with American kestrels (*Falco sparverius*) resulted in an LD50 of 97 mg ai/kg bw, indicating that kestrels are over 20 times more sensitive than northern bobwhite, and over 30 times more sensitive than mallards. In addition, the results of a study in which diphacinone-poisoned mice (*Peromyscus maniculatus*) were fed to great-horned owls (*Buto virginianus*) and a saw-whet owl (*Aegolius acadicus*)

suggests that owl species are more sensitive than northern bobwhite (Mendenhall and Pank 1980). Given the lack of diphacinone toxicity data for gull species and the high uncertainty regarding toxicity to untested species, we used the results for American kestrels from Barnett and Rattner (2010) as a surrogate for the western gull. A log-probit regression analysis conducted by the study authors indicated an LD50 of 97 mg ai/kg bw with a probit slope of 6.69. These parameters were used in the western gull model for diphacinone.

ORAL GAVAGE VERSUS DIETARY EXPOSURE STUDIES

Often oral gavage studies such as used to estimate diphacinone toxicity to American kestrels overestimate toxicity when compared to dietary studies. In dietary studies, metabolism and excretion over the course of the study can reduce accumulation of the pesticide thus reducing toxicity compared to oral gavage studies (EPA, 2004). However, in the case of brodifacoum, metabolism and excretion are unlikely to mediate toxicity when ingested over an extended period because the compound is highly persistent (Eason et al., 2002). The mean liver retention time for brodifacoum in birds is 217 days, respectively (Erickson and Urban, 2004). Diphacinone is also persistent in the liver with a mean retention time of 90 days (Erickson and Urban, 2004). As a result, there may be no significant difference between toxicity results from oral gavage and dietary exposure studies (Erickson and Urban, 2004).

To compare effects metrics from oral gavage and dietary exposure studies, the units have to be the same (i.e., mg ai/kg bw). For this analysis the LC50 value was utilized, which is the concentration of a chemical in air or water that is expected to cause death in 50% of test animals. This requires multiplying the LC50 from the dietary exposure study by the daily food intake rate normalized to body weight multiplied by the number of exposure days (the assumption being that metabolism and excretion are minimal). Long et al. (1992) determined an LC50 of mg ai/kg diet for mallards. The food consumption rate for birds in the treatment group closest to the LC50 (i.e., 1000 mg ai/kg diet) during the treatment period was 0.064 kg diet/bird/day. The average body weight (*BW*) during the treatment period of birds in the 1,000 mg/kg-diet treatment group was 0.236 kg. Thus, the median lethal daily dose is 246 mg ai/kg bw/day. Assuming that diphacinone is not metabolized or excreted to any significant extent over the exposure period, the daily dose is multiplied by the exposure period (5 d) to determine an LD50 of 1,231 mg ai/kg bw. For mallards exposed to diphacinone, the dietary exposure LD50 is lower (i.e., more toxic) than the corresponding oral gavage LD50 of 3,158 mg ai/kg bw cited by Erickson and Urban (2004). No other species have the required information to determine the relative toxicity of oral gavage and dietary exposure studies for diphacinone. Based on the limited evidence for mallards and the expected persistence of diphacinone in birds, we assume that it is reasonable to use the results of an oral gavage study in deriving the avian effects metric for this pesticide.

RISK CHARACTERIZATION

Model runs were conducted to determine how different application options (e.g., different application dates, differing rates of hazing success, etc.) for brodifacoum and diphacinone affected predictions regarding mortality of western gulls. The following sections describe the results of an analysis conducted to determine how many simulations were required to produce consistent model predictions. Subsequent sections describe the results of the model analyses conducted for brodifacoum and diphacinone. An analysis conducted by Nur et al. (2012) for western gulls on SFI indicated that a one-time mortality event of up to 1700 individual gulls would not result in a detectably significant change in the population trend of the western gull on the Farallones over a 20-year period. We compare our model predictions to this benchmark in this chapter.

MODEL STABILITY

A model stability analysis was performed on the western gull risk model to determine the number of model simulations required to produce estimates of proportion mortality that are consistent from one model run to the next. The baseline scenario for this analysis assumed an initial application date of November 29 for brodifacoum, a hazing success rate of 90%[7], and the time to the first significant rainfall event after the second and final application of 28 days. All other input parameters are those listed in Table 3-1. We ran the model for simulation sizes ranging from 100 to 100,000 simulations, and the model was run 10 times for each simulation size. As expected, variability in predictions regarding proportion mortality decreased as the number of simulations increases (Figures 5-1 and 5-2). The proportion gulls at SFI experiencing mortality had a wide range of 0.0780 to 0.0.106 for 100 simulation model runs but a much narrower range of 0.0894 to 0.0902 for 100,000 simulation model runs. Further, the coefficients of variation for 100 and 100,000 simulation model runs were 10.3 and 0.287, respectively. Clearly, the more simulations, the lower the coefficient of variation and the increased likelihood that model runs will produce consistent predictions. For this assessment, 30,000 simulations were conducted for each model run because the coefficient of variation was quite low (0.603) with this number of simulations. In addition, little was gained in terms of model stability by increasing the number of simulations to 100,000 (Figures 5-1 and 5-2).

[7] The inputs chosen for the model stability analysis are unimportant in determining how many simulations are required to ensure a stable output (i.e., a consistent answer). Thus, readers should not interpret the inputs chosen for this analysis as being in any way relevant to the actual analyses of risk to western gulls. For example, in the actual analyses of risk to western gulls, we varied hazing success from 75 to 98% and application dates from November 1 to December 20.

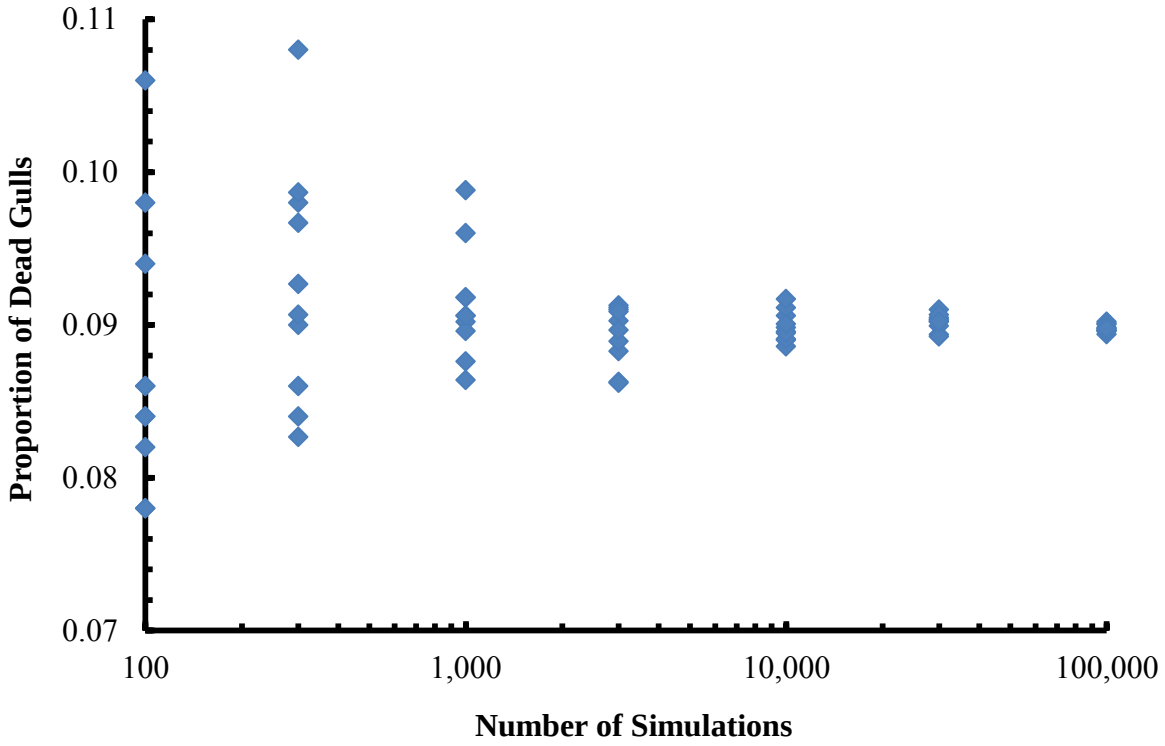

Figure 5-1. Results of the model stability analysis for proportion of dead western gulls exposed to brodifacoum in relation to the number of simulations. The analyses assumed a start date of November 29, a hazing success rate of 90%, and a time to first significant rainfall event after the final application of 28 days. All other assumptions are listed in Table 3-1.

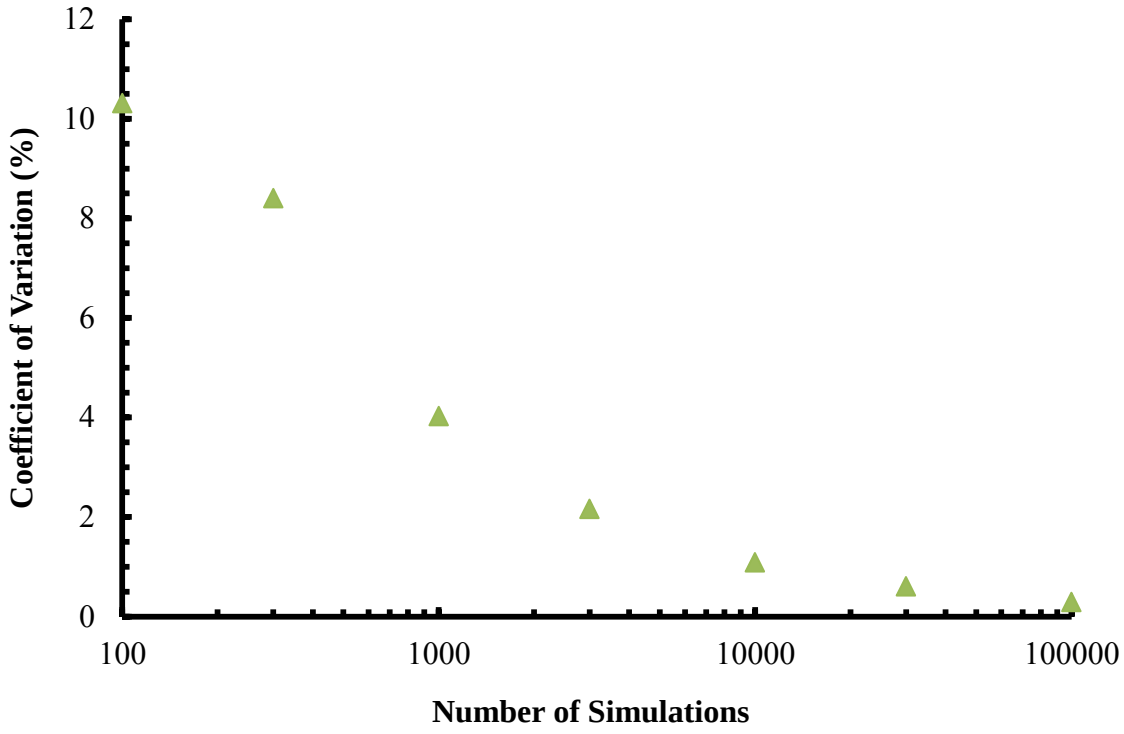

Figure 5-2. Results of the model stability analysis for the coefficient of variation of proportion of dead gulls exposed to brodifacoum in relation to number of simulations. The analyses assumed a start date of November 29, a hazing success rate of 90%, and a time to first significant rainfall event after the final application of 28 days. All other assumptions are listed in Table 3-1.

MODEL RESULTS FOR BRODIFACOUM

The results of all model runs conducted for brodifacoum can be found in Appendix A. The following sections summarize the results for each of the major factors considered potentially important in designing an application and risk management strategy for brodifacoum. Results are presented as the proportion and number of western gulls present at some point on SFI during the period November 1 to end of March that experience mortality based on various modifications of the input parameters. The text and figures below provide examples from the various possible scenarios.

Initial Application Date

Model runs were performed to determine how initial application date of brodifacoum affected the proportion of dead western gulls (Figure 5-3, Appendix A) and number of dead western gulls (Figure 5-4, Appendix A) on SFI. The results shown in Figures 5-3 and 5-4 involved a scenario where hazing was assumed to be 90% effective, and the first significant rainfall occurred 28 days after the second application. All other input values are listed in Table 3-1. The results from other scenarios are shown in Appendix A. As shown in Figures 5-3 and 5-4, western gull mortality increases with later initial application dates, coinciding with the increased numbers of gulls being

present on SFI. Predicted mortality did not change substantively with initial application date after approximately November 22nd.

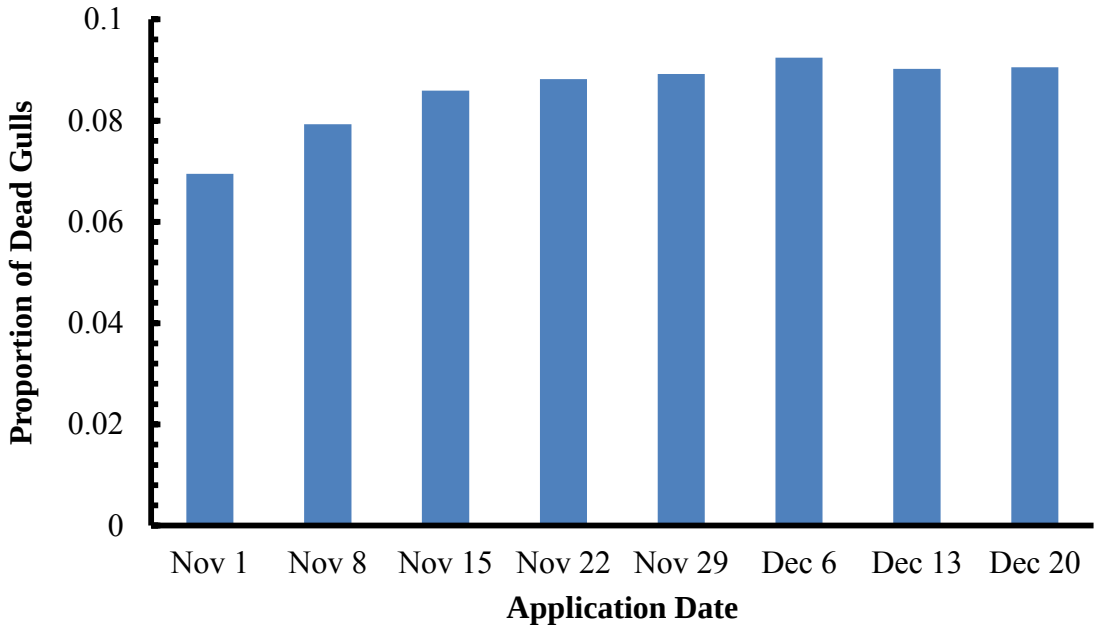

Figure 5-3. Model results for proportion of dead western gulls as a result of varying initial application date for brodifacoum, assuming 90% hazing effectiveness and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

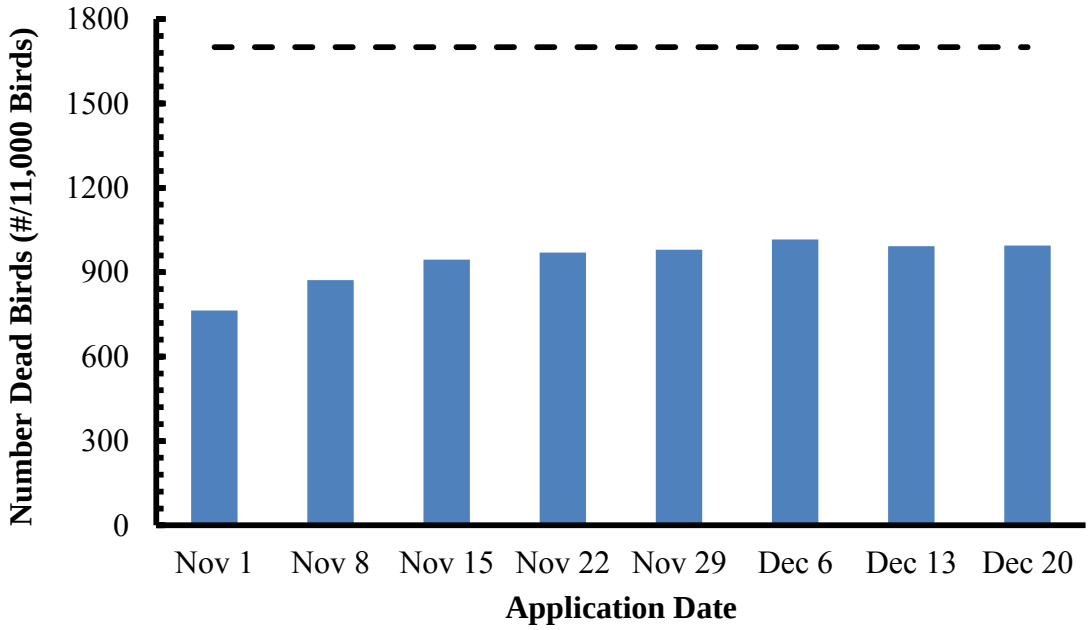

Figure 5-4. Model results for number of dead gulls as a result of varying initial application date for brodifacoum, assuming 90% hazing effectiveness and 28 days until the first

significant rainfall. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls, the number considered the maximum possible without affecting long-term population viability.

Proportion of Gulls Removed From SFI by Hazing

The utility of hazing in reducing gull mortality was investigated by varying hazing success from 75% to 98%. For the results shown in Figures 5-5 and 5-6, the date of initial application was November 29th, and there were 28 days until the first significant rainfall following the second application (see Table 3-1 for other inputs). The results of other scenarios are shown in Appendix A. As expected, there was a strong negative relationship between gull mortality and hazing success (Figures 5-5 and 5-6) and the threshold of 1700 dead gulls was surpassed with 75% hazing success (Figure 5-6). The results in Appendix A indicate that 90% hazing success is required to ensure that the threshold of 1700 gulls is not surpassed for all possible initial application dates and to cover the range of possible dates over which the first significant rainfall event occurs following the second application of brodifacoum.

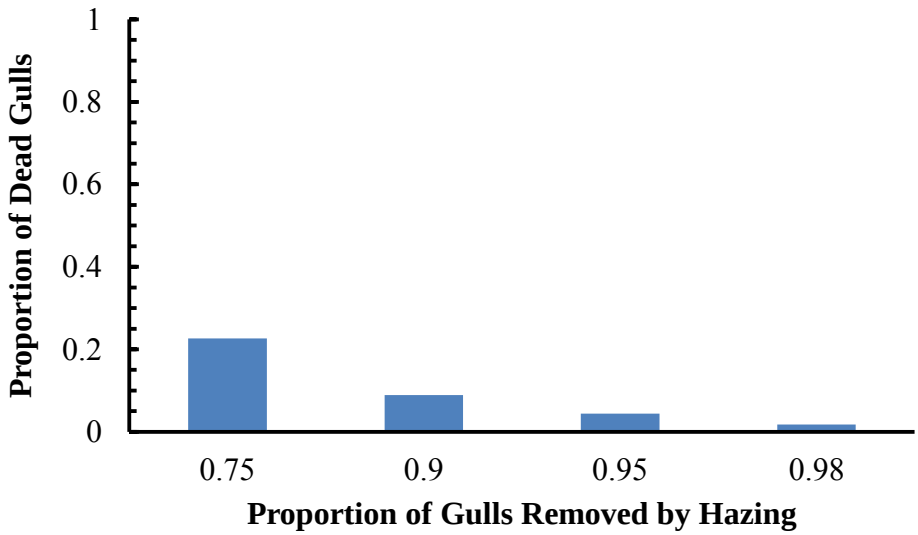

Figure 5-5. Model results for proportion of dead gulls as a function of hazing success, assuming November 29th date of first application and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

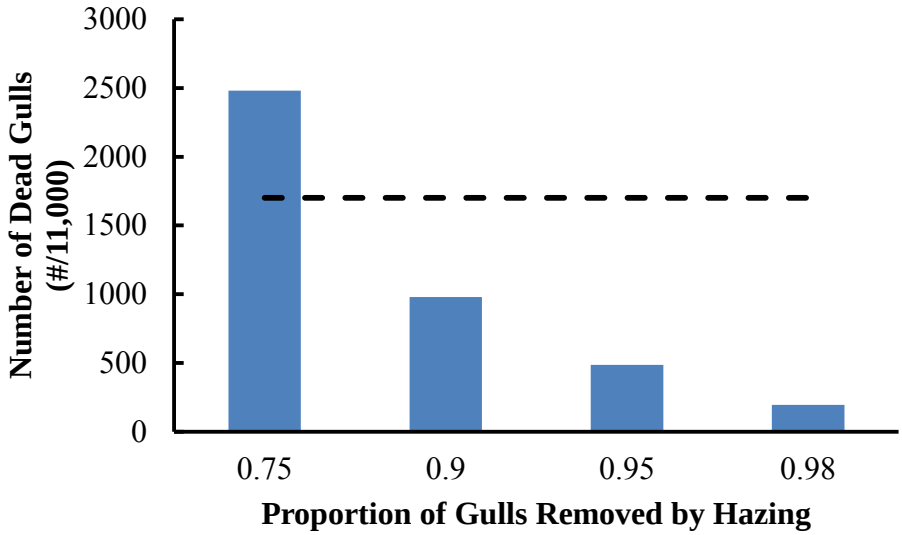

Figure 5-6. Model results for number of dead gulls as a function of hazing success, assuming November 29th date of first application and 28 days until the first significant rainfall. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

Time to Significant Rainfall Event

A significant rainfall event is one in which sufficient rain falls to degrade remaining bait pellets (i.e., at least 2 inches in 1-3 day time span). Dates of historic rainfall events were compiled and analyzed to determine a best, worst, and most likely scenario. The model was then run to determine the proportion (Figure 5-7) and number (Figure 5-8) of dead birds following each length of time until the rainfall event. The scenario shown in Figures 5-7 and 5-8 assumed an initial application date of November 29th and that hazing success was 90% (see Table 3-1 for other inputs). The results indicate that the proportion and number of dead birds increased with increasing time until the rainfall event. However, the quantity of dead birds was below the threshold of 1700 dead birds for all scenarios with 90% hazing success (Appendix A).

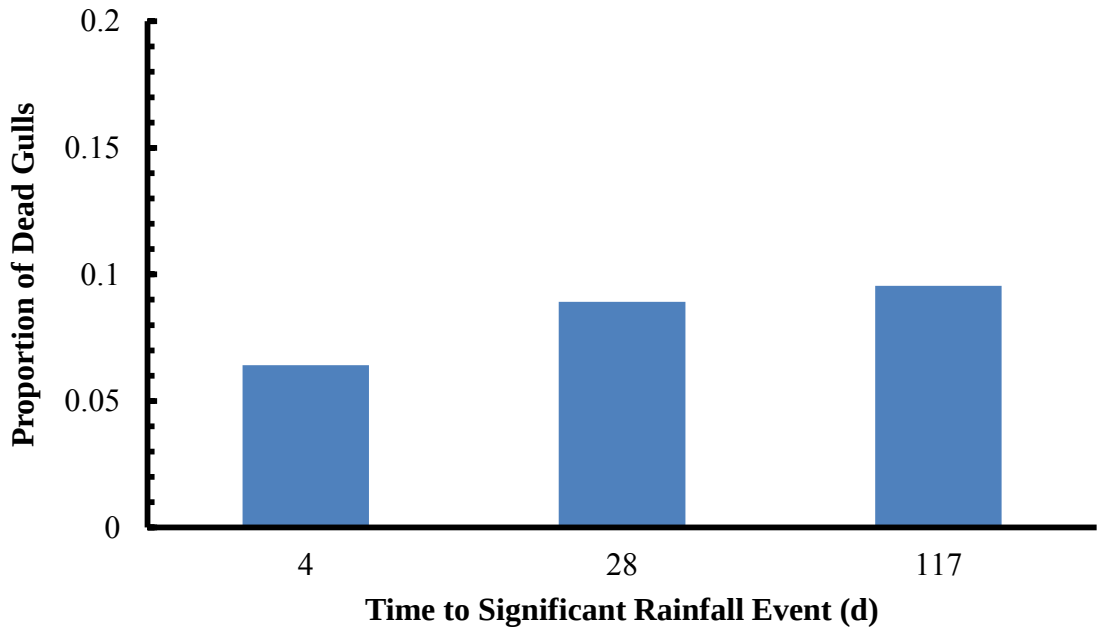

Figure 5-7. Model results for proportion of dead gulls as a function of time to significant rainfall after the second application, assuming November 29th date of first application and 90% hazing effectiveness. All other input values are listed in Table 3-1.

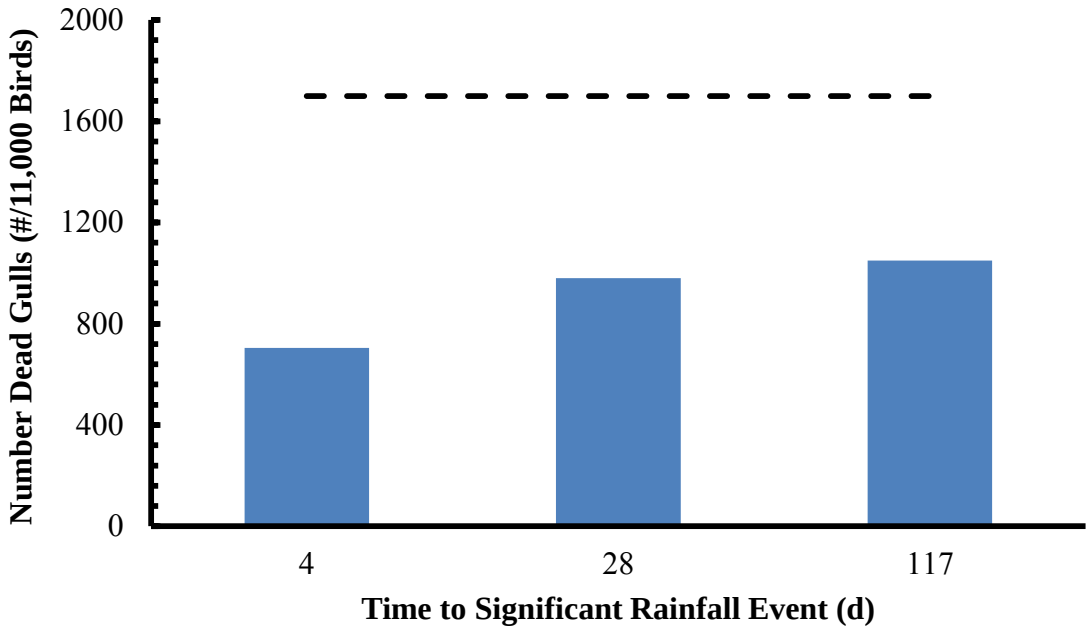

Figure 5-8. Model results for number of dead gulls as a function of time to significant rainfall after the second application, assuming November 29th date of first application and 90% hazing effectiveness. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

The worst case scenario of 117 days elapsing until the first significant rainfall event is likely unrealistic for SFI. The value was derived using November-December rainfall data from 1972-2010. Most of the Farallones annual rain falls in January and February, however, which would mean that the likelihood of going 117 days (or nearly 4 months) without a significant rainfall event from the time of the final brodifacoum application in November or December would be extremely low. Thus, the model predictions for 4 or 28 days to the first significant rainfall event after the final brodifacoum application are likely to be closer to reality.

Number of Applications

Although standard practice, and not a likely option for SFI, it is clear that reducing the number of brodifacoum applications to a single application significantly reduces expected gull mortality (Figures 5-9 and 5-10). The results shown in Figure 5-9 and 5-10 assumed an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall for the scenario involving two applications (see Table 3-1 for other inputs). Over 5 times more gulls died when two applications took place. Applying only one application, would not be best practice, and would likely compromise the effectiveness of the mouse eradication, which requires 100% lethal exposure to all mice.

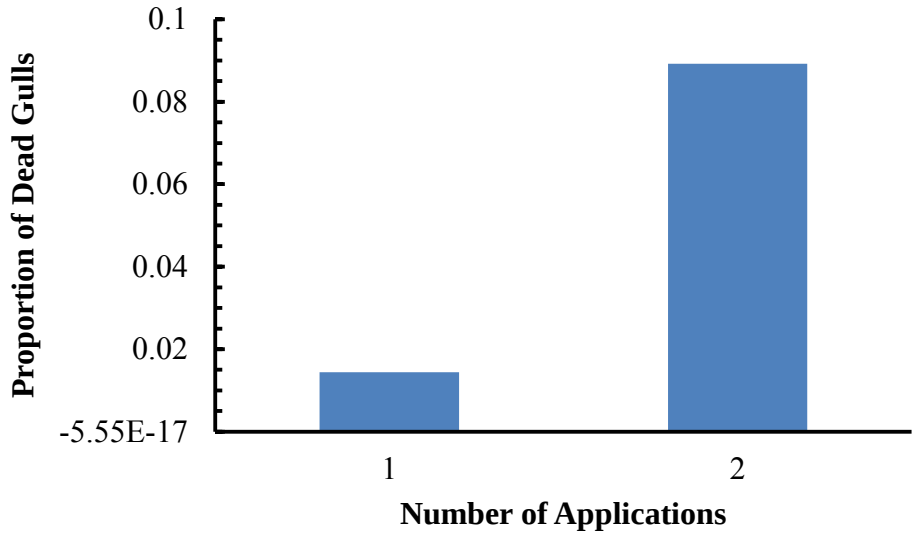

Figure 5-9. Model results for proportion of dead gulls as a function of number of applications of brodifacoum, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

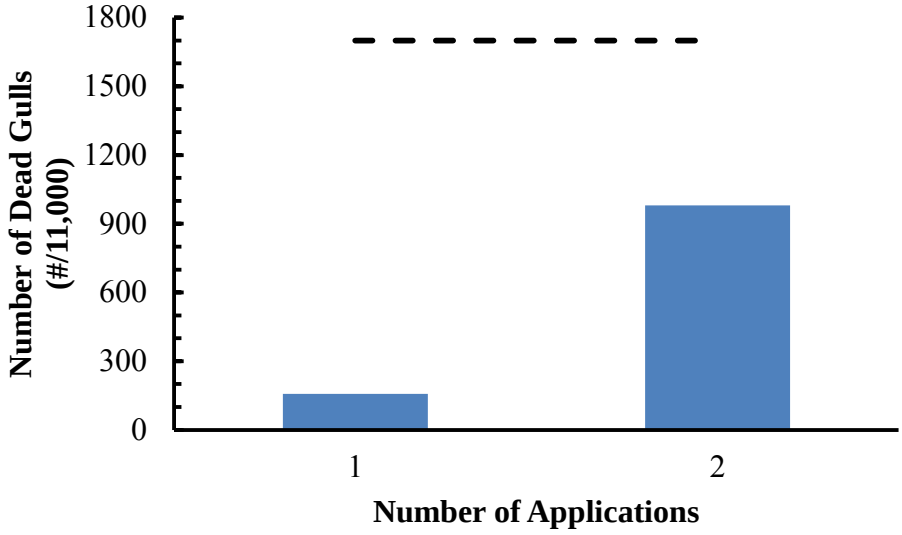

Figure 5-10. Model results for number of dead gulls as a function of number of applications of brodifacoum, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

Removal of Dead Mice

One possible management option to reduce mortality of western gulls is to remove dead mouse carcasses as they are discovered. Assuming an initial application date of November 29th, 90%

hazing effectiveness, and 28 days until the first rainfall (see Table 3-1 for other inputs), the results indicate no differences in the proportion and number of dead gulls as a result of not removing or removing dead mice (Figures 5-11 and 5-12). For brodifacoum, it appears that removal of dead mice would accomplish little in terms of reducing mortality of western gulls.

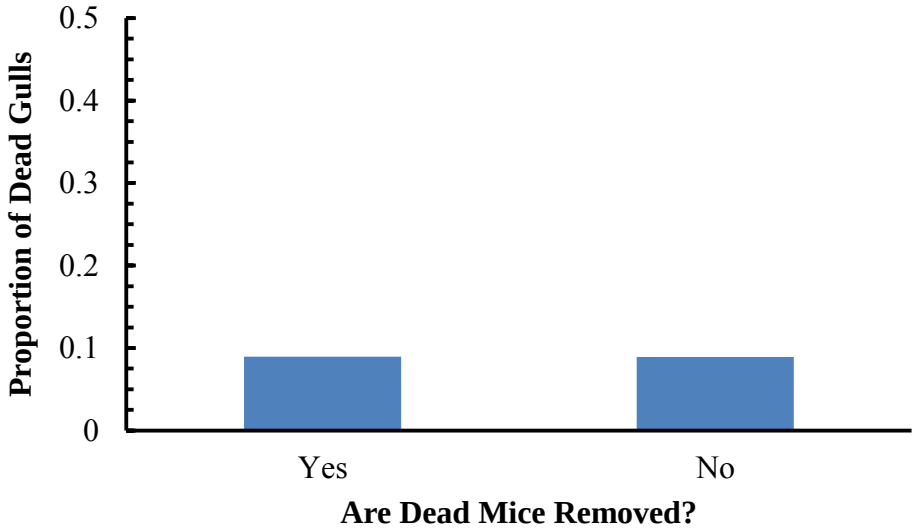

Figure 5-11. Model results for proportion of dead gulls as a function of whether dead mice are removed, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

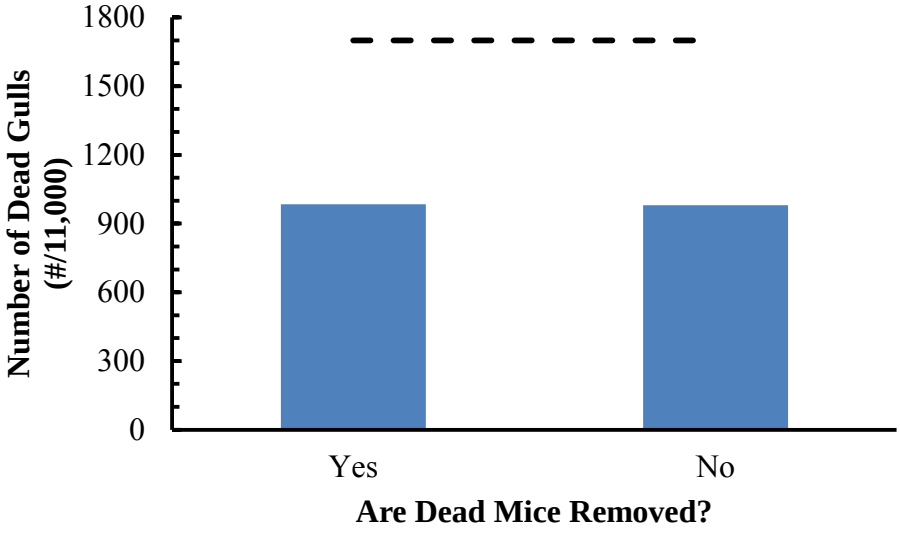

Figure 5-12. Model results for number of dead gulls as a function of whether mice are removed, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

MODEL RESULTS FOR DIPHACINONE

The results of all model runs conducted for diphacinone can be found in Appendix B. The following sections summarize the results for each of the major factors considered potentially important in designing an application and risk management strategy for diphacinone. Results are presented as the proportion and number of western gulls present at some point on SFI during the period November 1 to end of March that experience mortality based on various modifications of the input parameters. The text and figures below provide examples from the various possible scenarios.

Initial Application Date

Possible application dates for diphacinone were modeled to determine if the initial application date impacted the proportion (Figure 5-13) and number (Figure 5-14) of dead gulls. The results presented in Figures 5-13 and 5-14 assumed a hazing effectiveness of 90% and that the first rainfall event after the second application occurred 28 days later (see Table 3-1 for other inputs). Although the proportion of dead gulls was very low, it did increase with later initial application dates until approximately November 22nd (Figure 5-13). Likewise, Figure 5-14 shows that the number of dead gulls increased with later initial application dates, but that the threshold of 1700 dead gulls was never reached.

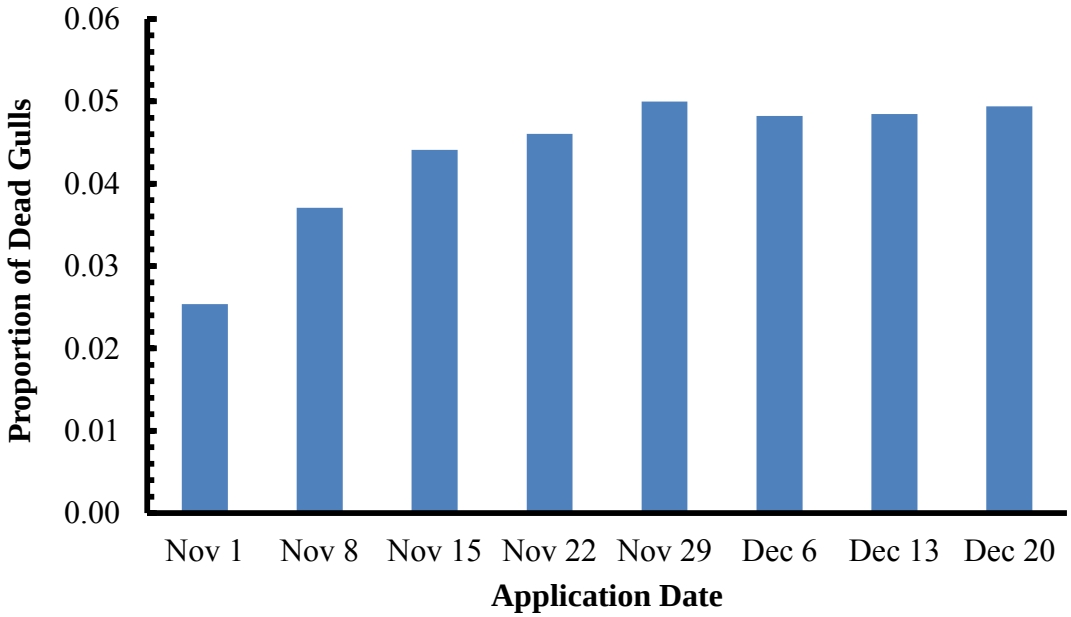

Figure 5-13. Model results for proportion of dead gulls as a result of varying initial application date for diphacinone, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

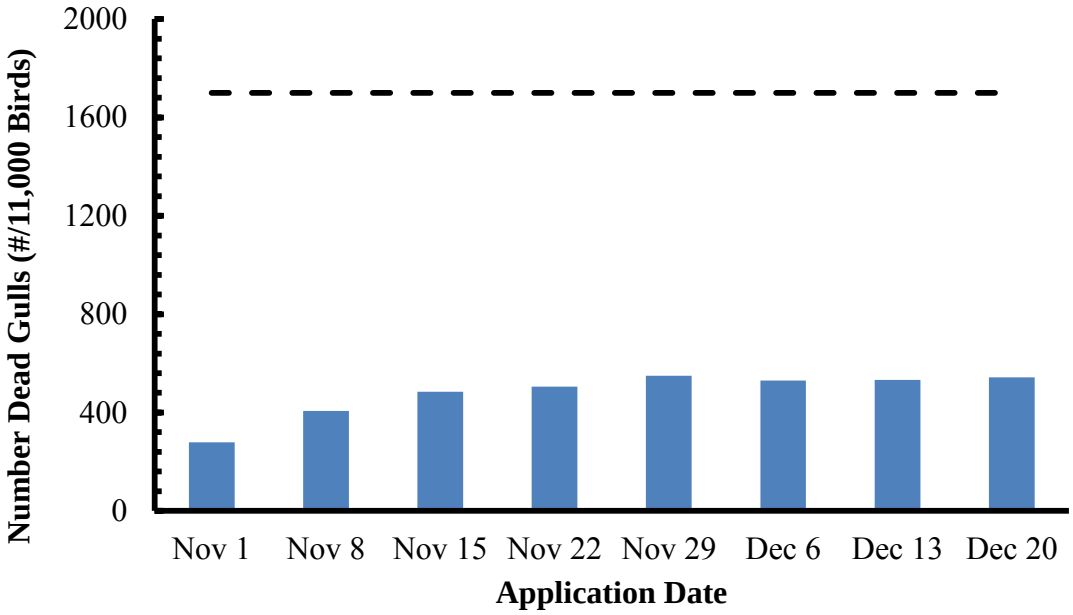

Figure 5-14. Model results for number of dead gulls as a result of varying initial application date for diphacinone, assuming an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

Proportion of Gulls Removed From SFI by Hazing

The utility of hazing in reducing gull mortality was investigated by varying hazing success from 75 to 98%. The results shown in Figures 5-15 and 5-16 assumed an initial application date of November 29th and that the first significant rainfall event occurred 28 days after the second application of diphacinone (see Table 3-1 for other inputs). As expected, the proportion and number of dead gulls decreased as hazing effectiveness increased. At 75% hazing effectiveness, the number of dead gulls was below the threshold of 1700.

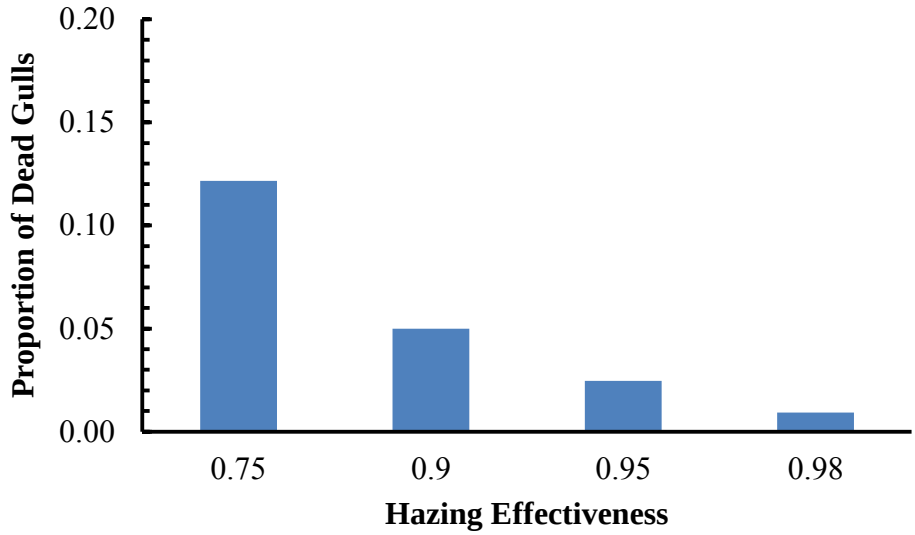

Figure 5-15. Model results for proportion of dead gulls as a function of hazing success, assuming an initial application date of November 29th, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1.

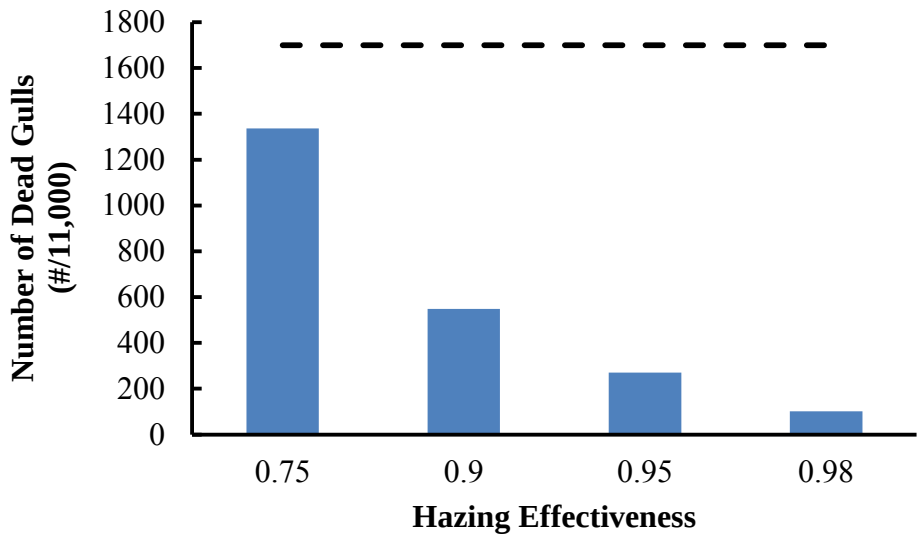

Figure 5-16. Model results for number of dead gulls as a function of hazing success, assuming an initial application date of November 29th, and 28 days until the first significant rainfall. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

Time to Significant Rainfall Event

The impact of time to a significant rainfall event after the second application on gull mortality was much more apparent for diphacinone than for brodifacoum. The results shown in Figures 5-17 and 5-18 assumed an initial application date of November 29th and 90% hazing effectiveness

(see Table 3-1 for other inputs). The proportion and number of dead gulls increased with increasing time until the rainfall event. However, the quantity of dead gulls was well below the threshold of 1700 for this scenario.

The worst case scenario of 117 days elapsing until the first significant rainfall event is likely unrealistic for SFI. The value was derived using November-December rainfall data from 1972-2010. Most of the Farallones annual rain falls in January and February, however, which would mean that the likelihood of going 117 days (or nearly 4 months) without a significant rainfall event from the time of the final diphacinone application in November or December would be extremely low. Thus, the model predictions for 4 or 28 days to the first significant rainfall event after the final diphacinone application are likely to be closer to reality.

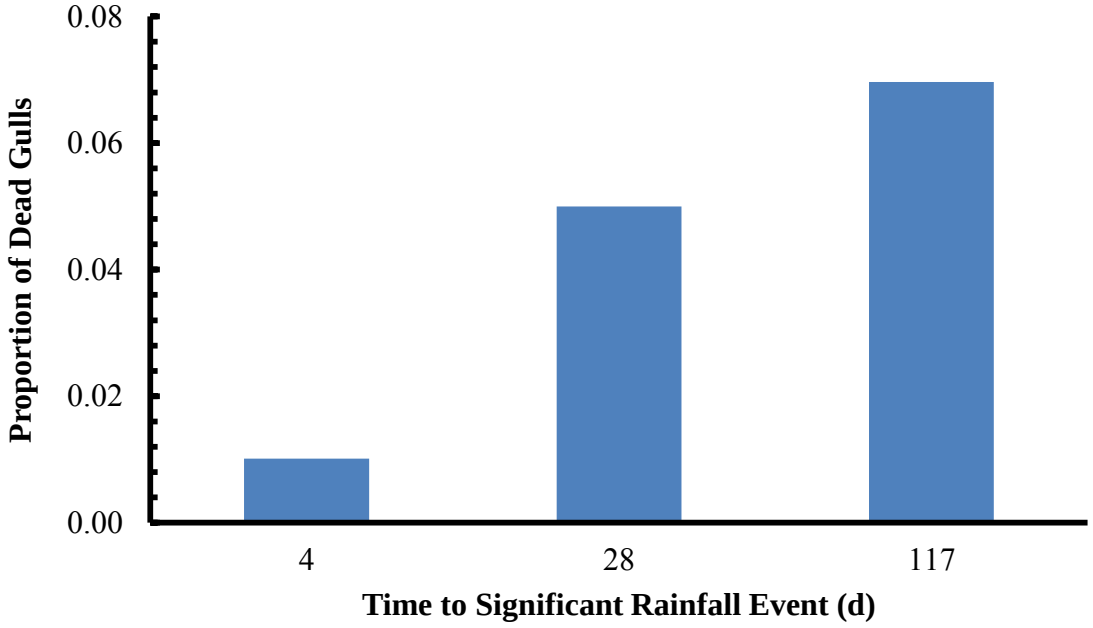

Figure 5-17. Model results for number of dead gulls as a function of time to significant rainfall after the second application, assuming an initial application date of November 29th, and 90% hazing effectiveness. All other input values are listed in Table 3-1.

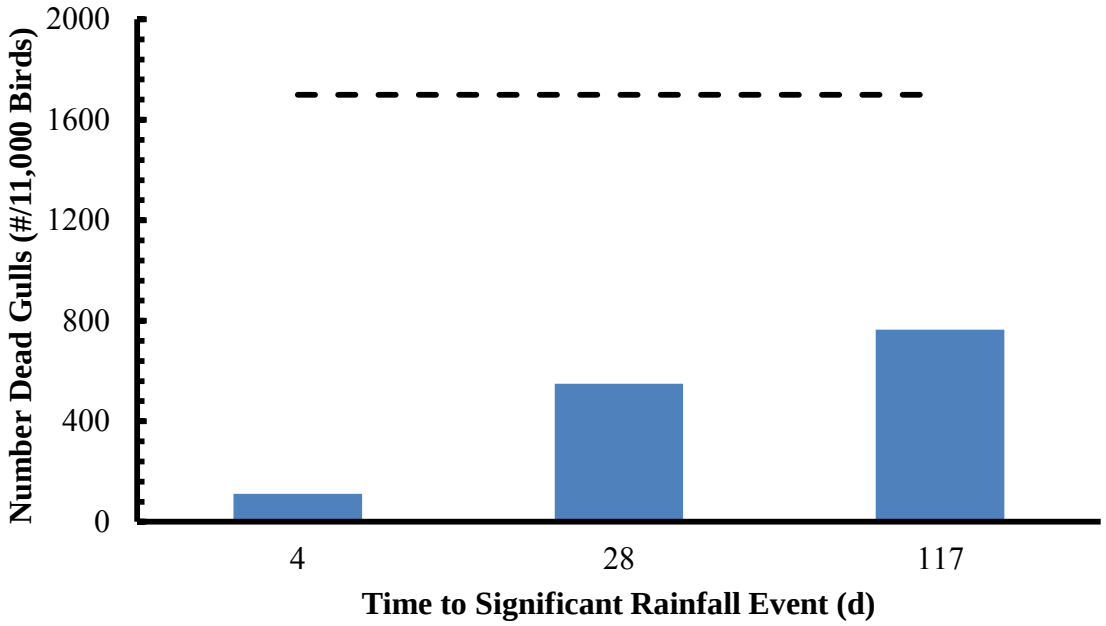

Figure 5-18. Model results for number of dead gulls as a function of time to significant rainfall after the second application, assuming an initial application date of November 29th, and 90% hazing effectiveness. All other input values are listed in Table 3-1. The dashed line represents 1700 dead gulls.

Number of Applications

The effect on number of applications was modeled for 1, 2 and 3 applications of diphacinone. The results shown in Figures 5-19 and 5-20 assumed an initial application date of November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall event after the second application (see Table 3-1 for other inputs). The results indicate that gull mortality would be near zero with only 1 or 2 applications of diphacinone but that a 3rd application greatly increases gull mortality.

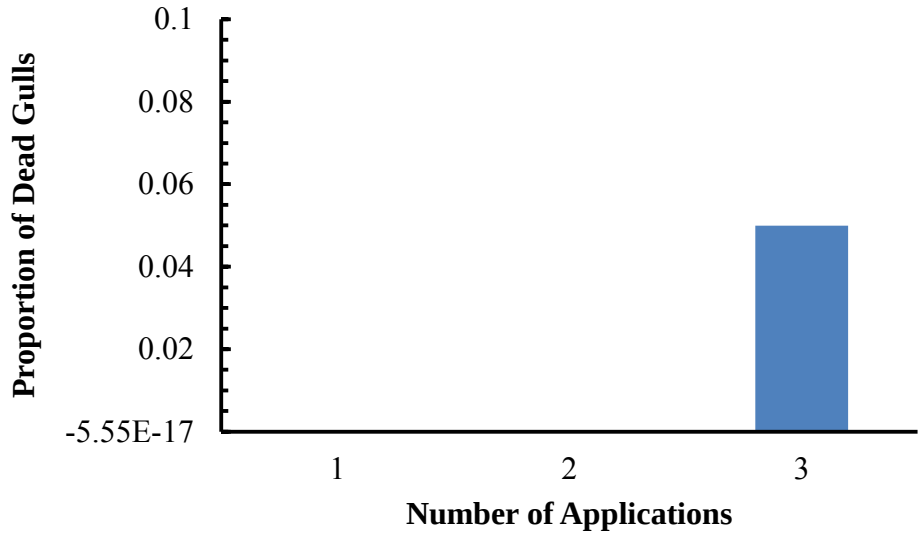

Figure 5-19. Model results for proportion of dead gulls as a function of number of applications, assuming an initial application date of November 29th, 28 days to first significant rainfall, and 90% hazing effectiveness. All other input values are listed in Table 3-1.

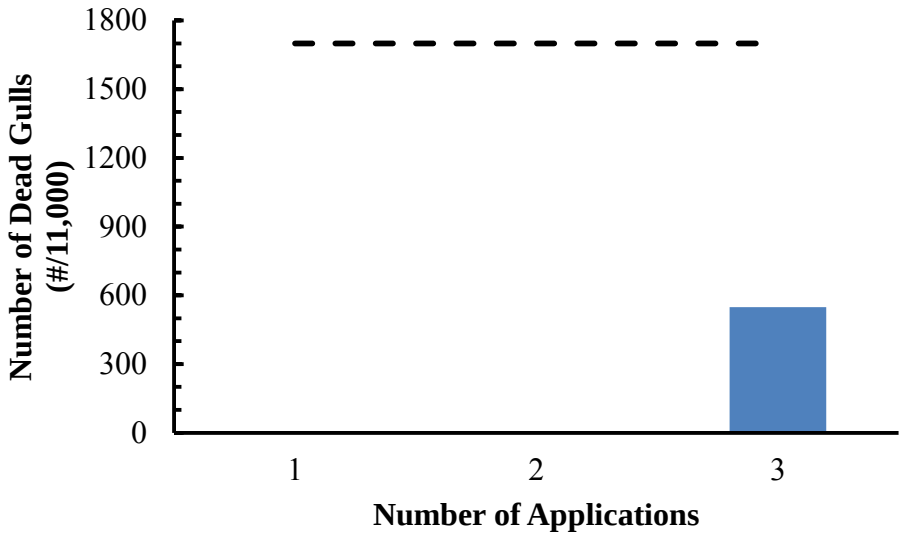

Figure 5-20. Model results for number of dead gulls as a function of number of applications, assuming an initial application date of November 29th, 28 days to first significant rainfall, and 90% hazing effectiveness. All other input values are listed in Table 3-1. The dash line represents 1700 dead gulls.

Removal of Dead Mice

Removal of dead mice was modeled to determine if this mitigation practice would reduce gull mortality. The results shown in Figures 5-21 and 5-22 assumed an initial application date of

November 29th, 90% hazing effectiveness, and 28 days until the first significant rainfall event after the second application (see Table 3-1 for other inputs). As with brodifacoum, removing dead mice did not significantly improve the survival of western gulls for diphacinone.

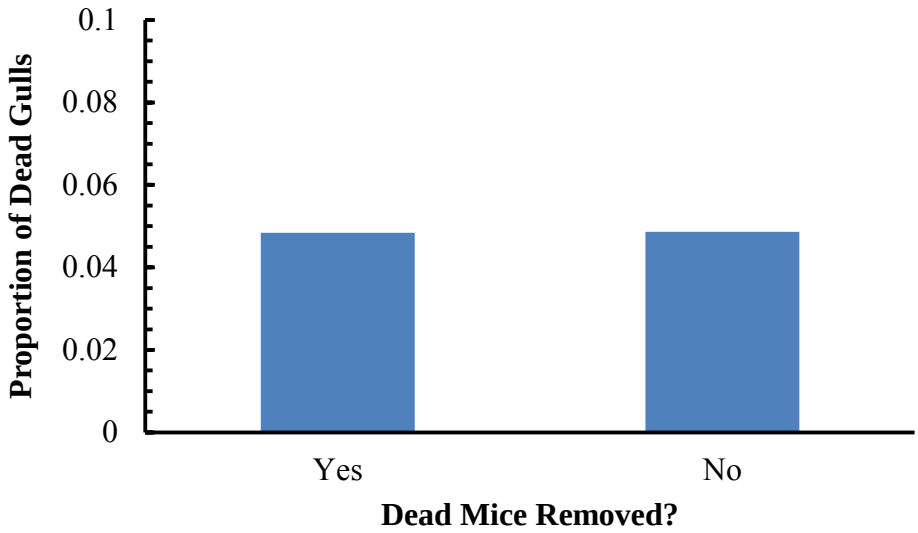

Figure 5-21. Model results for proportion of dead gulls as a function of whether mice are removed, assuming an initial application date of November 29th, 28 days to first significant rainfall, and 90% hazing effectiveness. All other input values are listed in Table 3-1.

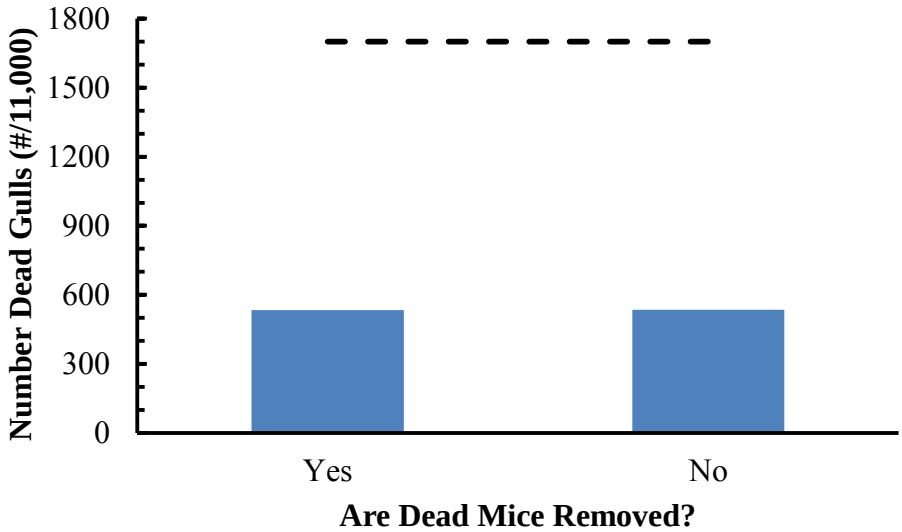

Figure 5-22. Model results for number of dead gulls as a function of whether mice are removed. The dashed line represents 1700 dead gulls, assuming an initial application date of November 29th, 28 days to first significant rainfall, and 90% hazing effectiveness. All other input values are listed in Table 3-1.

SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to identify how variation in the output of a model (e.g., number of dead birds) is influenced by uncertainty in the input variables. If the output variability precludes effective decision making, sensitivity analysis may be used to identify the input variables that contribute the most to the observed output variability. Subsequently, research efforts may be initiated to reduce uncertainty in those input variables.

Uncertainty and sensitivity analyses both focus on the output of a model and are therefore closely related. However, the purposes of the two types of analyses are different. An uncertainty analysis assesses the uncertainty in model outputs that derives from uncertainty in the inputs. A sensitivity analysis assesses the contributions of the inputs to the total uncertainty in the output.

Sensitivity analysis methods may be classified into three groups: screening methods, methods for local sensitivity analysis, and methods for global sensitivity analysis. Screening methods are generally used to separate influential input variables from non-influential ones, rather than quantify the impact that an input variable has on the output of the model. Screening methods are useful for models with large numbers of input variables. They are able to identify important input variables with little computational effort, but at a cost of losing quantitative information on the importance of the input variables. In contrast, local and global sensitivity measures provide quantitative estimates of the importance of each input variable. The difference between them is that the former focuses on estimating the impact of small changes in input variable values on model output, while the latter addresses the contribution to model output variance over the entire range of each input variable distribution.

Most screening methods revolve around the idea of "what if" analyses. That is, how would the outputs change if the value of a selected input variable was changed? With large models, this exercise needs to be systematic to be useful. Factorial designs, for example, are used to measure the influence of input variables on the output by taking into account both additive effects and interactions. The design involves selecting combinations of input variable values that provide the most information on the relationships between input and output variables. However, with a factorial design and a large model, the number of model runs (n^k, where k is the number of input variables, and n is the number of levels for each variable) quickly becomes unmanageable. Given the complexity of the western gull risk model, this approach was infeasible for this assessment.

One way to overcome the difficulties of a factorial design method is to set all input variable values to achieve the most likely response and only increase or decrease one input variable at a time (Cotter, 1979). The sensitivity analyses for the western gull risk models for brodifacoum and diphacinone relied on "what if" analyses using a "one-at-a-time" design. The baseline scenarios for brodifacoum and diphacinone assumed the input values in Table 3-1 except for the variable being investigated. Each variable being investigated was altered one at a time to explore the influence on the model outputs. The inputs values selected for the sensitivity analyses are listed in Table 5-1. Some of these values could be adjusted in future model simulations as, for example, new data become available.

Table 5-1. Values of input parameters varied in one at-a-time sensitivity analyses for western gull risk models for brodifacoum and diphacinone.

Variable	Values	Notes
First application date	Nov 1, 8, 15, 22, 29 and Dec 6, 13 and 20	This is the range of possible application dates being considered for SFI.
Applications interval - brodifacoum	5, 21 days	Label does not permit intervals of <5 days. An interval of 21 days or more will increase the likelihood that all individuals are exposed to the technique (Griffiths and Towns, 2008)
Application rate - diphacinone	32, 48 kg bait/ha per application	Application rate of 48 kg bait/ha is the current proposed rate for SFI whereas the rate of 32 kg bait/ha modeled elsewhere in this report is thought to be the minimum effective rate to ensure mouse eradication.
Applications interval - diphacinone	3, 10 days	No need for interval of less than <3 days to ensure availability of pellets. Mice could recover if pellets not available for a period of time which suggests upper bound of 10 days.
Number of applications - brodifacoum	1, 2	2 applications is maximum indicated in FWS (2012). 1 application is likely to be ineffective at eradicating mice.
Number of applications - diphacinone	1, 3	3 applications is maximum indicated by Island Conservation. 1 application is likely to be ineffective at eradicating mice.
Hazing effectiveness	0.75, 0.98	Range suggested by Island Conservation
Pellet half life (1st application)	0.5, 2 days	2010 SFI field trial and available literature indicate this approximate range.
Time to significant rainfall event after 2nd application	4, 117 days	Time to median significant rainfall at SFI (2" in 3 days) is 28 days. Best and worst case scenarios are 4 and 117 days, respectively given available rainfall data from 1972-2010.
Time to pellet removal after rainfall event	2, 7 days	Pellets generally degrade within 2-7 days of a significant rainfall event.
Mean concentration in mice - brodifacoum	2.71, 4.9 mg/kg bw	Range cited in Howald et al. (1999, 2001). Standard deviation adjusted to ensure same coefficient of variation.
Mean concentration in mice - diphacinone	30, 51.5 mg/kg bw	Upper value is upper bound calculated from Pitt et al. (2011). Lower value is somewhat arbitrary but approximately the lower bound value if there was some initial rapid elimination of diphacinone from the exposed mice in Pitt et al. (2011) study.
Daily probability of consuming mice	0.01, 0.15	Lower value reflects fact that mice are not normally part of the western gull diet. Upper value is arbitrary but kept generally low because gulls normally feed on other food items.
Daily probability of consuming pellets	0.22, 0.25	Highest average rate suggested by data collected during 2010 SFI field trial. Initial daily rates are much lower, ranging from 0 to 29% during first five days.
Conditional probability for consuming pellets	0.5, 0.9	Observational data from 2010 SFI field trial suggest that once a gull learns that pellets are a food source, they will continue to consume them as long as they are available. No data are available to quantify this variable and thus a wide range was selected. The same rationale was used for consumption of mice.
Conditional probability for consuming mice	0.5, 0.9	
Proportion of intoxicated mice below ground	0.87, 1 (brodifacoum) 0, 1 (diphacinone)	Data from literature suggests that at least 87% of brodifacoum-intoxicated mice will go below ground. No comparable information is available for diphacinone.
LD50 - brodifacoum	0.588, 5 mg/kg bw	Toxicity studies available for gull species indicate a range of 0.588 to <5 mg/kg bw (Wildlife International, 1979a,b; Godfrey, 1985, 1986).
LD50 - diphacinone	97, 3158 mg/kg bw	No gull toxicity studies are available. Most sensitive value is for American kestrel (Rattner et al., 2010) and most tolerant value is for mallards (Erickson and Urban, 2004).

Brodifacoum

Figures 5-23 to 5-25 show the results of the sensitivity analyses for brodifacoum for maximum gull tissue concentration, proportion mortality of gulls, and number of dead gulls. The results of the sensitivity analysis for maximum gull tissue concentration indicate that the three most important variables influencing exposure of western gulls to brodifacoum are the number of applications, hazing effectiveness and time to significant rainfall event following the second application (Figure 5-23). Hazing effectiveness is the most important variable, as it determines how many birds are foraging on the island during bait application and could, therefore, potentially consume the bait. Although hazing has been shown to be highly effective (~90-98%) at airports and landfills (Curtis et al., 1995; Slate et al., 2000; Chipman et al., 2004), it is unknown whether it would be similarly effective at SFI. A fall, 2012 trial is underway to investigate hazing effectiveness at SFI.

Time to the first significant rainfall event following the second application is also significant because rain removes the pellets from the environment, particularly after the second application when few, if any, mice are available to remove pellets. As a result, if there is an extended period of time to the first rainfall event after the second application, gulls will have much higher exposure doses due to the long-term availability of pellets. Although time to first significant rainfall event is a critical input variable, there is no need to conduct additional research on this variable. Thirty-eight years of data on daily rainfall at SFI are currently available (1972-2010), which is sufficient for determining best case, most likely case and worst case values for this variable.

The number of applications is a significant input variable because there will likely be very few mice available following the second application to consume the pellets. This increases the likelihood that the remaining pellets will be consumed by gulls. It is important that measures be taken to reduce the availability of pellets to gulls. This could be done by hazing, as the sensitivity analysis shows that effective hazing greatly reduces the dose ingested by the gulls. Overall, the most effective way to reduce exposure to gulls would be to enhance the hazing effort.

Varying pellet half-life after the first application from 0.5 to 2 days had only a modest influence on gull exposure to brodifacoum. The available data suggest that this is a reasonable range for this variable (e.g., Howald et al., 2001; FWS, 2012) and thus further research would not significantly reduce model uncertainty. Varying the daily probability of gulls ingesting pellets from 0.22 to 0.25 also had only a modest influence on gull exposure. Although data from the 2010 SFI trial were used to define this narrow range, the dataset was clearly limited and thus there is uncertainty regarding this input parameter. The 0.22-0.25 range was at the maximum end of the range actually observed at SFI using two different methods (proportion fecal pellets with dye and observations of foraging gulls). The conditional probability for ingesting pellets is also highly uncertain. However, varying this parameter value from 0.5 to 0.9 had little impact on predicted gull exposure. This result suggests that further research is not required for the conditional probability for ingesting pellets. The time required for pellets to break down

following a significant rainfall event had a modest influence on gull exposure. There are several studies that indicate a fairly rapid breakdown and molding of pellets when moisture levels are high (e.g., following a significant rainfall event) (e.g., Merton, 1987; Howald et al., 2001). As such, no further research is recommended for this variable. A site-specific bait degradation study is being conducted on SFI, however, during the fall 2012 season to determine how quickly the two bait pellet types would degrade during a normal fall/winter rainfall season, using non-toxic formulations.

Variables related to the secondary route of exposure (e.g., concentration in mice, probability of consuming mice, conditional probability for consuming mice, proportion of intoxicated mice below ground) had little influence on predicted exposure to western gulls. As shown in Figures 5-11 and 5-12, total removal of dead or intoxicated mice would do little to reduce gull mortality. Clearly, exposure to pellets is a far more important contributor to gull exposure than is exposure to mice. Thus, no research is recommended to reduce uncertainty in the parameters related to the secondary route of exposure.

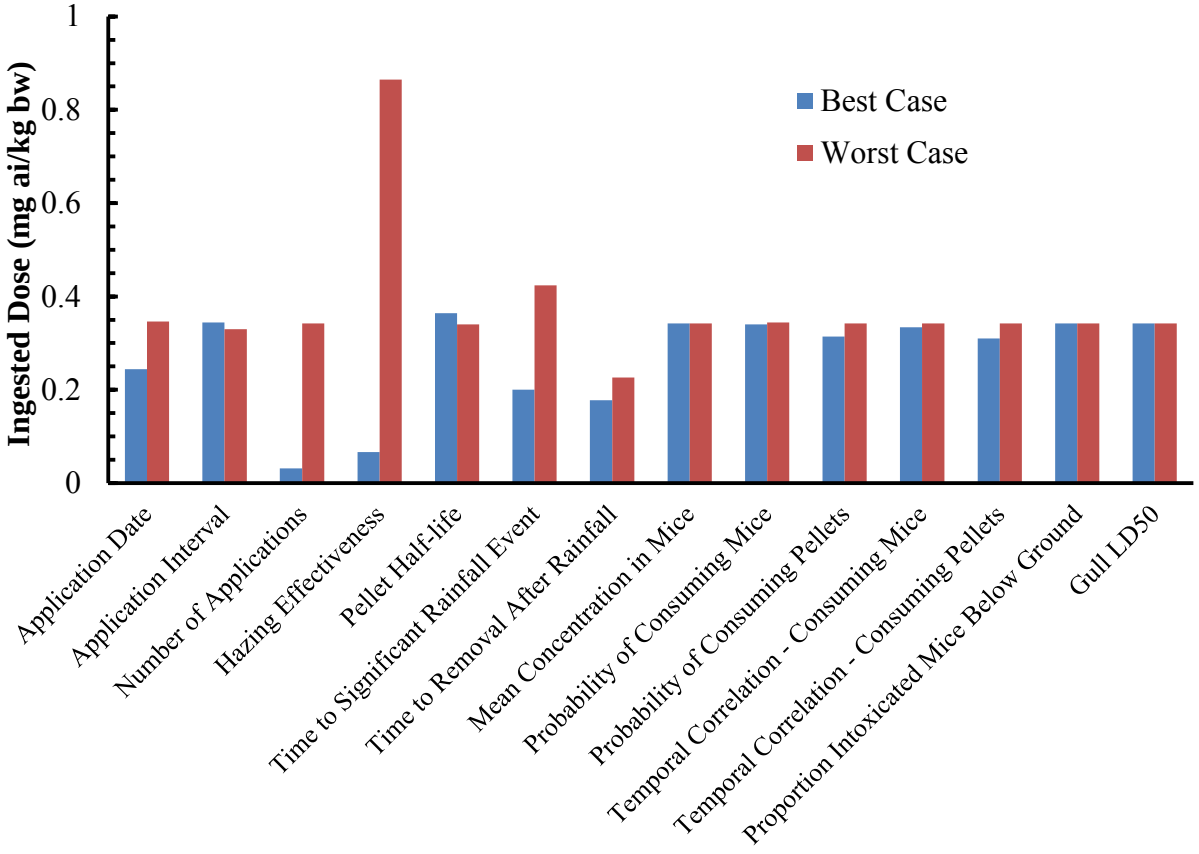

Figure 5-23. Results of sensitivity analysis for brodifacoum for maximum tissue concentration in western gulls exposed to brodifacoum.

The results of the sensitivity analysis for proportion and number of dead gulls were similar to the results for gull exposure except that the gull LD50 was also demonstrated to be important

(Figures 5-24 and 5-25). The range between the best and worst case gull LD50s is quite wide (5 mg ai/kg bw and 0.588 mg ai/kg bw, respectively). The worst case LD50 is based upon probit analysis of the results of toxicity studies conducted by Wildlife International (1979a,b) on the laughing gull (*Larus atricilla*). The best case LD50 is from Godfrey (1986) who found that the black-blacked gull (*Chroicocephalus bulleri*) had an LD50 of <5 mg ai/kg bw. No toxicity data are available for western gulls, thus there is no information available at this time to tighten the bounds on the gull LD50. Conducting a toxicity test specific for western gulls would reduce the uncertainty inherent in the LD50 values currently used for analyses.

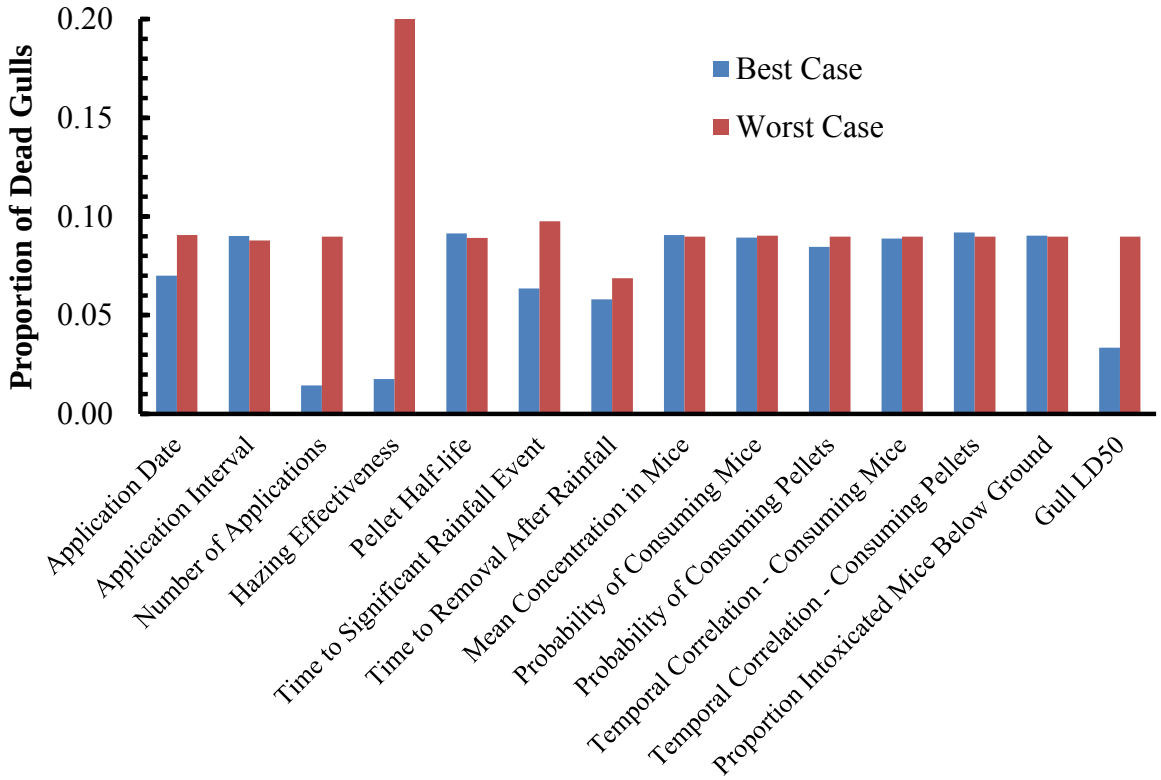

Figure 5-24. Results of sensitivity analysis for proportion of dead western gulls exposed to brodifacoum.

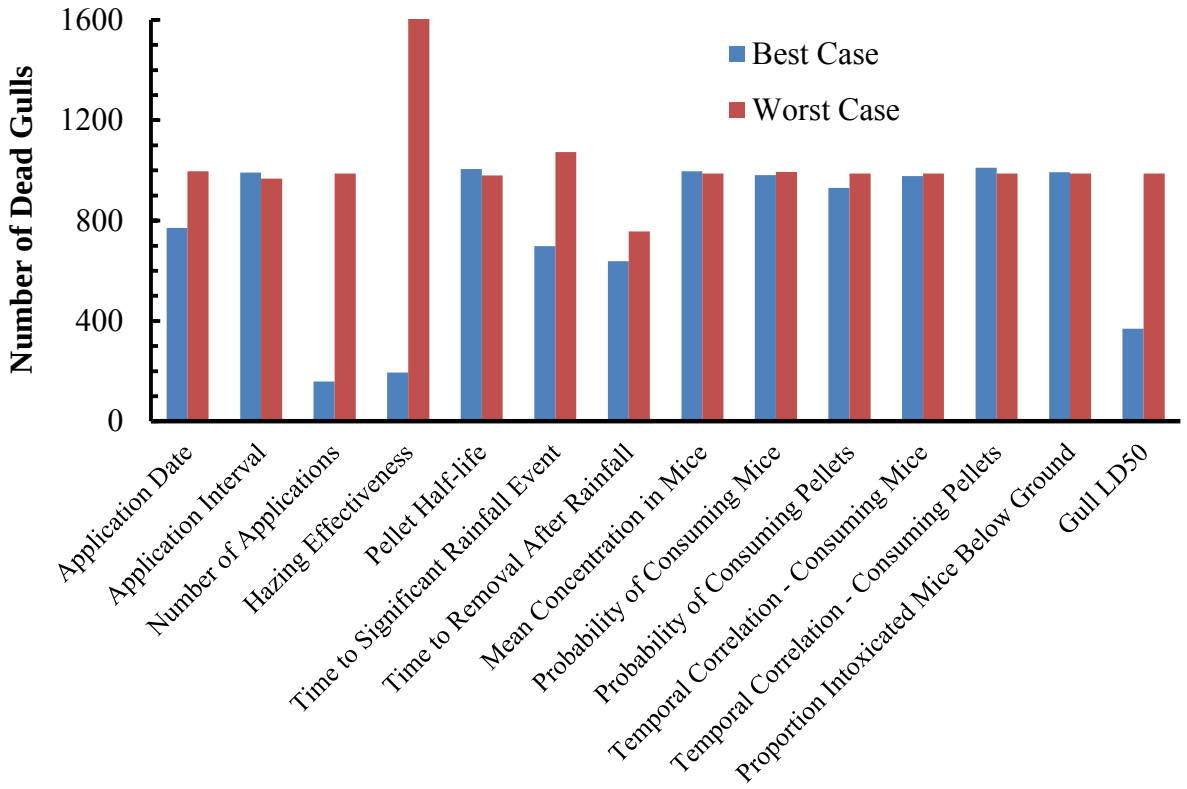

Figure 5-25. Results of sensitivity analysis for number of dead western gulls exposed to brodifacoum.

Diphacinone

Figures 5-26 to 5-28 show the results of the sensitivity analyses for diphacinone for maximum tissue concentration, proportion mortality of gulls, and number of dead gulls. The results of the sensitivity analysis for diphacinone are highly similar to those for brodifacoum but with three notable differences. First, number of applications has a profound impact on gull exposure and mortality. In particular, having a third application of diphacinone dramatically increases gull exposure and mortality. The reason that gull impacts are greater with more than 2 applications of diphacinone is due to the cumulative nature of diphacinone exposure. That is, a lethal dose requires many days to weeks of constant ingestion because diphacinone is metabolized at the same time that it is being consumed. For similar reasons, increasing the application rate to 48 kg bait/ha substantially increases expected dose and gull mortality. The application rate of 48 kg bait/ha is the current proposed rate for SFI whereas the rate of 32 kg bait/ha modeled elsewhere in this report is thought to be the minimum effective rate to ensure mouse eradication. The third highly influential variable was the LD50 assumed for the analysis. No toxicity tests have been carried out on gull species for diphacinone. As a result, the sensitivity of western gulls to this rodenticide is unknown. Assuming the worst case LD50 of 97 mg ai/kg bw for American kestrels (Rattner et al., 2010), led to predictions of significant mortality for western gulls (Figures 5-27 and 5-28). However, assuming the LD50s for northern bobwhite (2,014 mg ai/kg bw; Rattner et

al., 2010) or mallards (3,158 mg ai/kg bw; Erickson and Urban, 2004) resulted in predictions of no mortality of diphacinone to western gulls. Conducting a toxicity test specific for western gulls is recommended to reduce the uncertainty of using LD50 values from unrelated bird species.

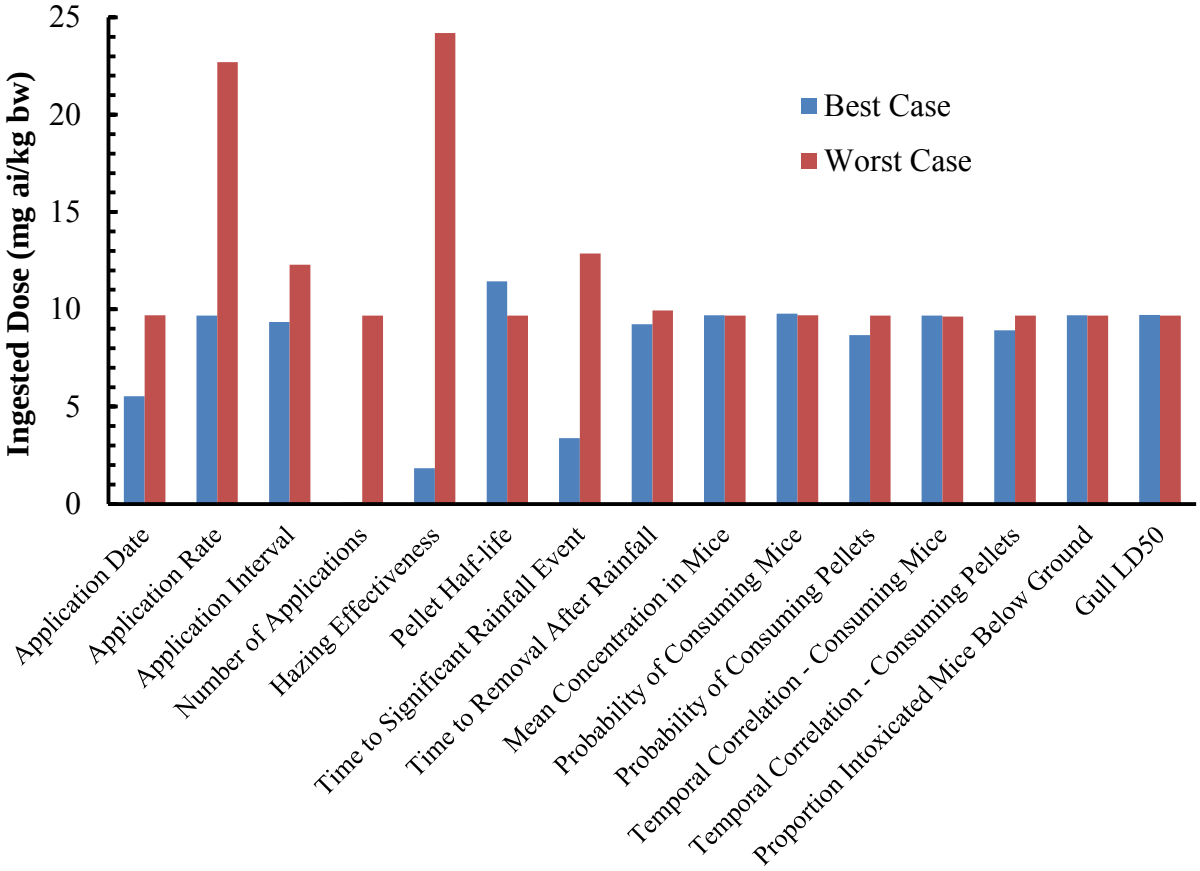

Figure 5-26. Results of sensitivity analysis for diphacinone for maximum tissue concentration in western gulls exposed to diphacinone.

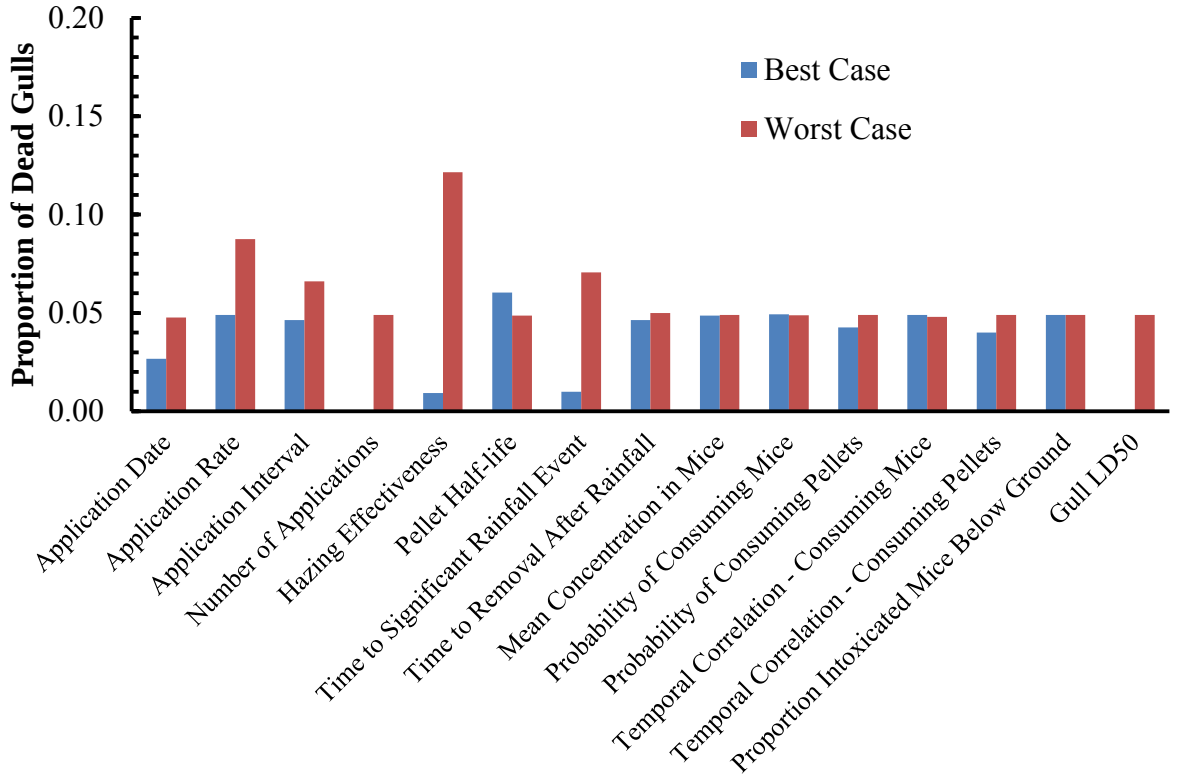

Figure 5-27. Results of sensitivity analysis for diphacinone for proportion of dead gulls exposed to diphacinone.

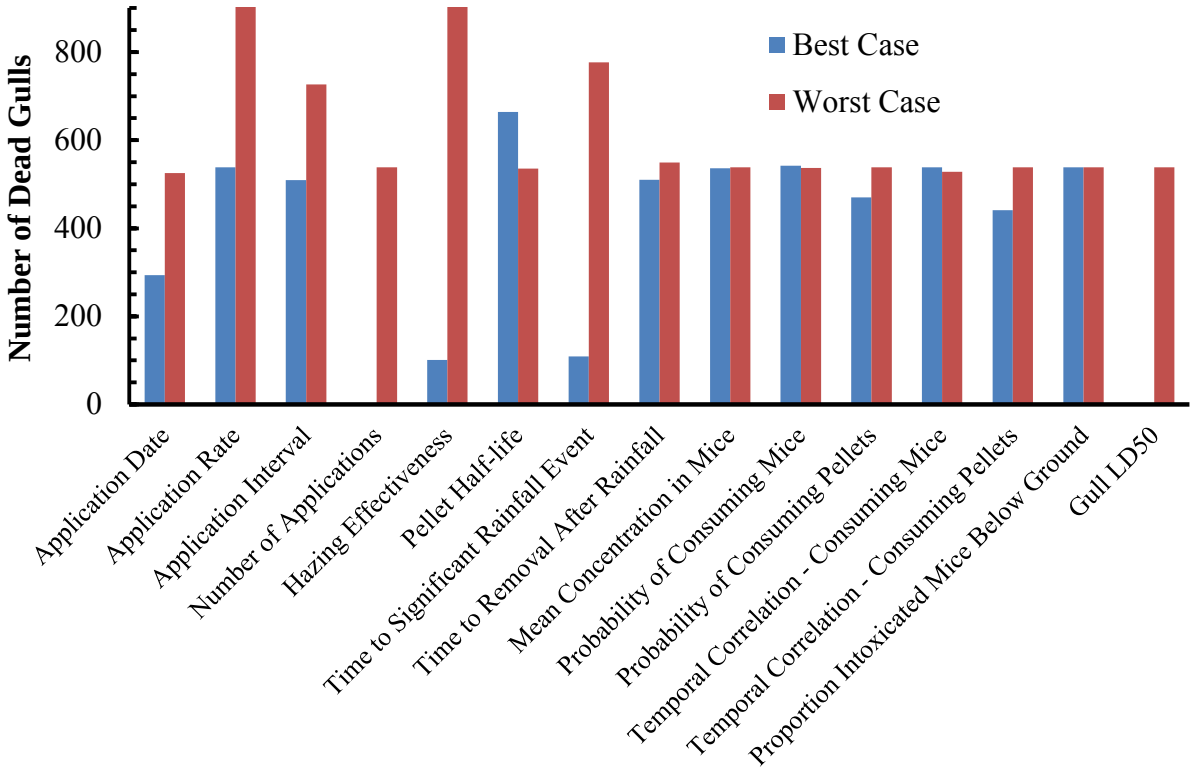

Figure 5-28. Results of sensitivity analysis for diphacinone for number of dead gulls exposed to diphacinone.

Data Gaps

Based on the results of the sensitivity analyses, we identified several data gaps for which more information would be beneficial to reduce uncertainty:

- Hazing effectiveness
- LD50s for western gull for brodifacoum and diphacinone
- Daily probability of western gulls ingesting pellets

In most other projects involving application of rodenticides, gull populations have not been significantly affected. For example, a western gull colony on Anacapa Island in southern California (approximately 2,500 birds; Sowls et al., 1980) was not significantly affected by a rat eradication project involving application of brodifacoum. In that project, there was a loss of only 2 gulls documented (Howald et al. 2004). Eason et al. (2002) reported individual gull mortalities in relation to brodifacoum-based rodent eradication projects, but there were no significant population-level effects In fact, there has never been a reported population level effect to any gull species from a rodent eradication using a rodent bait. A number of factors could explain the discrepancy between the predictions of the western gull risk model and the general lack of gull incidents with previous rat eradication projects:

- Other island eradication projects often relied on use of bait stations instead of aerial broadcast of brodifacoum pellets. Gulls are unable to access pellets in bait stations which would eliminate the most important route of exposure, the primary route of exposure.
- Because rats are much larger than mice, gulls may have been more reluctant to prey upon rats on other islands even if they were intoxicated.
- Other islands may have had more frequent rainfall events which led to rapid breakdown and removal of pellets. Time to a significant rainfall event after the second application is a key variable in the western gull risk model affecting predicted exposure of gulls.
- The western gull population on SFI is much larger than most gull populations on other islands, which increases the likelihood of gulls learning from each other on SFI versus other islands. It also increases the likelihood of higher gull mortalities.
- One or more assumptions in the western gull model could be incorrect. Data were limited on several key components of the model (e.g., hazing effectiveness, daily probabilities of consuming pellets, LD50s). Although the use of best and worst case values attempted to bracket the uncertainty, there clearly is a need to conduct additional research to reduce uncertainty where possible in the model.

In the event that additional research is carried out on key input parameters, the western gull risk model can be updated and additional runs undertaken to refine model predictions of mortality of western gulls on SFI.

COMPARISON OF EFFECTS OF BRODIFACOUM AND DIPHACINONE ON WESTERN GULL MORTALITY

One of the objectives of this assessment was to determine the relative risks of brodifacoum and diphacinone to western gulls on SFI. It is somewhat difficult to compare the results presented in Appendices A and B because the diphacinone assessment was more conservative than the brodifacoum assessment. For example, because of limited data, the western gull risk model assumed that intoxicated mice do not go below ground after exposure to diphacinone whereas the brodifacoum model assumed that 87% of intoxicated mice go below ground. The LD50 assumed for diphacinone was based on a species unrelated to western gulls (i.e., American kestrel) and was highly conservative relative to other tested bird species. For brodifacoum, a conservative LD50 was also used but it was based on a gull species (i.e., laughing gull) and was reasonably close to the two other LD50s available for gull species (i.e., black-billed gull, southern black-backed gull).

In spite of the higher conservatism in the diphacinone model, the results from the western gull risk model clearly show that diphacinone poses a lower risk to western gulls on SFI than does brodifacoum (Appendices A and B). Assuming an early initial application date (November 1) and 75% hazing effectiveness, applications of diphacinone should not cause greater than 1700 gull mortalities (Figure 5-29). This would only be the case with brodifacoum if a significant rainfall event occurs shortly after the second application (Figure 5-29). If hazing success is 90% or higher, neither rodenticide is likely to cause 1700 or greater gull mortalities irrespective of initial application date or time to first significant rainfall event after the final application (Figure 5-30; Appendices A and B).

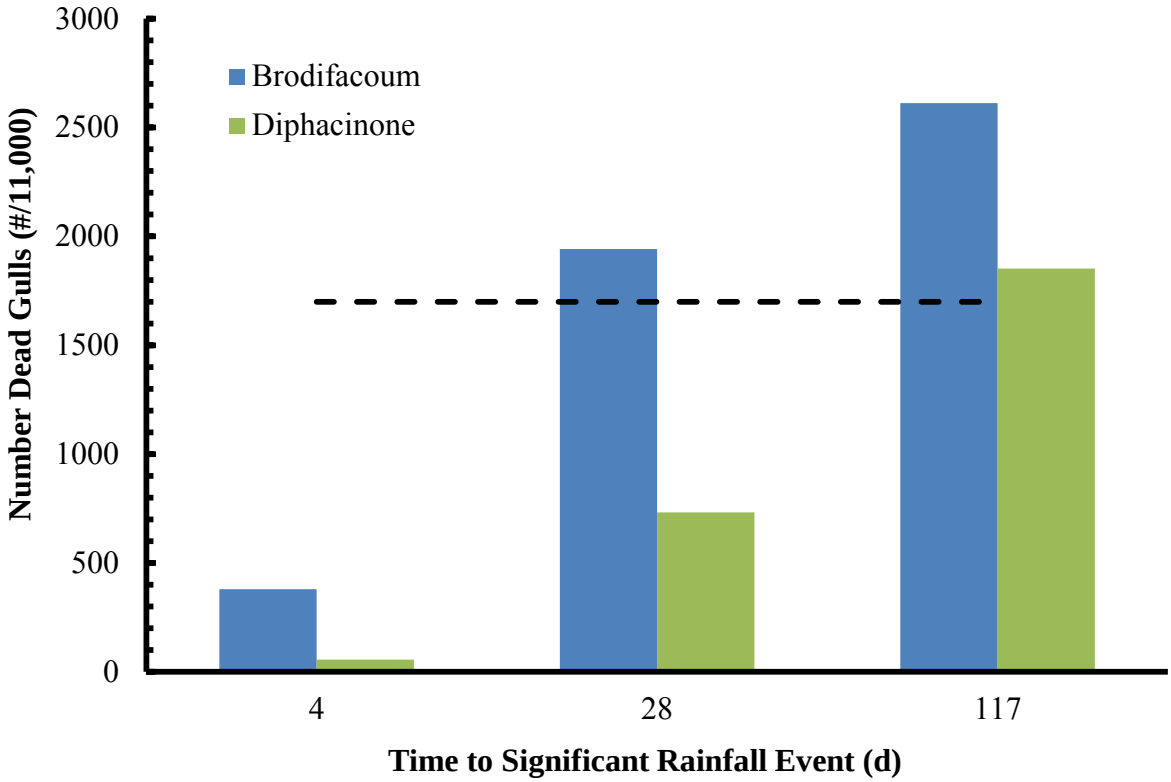

Figure 5-29. Effects of time to significant rainfall event on predicted gull mortality for brodifacoum and diphacinone assuming an initial application date of November 1 and 75% hazing success. The dashed line represents 1700 dead gulls.

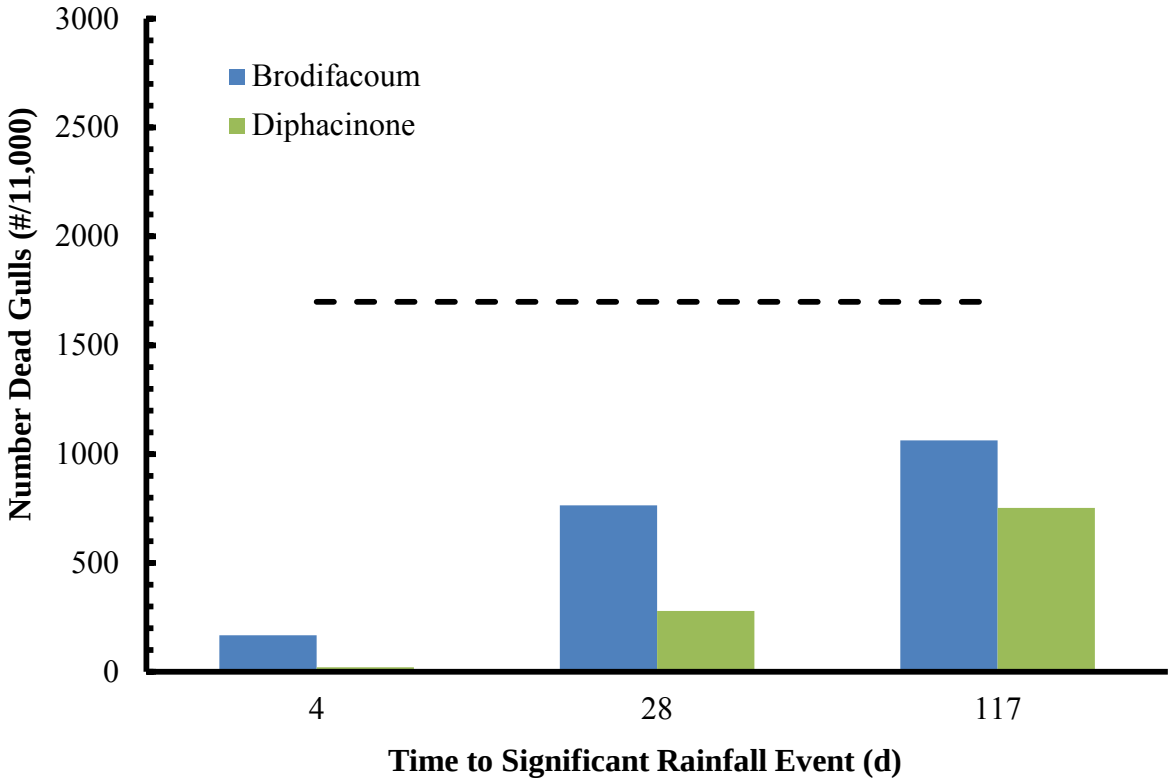

Figure 5-30. Effects of time to significant rainfall event on predicted gull mortality for brodifacoum and diphacinone assuming an initial application date of November 1 and 90% hazing success. The dashed line represents 1700 dead gulls.

CONCLUSIONS

The likelihoods of brodifacoum and diphacinone applications achieving total eradication of mice on SFI were not considered in this assessment. It is also clear that brodifacoum poses a higher risk to non-target western gulls than does diphacinone. To most effectively reduce gull mortalities, it would be advisable to consider having an effective gull hazing program, an early start date, and other measures to reduce gull exposure to bait, including some use of bait stations or possibly hand removal of bait pellets after several weeks, if any remain. Because the western gull risk model used conservative input parameters when exact values were unknown, it is likely that the model overestimated expected gull mortalities. Further, several important parameters that could affect uptake of rodenticide by gulls were not included in the model. For example, if plant cover is higher than usual at the time of application, gulls could have more trouble locating pellets, thus reducing exposure. Similarly, use of bait stations in some areas (e.g., where terrain is relatively flat and accessible) would reduce gull exposure. Use of bait stations on portions of SFI was not included in the model.

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APPENDIX A – MODELING RESULTS FOR WESTERN GULLS EXPOSED TO BRODIFACOUM ON THE FARALLON ISLANDS

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Nov 1	0.75	28	2	No	0.608	0.177	1942
Nov 8	0.75	28	2	No	0.726	0.203	2229
Nov 15	0.75	28	2	No	0.787	0.213	2345
Nov 22	0.75	28	2	No	0.848	0.226	2486
Nov 29	0.75	28	2	No	0.865	0.226	2480
Dec 6	0.75	28	2	No	0.877	0.229	2523
Dec 13	0.75	28	2	No	0.869	0.226	2483
Dec 20	0.75	28	2	No	0.863	0.226	2487
Nov 1	0.9	28	2	No	0.241	0.0695	764
Nov 8	0.9	28	2	No	0.285	0.0793	872
Nov 15	0.9	28	2	No	0.317	0.0859	945
Nov 22	0.9	28	2	No	0.330	0.0882	970
Nov 29	0.9	28	2	No	0.339	0.0892	980
Dec 6	0.9	28	2	No	0.355	0.0924	1016
Dec 13	0.9	28	2	No	0.341	0.0902	992
Dec 20	0.9	28	2	No	0.345	0.0905	995
Nov 1	0.95	28	2	No	0.118	0.0342	376
Nov 8	0.95	28	2	No	0.155	0.0432	475
Nov 15	0.95	28	2	No	0.159	0.0429	472
Nov 22	0.95	28	2	No	0.167	0.0439	483
Nov 29	0.95	28	2	No	0.168	0.0443	486
Dec 6	0.95	28	2	No	0.170	0.0439	483
Dec 13	0.95	28	2	No	0.168	0.0437	481
Dec 20	0.95	28	2	No	0.180	0.0476	523
Nov 1	0.98	28	2	No	0.048	0.0138	151
Nov 8	0.98	28	2	No	0.0556	0.0152	167
Nov 15	0.98	28	2	No	0.0622	0.0166	182
Nov 22	0.98	28	2	No	0.0656	0.0173	190
Nov 29	0.98	28	2	No	0.0663	0.0177	194
Dec 6	0.98	28	2	No	0.0656	0.0174	191
Dec 13	0.98	28	2	No	0.0730	0.0190	209
Dec 20	0.98	28	2	No	0.0666	0.0178	195

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Nov 1	0.75	4	2	No	0.110	0.0346	380
Nov 8	0.75	4	2	No	0.112	0.0353	388
Nov 15	0.75	4	2	No	0.348	0.108	1192
Nov 22	0.75	4	2	No	0.362	0.113	1244
Nov 29	0.75	4	2	No	0.492	0.157	1729
Dec 6	0.75	4	2	No	0.516	0.161	1771
Dec 13	0.75	4	2	No	0.527	0.167	1837
Dec 20	0.75	4	2	No	0.540	0.170	1871
Nov 1	0.9	4	2	No	0.0489	0.0153	167
Nov 8	0.9	4	2	No	0.0475	0.0152	166
Nov 15	0.9	4	2	No	0.135	0.0431	474
Nov 22	0.9	4	2	No	0.146	0.0445	489
Nov 29	0.9	4	2	No	0.204	0.0641	704
Dec 6	0.9	4	2	No	0.208	0.0658	723
Dec 13	0.9	4	2	No	0.212	0.0678	745
Dec 20	0.9	4	2	No	0.212	0.0672	739
Nov 1	0.95	4	2	No	0.0254	0.00770	84
Nov 8	0.95	4	2	No	0.0246	0.00740	81
Nov 15	0.95	4	2	No	0.0677	0.0213	234
Nov 22	0.95	4	2	No	0.0716	0.0220	242
Nov 29	0.95	4	2	No	0.102	0.0321	353
Dec 6	0.95	4	2	No	0.106	0.0326	358
Dec 13	0.95	4	2	No	0.106	0.0327	360
Dec 20	0.95	4	2	No	0.108	0.0344	378
Nov 1	0.98	4	2	No	0.00864	0.00267	29
Nov 8	0.98	4	2	No	0.00789	0.00240	26
Nov 15	0.98	4	2	No	0.0244	0.00727	79
Nov 22	0.98	4	2	No	0.0300	0.00910	100
Nov 29	0.98	4	2	No	0.0412	0.0132	145
Dec 6	0.98	4	2	No	0.0425	0.0126	138
Dec 13	0.98	4	2	No	0.0432	0.0136	149
Dec 20	0.98	4	2	No	0.0433	0.0134	147
Nov 1	0.75	117	2	No	0.997	0.238	2612
Nov 8	0.75	117	2	No	1.04	0.243	2674
Nov 15	0.75	117	2	No	1.06	0.245	2695
Nov 22	0.75	117	2	No	1.07	0.245	2690
Nov 29	0.75	117	2	No	1.05	0.244	2680

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Dec 6	0.75	117	2	No	1.04	0.240	2644
Dec 13	0.75	117	2	No	1.03	0.239	2626
Dec 20	0.75	117	2	No	1.02	0.237	2611
Nov 1	0.9	117	2	No	0.412	0.0967	1063
Nov 8	0.9	117	2	No	0.404	0.0942	1036
Nov 15	0.9	117	2	No	0.409	0.0949	1044
Nov 22	0.9	117	2	No	0.430	0.0989	1087
Nov 29	0.9	117	2	No	0.412	0.0955	1050
Dec 6	0.9	117	2	No	0.422	0.0975	1072
Dec 13	0.9	117	2	No	0.411	0.0945	1039
Dec 20	0.9	117	2	No	0.415	0.0968	1064
Nov 1	0.95	117	2	No	0.199	0.0469	516
Nov 8	0.95	117	2	No	0.205	0.0476	523
Nov 15	0.95	117	2	No	0.204	0.0469	515
Nov 22	0.95	117	2	No	0.203	0.0466	512
Nov 29	0.95	117	2	No	0.202	0.0465	511
Dec 6	0.95	117	2	No	0.210	0.0483	530
Dec 13	0.95	117	2	No	0.211	0.0484	532
Dec 20	0.95	117	2	No	0.203	0.0474	521
Nov 1	0.98	117	2	No	0.0823	0.0194	213
Nov 8	0.98	117	2	No	0.0799	0.0188	206
Nov 15	0.98	117	2	No	0.0858	0.0200	220
Nov 22	0.98	117	2	No	0.0829	0.0192	210
Nov 29	0.98	117	2	No	0.0815	0.0193	212
Dec 6	0.98	117	2	No	0.0821	0.0192	210
Dec 13	0.98	117	2	No	0.0762	0.0177	194
Dec 20	0.98	117	2	No	0.0854	0.0200	220
Nov 29	0.9	28	1	No	0.0316	0.0144	158
Nov 29	0.9	28	2	Yes	0.340	0.0894	984

APPENDIX B – MODELING RESULTS FOR WESTERN GULLS EXPOSED TO DIPHACINONE ON THE FARALLON ISLANDS

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Nov 1	0.75	28	3	No	13.8	0.0666	732
Nov 8	0.75	28	3	No	19.1	0.0910	1001
Nov 15	0.75	28	3	No	22.3	0.110	1215
Nov 22	0.75	28	3	No	23.6	0.121	1332
Nov 29	0.75	28	3	No	24.2	0.122	1337
Dec 6	0.75	28	3	No	24.1	0.122	1339
Dec 13	0.75	28	3	No	24.6	0.123	1355
Dec 20	0.75	28	3	No	24.3	0.123	1349
Nov 1	0.9	28	3	No	5.42	0.0254	279
Nov 8	0.9	28	3	No	7.52	0.0371	407
Nov 15	0.9	28	3	No	8.72	0.0441	485
Nov 22	0.9	28	3	No	9.28	0.0460	506
Nov 29	0.9	28	3	No	9.88	0.0500	549
Dec 6	0.9	28	3	No	9.87	0.0482	530
Dec 13	0.9	28	3	No	9.78	0.0485	533
Dec 20	0.9	28	3	No	9.74	0.0494	543
Nov 1	0.95	28	3	No	2.72	0.0124	136
Nov 8	0.95	28	3	No	3.94	0.0190	209
Nov 15	0.95	28	3	No	4.46	0.0226	248
Nov 22	0.95	28	3	No	4.80	0.0236	259
Nov 29	0.95	28	3	No	4.79	0.0247	271
Dec 6	0.95	28	3	No	4.55	0.0221	243
Dec 13	0.95	28	3	No	4.68	0.0241	265
Dec 20	0.95	28	3	No	4.90	0.0243	267
Nov 1	0.98	28	3	No	0.99	0.00477	52
Nov 8	0.98	28	3	No	1.50	0.00723	79
Nov 15	0.98	28	3	No	1.82	0.00940	103
Nov 22	0.98	28	3	No	1.90	0.00957	105
Nov 29	0.98	28	3	No	1.84	0.00927	101
Dec 6	0.98	28	3	No	2.03	0.0104	114
Dec 13	0.98	28	3	No	2.02	0.0101	111
Dec 20	0.98	28	3	No	1.96	0.0100	110

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Nov 1	0.75	4	3	No	1.80	0.0052	56
Nov 8	0.75	4	3	No	1.85	0.0053	58
Nov 15	0.75	4	3	No	5.56	0.0175	192
Nov 22	0.75	4	3	No	6.16	0.0184	202
Nov 29	0.75	4	3	No	8.23	0.0255	280
Dec 6	0.75	4	3	No	8.85	0.0246	270
Dec 13	0.75	4	3	No	8.61	0.0241	265
Dec 20	0.75	4	3	No	8.80	0.0249	273
Nov 1	0.9	4	3	No	0.740	0.00190	20
Nov 8	0.9	4	3	No	0.745	0.00237	26
Nov 15	0.9	4	3	No	2.49	0.00777	85
Nov 22	0.9	4	3	No	2.48	0.00800	88
Nov 29	0.9	4	3	No	3.46	0.0101	111
Dec 6	0.9	4	3	No	3.45	0.0106	116
Dec 13	0.9	4	3	No	3.64	0.0112	123
Dec 20	0.9	4	3	No	3.53	0.0104	114
Nov 1	0.95	4	3	No	0.384	0.00110	12
Nov 8	0.95	4	3	No	0.325	0.000933	10
Nov 15	0.95	4	3	No	1.07	0.00343	37
Nov 22	0.95	4	3	No	1.26	0.00337	37
Nov 29	0.95	4	3	No	1.70	0.00577	63
Dec 6	0.95	4	3	No	1.82	0.00513	56
Dec 13	0.95	4	3	No	1.78	0.00467	51
Dec 20	0.95	4	3	No	1.75	0.00550	60
Nov 1	0.98	4	3	No	0.149	0.000367	4
Nov 8	0.98	4	3	No	0.142	0.000433	4
Nov 15	0.98	4	3	No	0.447	0.00137	15
Nov 22	0.98	4	3	No	0.482	0.00117	12
Nov 29	0.98	4	3	No	0.715	0.00203	22
Dec 6	0.98	4	3	No	0.740	0.00217	23
Dec 13	0.98	4	3	No	0.664	0.00170	18
Dec 20	0.98	4	3	No	0.650	0.00157	17
Nov 1	0.75	117	3	No	30.6	0.168	1852
Nov 8	0.75	117	3	No	32.2	0.177	1941
Nov 15	0.75	117	3	No	31.5	0.173	1900
Nov 22	0.75	117	3	No	31.8	0.174	1913
Nov 29	0.75	117	3	No	31.8	0.177	1942

Date of Application	Proportion of Gulls Removed by Hazing	Time to Significant Rainfall Event (d)	Number of Applications	Dead Mice Removed?	Mean Total Ingested Dose (mg ai/kg bw)	Proportion of Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Dec 6	0.75	117	3	No	31.7	0.175	1921
Dec 13	0.75	117	3	No	31.5	0.174	1911
Dec 20	0.75	117	3	No	31.1	0.169	1864
Nov 1	0.9	117	3	No	12.4	0.0685	753
Nov 8	0.9	117	3	No	12.9	0.0707	778
Nov 15	0.9	117	3	No	13.0	0.0722	794
Nov 22	0.9	117	3	No	12.6	0.0704	774
Nov 29	0.9	117	3	No	12.6	0.0696	765
Dec 6	0.9	117	3	No	12.8	0.0704	774
Dec 13	0.9	117	3	No	12.9	0.0708	778
Dec 20	0.9	117	3	No	12.5	0.0688	757
Nov 1	0.95	117	3	No	6.07	0.0332	364
Nov 8	0.95	117	3	No	6.31	0.0352	386
Nov 15	0.95	117	3	No	6.27	0.0346	380
Nov 22	0.95	117	3	No	6.22	0.0345	379
Nov 29	0.95	117	3	No	6.31	0.0352	386
Dec 6	0.95	117	3	No	6.27	0.0350	385
Dec 13	0.95	117	3	No	6.40	0.0347	381
Dec 20	0.95	117	3	No	6.10	0.0331	363
Nov 1	0.98	117	3	No	2.28	0.0130	142
Nov 8	0.98	117	3	No	2.53	0.0147	161
Nov 15	0.98	117	3	No	2.59	0.0142	156
Nov 22	0.98	117	3	No	2.35	0.0131	143
Nov 29	0.98	117	3	No	2.45	0.0143	157
Dec 6	0.98	117	3	No	2.46	0.0133	146
Dec 13	0.98	117	3	No	2.43	0.0131	143
Dec 20	0.98	117	3	No	2.49	0.0130	143
Nov 29	0.75	28	1	No	0.345	0	0
Nov 29	0.75	28	2	No	12.7	0.000515	6
Nov 29	0.75	28	3	Yes	48.2	0.121	1332

APPENDIX C – SENSITIVITY ANALYSIS FOR BRODIFACOUM MODEL

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Application Date	Nov 1		0.244	0.070	771
	Nov 8		0.288	0.080	880
	Nov 15		0.316	0.0852	936
	Nov 22		0.33	0.0878	966
	Nov 29		0.342	0.0898	988
	Dec 6		0.342	0.0898	987
	Dec 13		0.344	0.0904	993
	Dec 20		0.346	0.0906	997
Applications Interval	5	days	0.33	0.088	967
	12	days	0.342	0.0898	988
	21	days	0.34	0.090	992
Number of Applications	1		0.032	0.0144	158
	2		0.342	0.0898	988
Hazing Effectiveness	0.75		0.865	0.226	2480
	0.9		0.342	0.0898	988
	0.95		0.168	0.0443	486
	0.98		0.0663	0.0177	194
Pellet Half-life	0.5	days	0.36	0.0914	1005
	1	days	0.34	0.0898	988
	2	days	0.34	0.089	980
Time to Significant Rainfall Event After 2nd Application	4	days	0.20	0.0636	698
	28	days	0.342	0.0898	988
	117	days	0.424	0.0976	1073
Time to Removal of Bait Following Significant Rainfall Event	2	days	0.178	0.058	638
	4.5	days	0.342	0.0898	988
	7	days	0.23	0.069	756
Mean (SD) Concentration in Mice	2.71 (0.7)	mg/kg ww	0.34	0.091	996
	4.9 (1.26)	mg/kg ww	0.342	0.0898	988
Daily Probability of Consuming Mice Prior to Brodifacoum Application	0.01		0.34	0.089	982
	0.125		0.342	0.0898	988
	0.15		0.34	0.090	994
Daily Probability of Consuming Pellets	0.22		0.31	0.085	931

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Following Brodifacoum Application	0.25		0.342	0.0898	988
Conditional Probability for Consuming Mice	0.5		0.34	0.089	977
	0.7		0.34	0.090	991
	0.9		0.342	0.0898	988
Conditional Probability for Consuming Pellets	0.5		0.31	0.092	1011
	0.7		0.31	0.090	990
	0.9		0.34	0.090	988
Proportion of Mouse Population Below Ground Following Onset of Symptoms	0.87		0.34	0.090	988
	0.935		0.34	0.089	980
	1		0.34	0.090	993
LD50	0.588	mg/kg bw	0.34	0.090	988
	2.79	mg/kg bw	0.35	0.055	600
	5	mg/kg bw	0.34	0.034	369

APPENDIX D – SENSITIVITY ANALYSIS FOR DIPHACINONE MODEL

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Birds (#/11,000 birds)
Application Date	Nov 1		5.54	0.0267	294
	Nov 8		7.65	0.0366	402

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Birds (#/11,000 birds)
	Nov 15		8.92	0.0448	493
	Nov 22		9.44	0.0468	514
	Nov 29		9.68	0.0490	538
	Dec 6		9.72	0.0490	539
	Dec 13		9.75	0.0490	539
	Dec 20		9.69	0.0478	525
Application Rate	32	kg bait/ha	9.68	0.049	538
	48	kg bait/ha	22.7	0.0876	963
Applications Interval	5	days	12.3	0.0661	726
	12	days	9.68	0.0490	538
	21	days	9.35	0.0463	510
Number of Applications	1		0.0689	0	0
	2		2.53	0.000207	2
	3		9.68	0.049	538
Hazing Effectiveness	0.75		72.2	0.366	4022
	0.9		48.4	0.245	2691
	0.95		24.2	0.122	1337
	0.98		9.68	0.0490	540
Pellet Half-life	0.5	days	4.79	0.0247	271
	1	days	1.84	0.00927	101
	2	days	11.4	0.0604	664
Time to Significant Rainfall Event After 2nd Application	4	days	9.68	0.0490	538
	28	days	9.68	0.0487	536
	117	days	3.37	0.00995	109
Time to Removal of Bait Following Significant Rainfall Event	2	days	9.68	0.0490	538
	4.5	days	12.9	0.0706	777
	7	days	9.24	0.0463	510
Mean (SD) Concentration in Mice	30 (7.5)	mg/kg ww	9.68	0.0490	538
	51.5 (13)	mg/kg ww	9.93	0.0499	549
Daily Probability of Consuming Mice Prior to Diphacinone Application	0.01		9.69	0.0487	536
	0.125		9.68	0.0490	538
	0.15		9.77	0.0493	542
Daily Probability of Consuming Pellets Following	0.22		9.68	0.0490	538
	0.25		9.69	0.0488	537

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Birds (#/11,000 birds)
Diphacinone Application					
Conditional Probability for Consuming Mice	0.5		9.62	0.0480	528
	0.7		9.66	0.0485	534
	0.9		9.68	0.0490	538
Conditional Probability for Consuming Pellets	0.5		8.91	0.0401	441
	0.7		8.83	0.0410	451
	0.9		9.68	0.0490	538
Proportion of Mouse Population Below Ground Following Onset of Symptoms	0		9.68	0.0490	538
	0.87		9.64	0.0483	531
	1		9.70	0.0490	539
LD50	97	mg/kg bw	9.68	0.0490	538
	2014	mg/kg bw	9.67	0	0
	3158	mg/kg bw	9.72	0	0

8.6 Appendix G – Wilderness Act Minimum Requirements Analysis

ARTHUR CARHART NATIONAL WILDERNESS TRAINING CENTER

MINIMUM REQUIREMENTS DECISION GUIDE

WORKBOOK

"…except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act…"

-- The Wilderness Act of 1964

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG STEP 1

Determine if Administrative Action is Necessary

Description of the Situation

What is the situation that may prompt administrative action?

The house mouse (*Mus musculus*), a non-native, invasive species, occurs on the South Farallon Islands (hereafter, Farallon Islands or Farallones), part of the Farallon National Wildlife Refuge off the central California coast. Mice were introduced by previous human visitors to the islands, most likely in the 19th century. All of the islands, except Southeast Farallon Island, are included in the Farallon Wilderness. The mice occur both inside and outside the Farallon Wilderness.The Farallones host a unique island ecosystem. Between 200,000-300,000 seabirds breed there, including about half of the world population of the rare Ashy Storm-Petrel (*Oceanodroma homochroa*). The islands are also home to an endemic subspecies, the Farallon arboreal salamander (*Aneides lugubris farallonensis)*, and an endemic species, the Farallon camel cricket (*Farallonophilus cavernicolus*). The Refuge is closed to the public.

Studies have shown that house mice are impacting the native Farallon ecoystem. In particular, high mouse abundance in the fall attracts unnaturally large numbers of migrating Burrowing Owls. When the owls stop at the islands to rest, they find an abundant food supply of mice. Several owls then remain through the winter instead of continuing on their migration. Over the winter, the mouse population crashes and they become nearly unavailable as prey. During the winter, the island population of Ashy Storm-Petrels begin to visit the islands for pre-breeding activities. With their fairly small size and nocturnal habits, the storm-petrels become the main prey of the owls. The high predation rates suffered by the storm-petrels has been shown to be impacting the population of this already rare bird.

In addition, mice are likely having impacts on other components of the Farallon ecoystem. Mice feed heavily on terrestrial invertebrates, including the camel cricket, and are likely suppressing their populations. The mouse's diet is similar to that of the endemic salamander, which also feeds mainly on terrestrial invertebrates. It is believed that competition for food with the abundant mice may be suppressing the population of salamanders. Mice also feed on seeds and other parts of native plants; thus, mice are likely impacting native plant populations. It is believed that removing house mice from the Farallones will eliminate their impacts ecosystem.

Options Outside of Wilderness

Can action be taken outside of wilderness that adequately addresses the situation?

☐ YES

☑ NO

EXPLAIN & COMPLETE STEP 1 OF THE MRDG

Explain:

Invasive house mice occur and are impacting the Farallon ecoystem both inside and outside the wilderness. If measures were taken to remove mice only from outside the wilderness, invasive mice would remain in the designated wilderness. Also, narrow channels separating the wilderness from non-wilderness could easily be crossed by mice, reintroducing them to Southeast Farallon Island from the wilderness.

Criteria for Determining Necessity

Is action necessary to meet any of the criteria below?

A. Valid Existing Rights or Special Provisions of Wilderness Legislation

Is action necessary to satisfy valid existing rights or a special provision in wilderness legislation (the Wilderness Act of 1964 or subsequent wilderness laws) that ***requires*** *action? Cite law and section.*

☐ YES ☑ NO

Explain:

B. Requirements of Other Legislation

Is action necessary to meet the requirements of other federal laws? Cite law and section.

☐ YES ☑ NO

Explain:

Executive Order 13112 (February 3, 1999) titled *Invasive Species* states that federal agencies shall, to the extent practicable, detect non-native invasive species, respond rapidly to infestations, and provide for restoration of native species and habitat conditions in ecosystems that have been invaded.

C. Wilderness Character

Is action necessary to preserve one or more of the qualities of wilderness character including: Untrammeled, Undeveloped, Natural, Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation, or Other Features of Value?

UNTRAMMELED

☐ YES ☑ NO

Explain:

UNDEVELOPED

☐ YES ☑ NO

Explain:

NATURAL

☑ YES ☐ NO

Explain:

Since humans introduced house mice to the South Farallones, they have influenced the islands' natural ecosystem. The influence of house mice has altered the abundance of certain native species on the islands and thereby reduced the influence of natural forces on the islands. These effects are widespread. The removal of mice would allow the wilderness to be more influenced by natural forces.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

☐ YES ☑ NO

Explain:

OTHER FEATURES OF VALUE

☑ YES ☐ NO

Explain:

The Farallon National Wildlife Refuge was created under Executive Order 1043 as a "…preserve and breeding ground for marine birds." The National Wildlife Refuge System Improvement Act requires the Service to provide for the conservation of fish, wildlife, plants, and their habitats within the Refuge System; and to ensure that the biological integrity, diversity, and environmental health of the Refuge System are maintained. Wildlife conservation is the singular Refuge System mission.

The Farallon Islands are home to the largest breeding colony of seabirds in the contiguous United States, including the world's largest colony of the rare Ashy Storm-Petrel which is impacted my mouse presence on the Farallones. The Ashy Storm-Petrel is a California Bird Species of Special Concern. The islands are also home to the endemic Farallon arboreal salamander and Farallon camel cricket, which are also believed to be impacted by the mice.

In keeping with the purposes for which the Refuge was established and to comply with the Refuge System Improvement Act, the Service finalized a Comprehensive Conservation Plan (CCP) for the Refuge in 2009. One of the goals of the CCP is to protect and restore to historic levels breeding populations of 12 seabird species, including the Ashy Storm-Petrel. The CCP identified mouse eradication from the South Farallon Islands as an objective for the Refuge's management direction of removing invasive species and restoring the native ecosystem of the Farallon Islands.

Step 1 Decision

Is administrative action necessary in wilderness?

Decision Criteria	Summary Responses
A. Existing Rights or Special Provisions	Action IS NOT necessary to meet this criterion.
B. Requirements of Other Legislation	Action IS NOT necessary to meet this criterion.
C. Wilderness Character	
Untrammeled	Action IS NOT necessary to meet this criterion.
Undeveloped	Action IS NOT necessary to meet this criterion.
Natural	Action IS necessary to meet this criterion.
Outstanding Opportunities	Action IS NOT necessary to meet this criterion.
Other Features of Value	Action IS necessary to meet this criterion.

Is administrative action necessary in wilderness?

☑ YES

EXPLAIN & PROCEED TO STEP 2 OF THE MRDG

☐ NO

Explain:

To help restore the natural Farallon ecosystem and to achieve teh purposes for which the Refuge was established, the impacts of invasive house mice must be eliminated. Mice occur in abundance in the Farallon Wilderness. To remove mice from the South Farallon Islands, they must be removed from the wilderness.

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG STEP 2

Determine the Minimum Activity

Other Direction

Is there "special provisions" language in legislation (or other Congressional direction) that explicitly ***allows*** *consideration of a use otherwise prohibited by Section 4(c)?*

AND/OR

Has the issue been addressed in agency policy, management plans, species recovery plans, or agreements with other agencies or partners?

☑ YES

☐ NO

DESCRIBE DOCUMENTS & DIRECTION BELOW

Describe Documents & Direction:

The established purposes of the Farallon NWR set forth by **Executive Order 1043** (1909) is "as a preserve and breeding ground for native birds."

The Service's **National Wildlife Refuge System Improvement Act of 1997** (16 U.S.C. 668dd-668ee) states that "...the fundamental mission of our system is wildlife conservation..."

The Service's **Farallon National Wildlife Refuge Comprehensive Conservation Plan** (2009) identified eradication of invasive house mice from the Farallon Islands as a management priority to restore native species populations on the islands.

Fish and Wildlife Service Policy Part 601 FW 3 defines guidance for biological integrity, diversity, and environmental health for refuge management. Specifically for non-native species, prevention, and control of invasive species and restoration of native species and habitat conditions will be conducted through mechanical, chemical, biological, and cultural controls.

Fish and Wildlife Service Policy Part 610 FW 2.8 prohibits landing or flying over wilderness areas unless it is determined that such uses are the minimum requirement for administering the area as wilderness, and the use is necessary to accomplish the purposes of the refuge, including Wilderness Act purposes.

Fish and Wildlife Service Policy Part 610 FW 2.19 directs the Service to control invasive species, pests, and diseases in wilderness when it is demonstrated that they have degraded or there is a high probability they will degrade the biological integrity, diversity, environmental health, or wilderness character of a wilderness area; or it is demonstrated that they pose a significant threat to the health of fish, wildlife, plants, or their habitats. Control will be directed by an integrated pest management (IPM) approach to prevent, control, or eradicate invasive species, pests, and diseases subject to the criteria in 610 FW 2.16 and 601 FW 3.16.

Components of the Action

What are the discrete components or phases of the action?

Component X	*Example: Transportation of personnel to the project site*
Component 1	Application of rodenticide.
Component 2	Transportation of personnel for mouse removal.
Component 3	Transportation of personnel for gull hazing.
Component 4	Gull hazing tools, tent camp.
Component 5	Condition of the site after project completion.
Component 6	
Component 7	
Component 8	
Component 9	

Proceed to the alternatives.

Refer to the **MRDG Instructions** regarding alternatives and the effects to each of the comparison criteria.

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 1: No Action

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

If this alternative was selected, mice would not be eradicated, but other ongoing invasive species management programs on the South Farallones would continue. The Service currently manages invasive plants in the wilderness through manual control. Vegetation on the islands is closely monitored so that new invasions can be responded to and populations of current invasive species can be contained. The Service would also continue management activities focused on protecting storm-petrels and their habitats on the islands, including nest habitat construction. If mice were allowed to remain on the islands, ongoing negative impacts are anticipated affecting seabird, plant, and terrestrial invertebrate populations. The population decline seen in ashy storm-petrels is expected to continue, and impacts to the similar Leach's storm-petrel (*Oceanodroma leucorhoa*) 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 be seen. Native plant species including the maritime goldfield would continue to be affected. House mice also represent an ongoing potential vector of disease that could affect the islands' marine mammals.

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. 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 mouse 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, removal of invasive species, and management of designated wilderness.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	No bait application will occur.
2	Transportation of personnel for mouse removal.	No transportation of personnel for mouse removal will occur.
3	Transportation of personnel for gull hazing.	No transportation of personnel for gull hazing will occur.
4	Gull hazing tools, tent camp.	No gull hazing tools will be used.
5	Condition of the site after project completion.	Condition of the site will be unchanged.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	☑
2	No transportation of personnel for mouse removal will occur.	☐	☐	☑
3	No transportation of personnel for gull hazing will occur.	☐	☐	☑
4	No gull hazing tools will be used.	☐	☐	☑
5	Condition of the site will be unchanged.	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Untrammeled Total Rating			**0**	

Explain:

Untrammeled is defined as free from the action of modern human control or manipulation. The No Action alternative would not affect the untrammeled character of the wilderness because the presence of mice does not constitute human control or manipulation.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Undeveloped Total Rating			**0**	

Explain:

The presence of mice does not affect the undeveloped character of the wilderness, therefore, the No Action alternative would have no impact to this wilderness component.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	✓	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	1	NE
Natural Total Rating			**-1**	

Explain:

Under the No Action alternative, mice would not be eradicated from the South Farallon Islands and their negative impacts the the natural quality of wilderness would continue. However, proposed eradication methods and non-target mitigation activities (gull hazing) will have short-term impacts from potential non-target mortality to gulls and other species, and disturbance to pinnipeds, birds, plants, and other species. activities associated.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**0**	

Explain:

The presence of mice does not affect solitude or unconfined recreation in the wilderness. Therefore, the No Action alternative would have no impact on this wilderness character.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	✓	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	1	NE
Other Features of Value Total Rating			**-1**	

Explain:

By not changing the condition of the site by removing invasive house mice, mouse impacts to the endemic and rare species of the Farallones, part of the unique character of the Farallon Wilderness, would continue under the No Action alternative.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	✓	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	1	NE
Special Provisions Total Rating			**-1**	

Explain:

Because of continued impacts of house mice on native seabirds and other ecological features of the Farallon Wilderness, tNo Action would not satisfy **Executive Order 1043** (1909) designation as "as a preserve and breeding ground for native birds," the goals of the The Service's **Farallon National Wildlife Refuge Comprehensive Conservation Plan** (2009), **Executive Order 13112** requiring federal agencies to detect non-native invasive species, respond rapidly to infestations, and provide for restoration of native species and habitat conditions in ecosystems that have been invaded, and the **Fish and Wildlife Service Policy Part 610 FW 2.19** directing the Service to control invasive species, pests, and diseases in wilderness.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	✓	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	1	NE
Economics & Time Contraints Total Rating			**-1**	

Explain:

By not removing house mice, there likely will be other future but unknown costs associated with protecting or restoring species impacted by mice to mitigate impacts of mice. In the long-term, these costs could be significant.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	No bait application will occur.	☐	☐	✓
2	No transportation of personnel for mouse removal will occur.	☐	☐	✓
3	No transportation of personnel for gull hazing will occur.	☐	☐	✓
4	No gull hazing tools will be used.	☐	☐	✓
5	Condition of the site will be unchanged.	☐	✓	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	1	NE
Safety of Visitors & Workers Total Rating		**-1**		

Explain:

Although no impacts have been documented to date on the Farallon Islands, house mice are known vectors of disease. Removal of house mice would eliminate this potential threat.

Summary Ratings for Alternative 1

Wilderness Character	
Untrammeled	0
Undeveloped	0
Natural	-1
Solitude or Primitive & Unconfined Recreation	0
Other Features of Value	-1
Wilderness Character Summary Rating	**-2**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	-1
Economics & Time Constraints	-1
Other Criteria Summary Rating	**-2**

Safety	
Safety of Visitors & Workers	-1
Safety Summary Rating	**-1**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 2: Brodificoum 25-D Conservation

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

In Alternative 2, mice would be eradicated from the Farallones using an aerial (helicopter) application of Brodifacoum-25D Conservation rodent bait pellets as the primary application method. Application would occur in the fall between October and December when the risk to non-target wildlife is minimal. Bait would need to be applied to every mouse territory. Bait would be broadcast in 2 or possibly 3 applications separated by intervals of 10 to 21 days. Application rates would be up to 16 lb/acre (18 kg/ha) for the initial application and 8 lb/acre (9 kg/ha) for subsequent applications, for a total of 24 lb/acre (27kg/ha) assuming two applications. Using a helicopter guided by GPS, bait would be applied from a specialized bait spreading bucket , 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). Assuming two bait applications, estimated helicopter flight time over all islands is 3 hours (1.5 hours per application). Certain areas not accessible by aircraft would be hand-baited. At estimated application rates, the total amount of bait needed would be about 2,917 lb (1,323 kg). For ground-based operations, personnel would access West End Island, the largest island in the wilderness, from SE Farallon on foot and via a zip-line cable across the narrow Jordan Channel. Personnel access to other islets in the wilderness would be by drop-off from a small, motor-powered boat; motor boats would not land in wilderness. For islands of the size and rugged topography of the Farallones, aerial broadcast of rodent bait is currently regarded as the only primary method available to successfully and safely eradicate rodent populations.

Studies have shown that Western and other species of gulls are at high risk of mortality if they are exposed to Brodifacoum rodent bait. Potential bait exposure could be through direct consumption of bait pellets, or predation or scavenging of exposed mice, birds, invertebrates, or other organisms. Also, gull consumption of bait reduces bait availability to mice, risking failure of the eradication. To miminize these risks, gulls will be actively hazed from the islands for the duration of the application and for a period of time until the risk of exposure is negligible. Based on trials conducted in 2012, rodent bait is projected to be available to gulls for up to 8 weeks; thus, gull hazing would need to be conducted for at least that entire period. Gull hazing techniques might include gull effigies, flushing by human approach, air cannons, and an assortment of pyrotechnics. Gull hazing staff and supplies would access the wilderness on West End Island on foot and via a zip-line cable across the narrow Jordan Channel. A small, primitive tent-camp would be erected in a location where disturbance to natural resources would be minimal , with staff change-over approximately every 4 days. For each staff change-over, at least two trips would be necessary to access or depart from the wilderness (one for arriving crew, one for departing crew), for a total of 30 trips. Human foot traffic would cause unavoidable disturbances to resting seals and sea lions both inside and outside wilderness during each trip.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Brodificoum, some hand-baiting.
2	Transportation of personnel for mouse removal.	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.
3	Transportation of personnel for gull hazing.	On foot.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	✓	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	✓	☐
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Untrammeled Total Rating		**-3**		

Explain:

The wilderness would be trammeled by both aerial and hand-broadcasting broadcast of bait pellets (which will be readily noticeable for up to several weeks). For a successful operation, bait broadcast will be necessary over the entire island above the mean high tide line. Multiple low-level helicopter fly-overs will be necessary on 2-3 separate days, with about half of the total flight of three hours per day over wilderness. To minimize overflights of wilderness, flights not directly associated with bait broadcast will be prohibited over wilderness. The use of motorized boats in or to access wilderness is generally prohibited. Boats would not land in wilderness; motorized boat access to wilderness would be limited to either hand-broadcasting from the boat or drop off and later pickup (without boat landing) of personnel. Active gull hazing using techniques such as gull effigies, air cannons and pyrotechnics constitutes human manipulation of the environment. Besides gull effigies, which are set in place, gull hazing will be limited to when gulls have landed in or are approaching to land in wilderness, and will not be used when gulls are not present.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	■	■	✓
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	■	■	✓
3	On foot.	■	■	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	■	✓	■
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	■	■	✓
6		■	■	■
7		■	■	■
8		■	■	■
9		■	■	■
Totals		0	1	NE
Undeveloped Total Rating		**-1**		

Explain:

Gull effigies would be hung from posts erected temporarily. Effigies will be placed just prior to the start of eradication or as soon as deemed necessary is a particular location. Effigies would be removed at the end of the operation or as soon as considered to be unnecessary.

The small tent camp would be primitive, with no mechanized equipment or facilities. Primitive tent camps are not prohibited or discouraged in wilderness. However, because the Farallon Wilderness is closed to the public, overnight access and erection of camps has generally not been permitted. However, gull hazing may be required at nearly any time of day or night, as necessary. Also, by allowing longer-period stays, the numbers of trips into and out of the wilderness will be dramatically reduced, thereby substantially reducing disturbance to resting seals and sea lions. Thus, a camp is regarded as necessary.

NATURAL

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	✓	✓	
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.		✓	
3	On foot.		✓	
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	✓	✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		3	4	NE
Natural Total Rating		**-1**		

Explain:

1) & 5) The use of rodenticide to remove invasive mice will have a positive effect on the natural character of wilderness in perpetuity. Operations associated with broadcast of rodenticide bait will result in a substantial amount of short-term disturbance to birds and pinnipeds. Most disturbance will be from helicopter operations and a lesser amount from hand-baiting operations. However, this disturbance will only last for the duration of application activities, about 1.5 hours of helicopter operations and during the course of about 4 days for hand-baiting operations (assuming two bait applications). Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance. Also, some non-target take of birds, especially gulls, will almost certainly occur. Hazing and raptor capture will be conducted on a relatively large-scale to minimize non-target take.
2 & 3) To access many coastal areas, disturbance to resting pinnipeds will be an unavoidable negative effect. Most disturbance will occur while accessing West End I. for gull hazing. Based on data from 2009-early 2013, 34 trips to West End I. for research purposes, an average of 805 pinnipeds were disturbed per trip, including 468 animals flushed and 329 animals moved. Based on an estimated 30 trips in this alternative for gull hazing, 24,143 total pinniped takes would occur, including 14,029 flushed and 9,861 moved. Efforts to reduce disturbance would include slow movement and remaining as far from pinnipeds as possible. 4) Gulls and other birds will be disturbed by gull hazing operations for about 8 weeks. However, the use of these techniques will substantially reduce non-target take of gulls to a level below that at which there would be any long-term population level impacts. The adverse effects of hazing and the loss of individual gulls are outweighed by the long-term benefits of eradicating non-native mice and their impacts on the natural quality of wilderness.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	☑	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	☑	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	2	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-2**	

Explain:

Low-flying helicopters over the wilderness, as well as the use of pyrotechnics for gull hazing, could negatively effect solitude for researchers working on the islands and recreational boaters offshore. Pyrotechnics would only be used to haze gulls that otherwise cannot be accessed with gull effigies or on foot. Impacts are expected to be mimimal because the wilderness is closed to the public, only personnel affiliated with the project will be present on the Farallon Islands, and limited boat activity occurs off the islands during the period of proposed operations.

OTHER FEATURES OF VALUE

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	☐	☑
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☑	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The Refuge was established as a preserve and breeding ground for marine birds. One of the goals of the Refuge's CCP is to protect and restore to historic levels breeding populations of 12 seabird species, including the ashy storm-petrel. The presence of introduced house mice compromises the value of the Refuge as a preserve and breeding ground for marine birds. Nesting seabirds are expected to benefit as a consequence of mouse eradication through improved survivorship. In particular, eradicating house mice is expected to result in increased populations of at least two seabird species, the ashy storm-petrel and Leach's storm-petrel by reducing the numbers of overwintering burrowing owls and resulting owl predation on storm-petrels. Implementation of the project will result in the mortality of individual gulls and other birds due to direct or indirect consumption of bait. However, the success of the hazing program is expected to substantially reduce non-target mortality for birds, even though the hazing itself is a form of disturbance. Hazing activities will last for approximately 8 weeks. Although the project will result in disturbance and mortality to individual birds, and Western gulls in particular, the project will not result in any long-term population effects to bird species. The long-term improvement to the value of the Refuge as a preserve and breeding ground outweighs the short-term impacts of hazing and rodenticide use.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	☐	☑
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

There will be no positive or negative effects to maintaining traditional skills.

SPECIAL PROVISIONS

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	☐	✓
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Special Provisions Total Rating		**1**		

Explain:

Because invasive house mice and their impacts would be removed from the Farallon ecosystem, this alternative would help achieve directives and guidelines of: **Executive Order 1043** (1909) designation as "as a preserve and breeding ground for native birds;" the goals of The Service's **Farallon National Wildlife Refuge Comprehensive Conservation Plan** (2009); **Executive Order 13112** directing federal agencies to the extent practicable to detect non-native invasive species, respond to infestations, and provide for restoration of native species and habitat conditions in ecosystems that have been invaded; and **Fish and Wildlife Service Policy Part 610 FW 2.19** directing the Service to control invasive species, pests, and diseases in wilderness.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	✓	☐	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	✓	☐	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	✓	☐	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		4	0	NE
Economics & Time Contraints Total Rating		**4**		

Explain:

Brodificoum bait will only require 2-3 bait broadcasts with total operational time of about 10 weeks, considerably less than the 3-4 broadcasts and about 20 weeks operational time for diphacinone.
Access to West End on foot will eliminate the cost for helicopter time to transport personnel.
Limiting the use of gull hazing techniques to these techniques will reduce costs dramatically by not needing expensive biosonics systems.
Removing house mice will eliminate other potential but unknown costs for restoration of sensitive species impacted by mice.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting.	☐	✓	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	✓	✓	☐
3	On foot.	✓	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, small tent camp.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	4	NE
Safety of Visitors & Workers Total Rating		**-1**		

Explain:

The use of helicopters is always a safety risk, with potentially life-threatening results if a mishap occurs. Because of the rugged terrain and risk associated with zip line, foot travel to West End also has it's safety risk but this is substantiallly lower than for helicopter transport. The use of pyrotechnics can also lead to serious injury. Proper safety training and certifications will be used to reduce these risks as much as possible.
Exposure to rodenticides poses a threat to applicators and other project staff. Bait would only be applied by a California licensed applicator, and all project personnel would receive training on safe handling and other methods to minimize risk of exposure.
Working in boats in the marine environment poses safety risks to project staff. All boat drivers will be certified motorboat operators. Other boat staff will receiving appropriate training for working in boats.
Although no impacts have been documented to date on the Farallon Islands, house mice are known vectors of disease. Removal of house mice would eliminate this potential threat.

Summary Ratings for Alternative 2

Wilderness Character	
Untrammeled	-3
Undeveloped	-1
Natural	-1
Solitude or Primitive & Unconfined Recreation	-2
Other Features of Value	1
Wilderness Character Summary Rating	**-6**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	1
Economics & Time Constraints	4
Other Criteria Summary Rating	**5**

Safety	
Safety of Visitors & Workers	-1
Safety Summary Rating	**-1**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 3: Brodificoum 25-D Conservation with bait stations, battery-operated tools

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

Alternative 3 would be identical to Alternative 2 except for the following:

For bait application, bait stations may be used in certain easily accessible areas where risk of bait consumption by gulls is considered to be high. Bait stations would be secured to the ground with anchors, placed into the soil, or drilled into rock or a wooden board as necessary to hold it in place. Bait stations would be removed upon the completion of the project (approximately 8 weeks).

Additional gull hazing techniques might include lasers, spotlights, and biosonics. Lasers and spotlights would be hand-held and battery-operated. These would only be used to haze gulls that have either landed on the island or are flying towards the island. Biosonics systems will include audio player, speaker(s), 12-volt battery, and possible photovoltaic array. Biosonics will only be placed at locations where either other less intrusive gull hazing techniques have been unsuccessful or where gulls continually return. For locations that are accessible without disturbing marine mammals, biosonics will turned on only as needed. In locations that cannot be accessed without disturbing marine mammals, biosonics will be turned on and off periodically by way of a timer.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.
2	Transportation of personnel for mouse removal.	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.
3	Transportation of personnel for gull hazing.	On foot.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	✓	☐
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Untrammeled Total Rating			**-3**	

Explain:

Like Alternative 2, except that the use of battery-operated lasers and biosonics will have a short-term negative effect on the untrammeled character of the wilderness. These items produce either unnatural light (lasers) or amplified sound of gull, predator, or other bird sounds. To reduce the impact of these items, lasers can only be used in low light conditions, and will only be used when are present in the wilderness or flying just offshore as opposed to continuous use. Most use will be in the dawn and dusk period, when hazing trials in 2012 found them to be most needed. Biosonics will only be used in areas where gulls have been found to frequent and where other, non-trammeling techniques have been found to be ineffective. Biosonics equipment will be removed either when gulls discontinue landing at the site or when the risk to gulls from toxic bait has diminished (bait is no longer available or palatable).

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	■	✓	■
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	■	■	✓
3	On foot.	■	■	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	■	✓	■
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	■	■	✓
6		■	■	■
7		■	■	■
8		■	■	■
9		■	■	■
Totals		0	2	NE
Undeveloped Total Rating			**-2**	

Explain:

Like Alternative 2, except for bait application. Bait stations would be utilized in certain easily-accessible areas where non-target risk of bait consumption is considered to be especially high. Also, like Alternative 2, gull hazing would include gull effigies but in addition, biosonics equipment will need to be placed temporarily in locations near certain gull roosts. Biosonics systems will include audio player, speaker(s), 12 volt battery, and possible photovoltaic array. Effigies and biosonics will be placed just prior to the start of eradication operations or as soon as deemed necessary in a particular location. Effigies and biosonics systems would be removed at the end of the operation or as soon as considered to be unnecessary.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	✓	☐
3	On foot.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	✓	☐	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	3	NE
Natural Total Rating			**0**	

Explain:

Like Alternative 2, except as follows. Bait stations may reduce some non-target take of birds and thereby reduce the negative effects on the natural quality that would otherwise result from the loss of some individuals.
Gulls can become habituated to hazing techniques. The use of additional gull hazing tools in this alternative will not only provide for more effective gull hazing, it will also lessen the chance for gulls to become habituated to the hazing techniques. The use of lasers and biosonics may increase disturbance to gulls in the short term but reduce non-target take of gulls or other birds due to their increased effectiveness. Chances of successful eradication (and its corresponding benefits) will also be increased with the use of these additional techniques.
Compared to Alternative 2, there would be additional short term adverse impacts to the natural quality from bait stations, lasers and biosonics. These impacts would end when the equipment is removed. The eradication of non-native mice would eliminate impacts on petrels from hyperpredation. It would also eliminate the impacts from their consumption of native invertebrates and their impacts on island vegetation. Elimination of these impacts from mice is expected to result in long-term benefits to petrel and invertebrate populations on the island. These long term benefits, which would help to restore the natural qualities of the Farallon Wilderness, outweigh the short term adverse impacts associated with project operations.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	2	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-2**	

Explain:

Like Alternative 2, but additional noise from biosonics will further degrade the solitude value of wilderness.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	☐	✓
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating			**1**	

Explain:

Like Alternative 2, but compared to Alternative 2, the use of additional hazing techniques may reduce mortality of gulls because these additional techniques would be more effective at keeping gulls off the islands while bait is available.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	☐	☑
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

Like Alternative 2.

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	☐	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	0	NE
Special Provisions Total Rating		**2**		

Explain:

Like Alternative 2.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	✓	☐	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	2	NE
Economics & Time Contraints Total Rating		**1**		

Explain:

Like Alternative 2, except: addition of bait stations will increase cost because of need to purchase bait stations, place bait stations, and maintain bait stations. However, this cost is partially offset because bait stations will be maintained by gull hazing personnel already on site. Biosonics also will add substantial cost, as much as $60,000 if certain equipment cannot be obtained on loan.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	✓	✓	☐
3	On foot.	✓	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	4	NE
Safety of Visitors & Workers Total Rating			**-1**	

Explain:

Like Alternative 2, except that with inclusion of bait stations and biosonics, access to more areas will be necessary, increasing risk of injury. However, the increase in this risk is not considered to be significant. Proper safety training for installation and use of bait stations will be provided to all staff conducted these activities.

Summary Ratings for Alternative 3

Wilderness Character	
Untrammeled	-3
Undeveloped	-2
Natural	0
Solitude or Primitive & Unconfined Recreation	-2
Other Features of Value	1
Wilderness Character Summary Rating	**-6**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	2
Economics & Time Constraints	1
Other Criteria Summary Rating	**3**

Safety	
Safety of Visitors & Workers	-1
Safety Summary Rating	**-1**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 4: Brodificoum 25-D Conservation with bait stations, battery-operated tools, helicopter landings

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

Alternative 4 would be identical to Alternative 3 except for the following:

Gull hazing staff change-over at West End Island will occur about every 4 days via helicopter drop-off and pick-up. With a one-passenger helicopter, for each staff change-over, five helicopter landings would be necessary to transport personnel and supplies. Assuming an 8-week hazing period, a total of 75 helicopter landings would occur in the wilderness. The benefit of the helicopter transport of personnel and supplies would be a reduction in the numbers of marine mammals disturbed during each staff change-over and a reduction in potential for staff injuries climbing over the rugged terrain of the islands.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.
2	Transportation of personnel for mouse removal.	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.
3	Transportation of personnel for gull hazing.	By helicopter.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	✓	☐
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	4	NE
Untrammeled Total Rating			**-4**	

Explain:

Like Alternative 3, except for the additional effect of helicopter landings (estimate = 75 over 8 weeks) in the wilderness for drop off and pick up of personnel and supplies for gull hazing. This is a major impact to the untrammeled character of the wilderness.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.		✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.			✓
3	By helicopter.			✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v			✓
6				
7				
8				
9				
Totals		0	2	NE
Undeveloped Total Rating			**-2**	

Explain:

Like Alternative 3.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.		✓	
3	By helicopter.		✓	
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	✓		
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		3	3	NE
Natural Total Rating			**0**	

Explain:

Like Alternative 3, except helicopter transport of personnel to West End Island should dramatically reduce incidental disturbance to hauled-out, resting pinnipeds (sea lions and seals) . Based on data from December 2012 gull hazing trials, an average of 343 pinnipeds were disturbed per helicopter trip to deliver personnel and gear to West End Island, including 16 animals flushed and 32 animals moved. Based on an estimated 75 trips in this alternative to transport gull hazing and bait station staff and gear , 25,708 total pinniped takes would occur, including 1,183 flushed and 9,892 moved (remainder alerted). The number of animals flushed and moved is dramatically lower than by foot transport (Alternatives 2-3).

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-3**	

Explain:

Like Alternative 3, except that helicopter transport of personnel and supplies to West End Island for gull hazing and bait station maintenance will dramatically degrade the wilderness quality of solitude.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	☐	✓
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating			**1**	

Explain:

Like Alternatives 2 and 3.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	☐	☑
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	☑
3	By helicopter.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

Like Alternatives 2 and 3.

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	☐	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	0	NE
Special Provisions Total Rating		**2**		

Explain:

Like Alternatives 2 and 3.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	✓	✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.			✓
3	By helicopter.		✓	
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		2	3	NE
Economics & Time Contraints Total Rating		**-1**		

Explain:

Like Alternative 3, except that helicopter transport to West End Island may dramatically increase cost. Change in cost will depend on whether or not it is decided to use a helicopter to search for gulls as part of the hazing efforts. If a helicopter is used and on site, additional costs for helicopter transport will be small. If a helicopter is not used and is not on site, cost will be approximately $1,550/day for eight weeks or $86,800.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Brodificoum, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	✓	✓	☐
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	4	NE
Safety of Visitors & Workers Total Rating			**-2**	

Explain:

Like Alternative 3, except that helicopter transport of personnel and supplies to West End Island for gull lhazing and bait station maintenance substantially increases the chances of an aircraft mishap, with potential for serious injury or mortality. This risk could be reduced by staff training and diligent adherence to safety protocols.

Summary Ratings for Alternative 4

Wilderness Character	
Untrammeled	-4
Undeveloped	-2
Natural	0
Solitude or Primitive & Unconfined Recreation	-3
Other Features of Value	1
Wilderness Character Summary Rating	**-8**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	2
Economics & Time Constraints	-1
Other Criteria Summary Rating	**1**

Safety	
Safety of Visitors & Workers	-2
Safety Summary Rating	**-2**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 5: Diphacinone-50 Conservation

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

In Alternative 5, mice would be eradicated from the Farallones using an aerial (helicopter) application of Diphacinone-50 Conservation rodent bait pellets as the primary application method. Application would occur in the fall between October and December when the risk to non-target wildlife is minimal. Bait would need to be applied to every mouse territory. Bait would be broadcast in 3 or possibly 4 applications separated by intervals of about 7 days. Application rates would be up to 43 lb/acre (48 kg/ha) for each application, for a total of 128 lb/acre (144 kg/ha) assuming three applications. Using a helicopter guided by GPS, bait would be applied from a specialized bait spreading bucket , 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). Assuming two bait applications, estimated helicopter flight time over all islands is 3 hours (1.5 hours per application). Certain areas not accessible by aircraft would be hand-baited. At estimated application rates, the total amount of bait needed would be about 15,560 lb (7,056 kg). For ground-based operations, personnel would access West End Island, the largest island in the wilderness, from SE Farallon on foot and via a zip-line cable across the narrow Jordan Channel. Personnel access to other islets in the wilderness would be by drop-off from a small, motor-powered boat. Boats would not land in wilderness. For islands of the size and rugged topography of the Farallones, aerial broadcast of rodent bait is currently regarded as the only primary method available to successfully and safely eradicate rodent populations.

Studies have shown that Western and other species of gulls are at risk of mortality if they are exposed to Diphacinone bait. Potential bait exposure could be through direct consumption of bait pellets, or predation or scavenging of exposed mice, birds, invertebrates, or other organisms. Also, gull consumption of bait removes bait from availability to mice, risking failure of the eradication. To miminize these risks, gulls will be actively hazed from the islands for the duration of the application and for a period of time until the risk of exposure is negligible. Based on trials conducted in 2012, Diphacinone bait is projected to be available to gulls for up to 18 weeks; thus, gull hazing would need to be conducted for at least that entire period. Gull hazing techniques might include gull effigies, flushing by human approach, air cannons, and an assortment of pyrotechnics. Gull hazing staff and supplies would access the West End wilderness area on foot and via a zip-line cable across the narrow Jordan Channel. A small, primitive tent-camp would be erected in a location where disturbance to natural resources would be minimal , with staff change-over approximately every 4 days. For each staff change-over, at least two trips would be necessary to access or depart from the wilderness (one for arriving crew, one for departing crew), for a total of 68 trips. Human foot traffic would cause unavoidable disturbances to resting seals and sea lions both inside and outside wilderness during each trip.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Diphacinone, some hand-baiting.
2	Transportation of personnel for mouse removal.	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.
3	Transportation of personnel for gull hazing.	On foot.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	✓	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	✓	☐
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Untrammeled Total Rating			**-3**	

Explain:

The wilderness would be trammeled by both aerial and hand-broadcasting broadcast of bait pellets (which will be readily noticeable for up to several weeks). For a successful operation, bait broadcast will be necessary over the entire island above the mean high tide line. Multiple low-level helicopter fly-overs will be necessary on 2-3 separate days, with about half of the total flight of three hours per day over wilderness. To minimize overflights of wilderness, flights not directly associated with bait broadcast will be prohibited over wilderness. The use of motorized boats in or to access wilderness is generally prohibited. Boats would not land in wilderness; motorized boat access to wilderness would be limited to either hand-broadcasting from the boat or drop off and later pickup (without boat landing) of personnel. Active gull hazing using techniques such as gull effigies, air cannons and pyrotechnics constitutes human manipulation of the environment. Besides gull effigies, which are set in place, gull hazing will be limited to when gulls have landed in or are approaching to land in wilderness, and will not be used when gulls are not present.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.			✓
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.			✓
3	On foot.			✓
4	Gull effigies, human approach, air cannons, pyrotechnics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v			✓
6				
7				
8				
9				
Totals		0	1	NE
Undeveloped Total Rating		**-1**		

Explain:

Gull effigies would be hung from posts erected temporarily. Effigies will be placed just prior to the start of eradication or as soon as deemed necessary is a particular location. Effigies would be removed at the end of the operation or as soon as considered to be unnecessary.

The small tent camp would be primitive, with no mechanized equipment or facilities. Primitive tent camps are not prohibited or discouraged in wilderness. However, because the Farallon Wilderness is closed to the public, overnight access and erection of camps has generally not been permitted. However, gull hazing may be required at nearly any time of day or night, as necessary. Also, by allowing longer-period stays, the numbers of trips into and out of the wilderness will be dramatically reduced, thereby substantially reducing disturbance to resting seals and sea lions. Thus, a camp is regarded as necessary.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	✓	✓	
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.		✓	
3	On foot.		✓	
4	Gull effigies, human approach, air cannons, pyrotechnics.	✓		
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		3	3	NE
Natural Total Rating			**0**	

Explain:

1) & 5) The use of rodenticide application to remove mice will have a positive effect on the natural character of wilderness in perpetuity. Operations associated with broadcast of rodenticide bait will result in a substantial amount of short-term disturbance to resting birds and pinnipeds. Most disturbance will be from helicopter and a lesser amount from hand-baiting operations. However, disturbance will only last for the duration of application activities, about 5 hours of helicopter operations and during the course of about 6 days for hand-baiting operations (assuming 3 bait applications). Minimizing time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance. Also, some non-target take of birds, especially gulls, may occur. Hazing and raptor capture will be conducted on a relatively large-scale to minimize non-target take. 2 & 3) To access many coastal areas, disturbance to resting pinnipeds will be an unavoidable negative effect. Most disturbance will occur while accessing West End I. for gull hazing. Based on data from 2009-early 2013 (N = 34 trips to West End I. for research purposes), an average of 805 pinnipeds were disturbed per trip, including 468 animals flushed and 329 animals moved. Based on an estimated 68 trips in this alternative for gull hazing, 54,724 total pinniped takes would occur, including 31,798 flushed and 22,352 moved. Efforts to reduce disturbance would include slow movement and remaining as far from pinnipeds as possible. 4) Gulls and other birds will be disturbed by gull hazing operations for 18 weeks. However, the use of these techniques will substantially reduce non-target take of gulls to a level below that at which there would be any long-term population level impacts. The adverse effects of hazing and the loss of individual gulls are outweighed by the long term benefits of eradicating non-native mice and their impacts on the natural quality of wilderness.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	✓	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	2	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-2**	

Explain:

Low-flying helicopters over the wilderness, as well as the use of air cannons and pyrotechnics for gull hazing, would negatively effect the character of solitude in the Farallon Wilderness. Pyrotechnics and air cannons would only be used to haze gulls that otherwise cannot be hazed with gull effigies or on foot. No impacts to unconfined or primitive recreation would occur.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	☐	✓
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The Refuge was established as a preserve and breeding ground for marine birds. One of the goals of the Refuge's CCP is to protect and restore to historic levels breeding populations of 12 seabird species, including the ashy storm-petrel. The presence of introduced house mice compromises the value of the Refuge as a preserve and breeding ground for marine birds. Nesting seabirds are expected to benefit as a consequence of mouse eradication through improved survivorship . In particular, eradicating house mice is expected to result in increased populations of at least two seabird species, the ashy storm-petrel and Leach's storm-petrel by reducing the numbers of overwintering burrowing owls and resulting owl predation on storm-petrels. Implementation of the project will result in the mortality of individual gulls and other birds due to direct or indirect consumption of bait. However, the success of the hazing program is expected to substantially reduce non-target mortality for birds, even though the hazing itself is a form of disturbance. Hazing activities will last for approximately 8 weeks. Although the project will result in disturbance and mortality to individual birds, and Western gulls in particular, the project will not result in any long-term population effects to bird species. The long-term improvement to the value of the Refuge as a preserve and breeding ground outweighs the short-term impacts of hazing and rodenticide use.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	☐	☑
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

There will be no positive or negative effects to maintaining traditional skills.

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	☐	✓
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Special Provisions Total Rating		**1**		

Explain:

Because invasive house mice and their impacts would be removed from the Farallon ecosystem, this alternative would help achieve directives and guidelines of: **Executive Order 1043** (1909) designation as "as a preserve and breeding ground for native birds;" the goals of The Service's **Farallon National Wildlife Refuge Comprehensive Conservation Plan** (2009); **Executive Order 13112** directing federal agencies to the extent practicable to detect non-native invasive species, respond to infestations, and provide for restoration of native species and habitat conditions in ecosystems that have been invaded; and **Fish and Wildlife Service Policy Part 610 FW 2.19** directing the Service to control invasive species, pests, and diseases in wilderness.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.	☐	✓	☐
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	☐	☐	✓
3	On foot.	✓	☐	☐
4	Gull effigies, human approach, air cannons, pyrotechnics.	✓	☐	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	1	NE
Economics & Time Contraints Total Rating		**2**		

Explain:

Diphacinone will require 3-4 bait broadcasts with total operational time of about 20 weeks, considerably more than the 2-3 broadcasts and about 10 weeks operational time for Brodificoum.
Access to West End on foot will eliminate the cost for helicopter time to transport personnel.
Limiting the use of gull hazing techniques to these techniques will reduce costs dramatically by not needing expensive biosonics systems.
Removing house mice will eliminate other potential but unknown costs for restoration of sensitive species impacted by mice.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting.		✓	
2	On foot to West End Island. Drop off by small motorized boat to other areas; no landing.	✓	✓	
3	On foot.	✓	✓	
4	Gull effigies, human approach, air cannons, pyrotechnics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		3	4	NE
Safety of Visitors & Workers Total Rating		**-1**		

Explain:

The use of helicopters is always a safety risk, with potentially life-threatening results if a mishap occurs. Because of the rugged terrain and risk associated with zip line, foot travel to West End also has it's safety risk but this is substantiallly lower than for helicopter transport. The use of pyrotechnics can also lead to serious injury. Proper safety training and certifications will be used to reduce these risks as much as possible.
Exposure to rodenticides poses a threat to applicators and other project staff. Bait would only be applied by a California licensed applicator, and all project personnel would receive training on safe handling and other methods to minimize risk of exposure.
Working in boats in the marine environment poses safety risks to project staff. All boat drivers will be certified motorboat operators. Other boat staff will receiving appropriate training for working in boats.
Although no impacts have been documented to date on the Farallon Islands, house mice are known vectors of disease. Removal of house mice would eliminate this potential threat.

Summary Ratings for Alternative 5

Wilderness Character	
Untrammeled	-3
Undeveloped	-1
Natural	0
Solitude or Primitive & Unconfined Recreation	-2
Other Features of Value	1
Wilderness Character Summary Rating	**-5**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	1
Economics & Time Constraints	2
Other Criteria Summary Rating	**3**

Safety	
Safety of Visitors & Workers	-1
Safety Summary Rating	**-1**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 6: Diphacinone-50 Conservation with bait stations, battery-operated tools

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

Alternative 6 would be identical to Alternative 5 except for the following:

For bait application, bait stations may be used in certain easily accessible areas where risk of bait consumption by gulls is considered to be high. Bait stations would be secured to the ground with anchors, placed into the soil, or drilled into rock or a wooden board as necessary to hold it in place. Bait stations would be removed upon the completion of the project (approximately 18 weeks).

Additional gull hazing techniques might include lasers, spotlights, and biosonics. Lasers and spotlights would be hand-held and battery-operated. These would only be used to haze gulls that have either landed on the island or are flying towards the island. Biosonics systems will include audio player, speaker(s), 12-volt battery, and possible photovoltaic array. Biosonics will only be placed at locations where either other less intrusive gull hazing techniques have been unsuccessful or where gulls continually return. For locations that are accessible without disturbing marine mammals, biosonics will turned on only as needed. In locations that cannot be accessed without disturbing marine mammals, biosonics will be turned on and off periodically by way of a timer.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.
2	Transportation of personnel for mouse removal.	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.
3	Transportation of personnel for gull hazing.	On foot.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	✓	☐
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Untrammeled Total Rating			**-3**	

Explain:

Like Alternative 5, except that the use of battery-operated lasers and biosonics will have a short-term negative effect on the untrammeled character of the wilderness. These items produce either unnatural light (lasers) or amplified sound of gull, predator, or other bird sounds. To reduce the impact of these items, lasers can only be used in low light conditions, and will only be used when are present in the wilderness or flying just offshore as opposed to continuous use. Most use will be in the dawn and dusk period, when hazing trials in 2012 found them to be most needed. Biosonics will only be used in areas where gulls have been found to frequent and where other, non-trammeling techniques have been found to be ineffective. Biosonics equipment will be removed either when gulls discontinue landing at the site or when the risk to gulls from toxic bait has diminished (bait is no longer available or palatable).

UNDEVELOPED

	Component Activity for this Alternative	Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.		✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.			✓
3	On foot.			✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v			✓
6				
7				
8				
9				
Totals		0	2	NE
Undeveloped Total Rating		**-2**		

Explain:

Like Alternative 5, except for bait application. Bait stations would be utilized in certain easily-accessible areas where non-target risk of bait consumption is considered to be especially high. Also, like Alternative 5, gull hazing would include gull effigies but in addition, biosonics equipment will need to be placed temporarily in locations near certain gull roosts. Biosonics systems will include audio player, speaker(s), 12 volt battery, and possible photovoltaic array. Effigies and biosonics will be placed just prior to the start of eradication operations or as soon as deemed necessary in a particular location. Effigies and biosonics systems would be removed at the end of the operation or as soon as considered to be unnecessary.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	☐	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	☐
3	On foot.	☐	☐	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Natural Total Rating			**0**	

Explain:

Like Alternative 5, except as follows. Bait stations may reduce some non-target take of birds and thereby reduce the negative effects on the natural quality that would otherwise result from the loss of some individuals.
Gulls can become habituated to hazing techniques. The use of additional gull hazing tools in this alternative will not only provide for more effective gull hazing, it will also lessen the chance for gulls to become habituated to the hazing techniques. The use of lasers and biosonics may increase disturbance to gulls in the short term but reduce non-target take of gulls or other birds due to their increased effectiveness. Chances of successful eradication (and its corresponding benefits) will also be increased with the use of these additional techniques.
Compared to Alternative 5, there would be additional short term adverse impacts to the natural quality from bait stations, lasers and biosonics. These impacts would end when the equipment is removed. The eradication of non-native mice would eliminate impacts on petrels from hyperpredation. It would also eliminate the impacts from their consumption of native invertebrates and their impacts on island vegetation. Elimination of these impacts from mice is expected to result in long-term benefits to petrel and invertebrate populations on the island. These long term benefits, which would help to restore the natural qualities of the Farallon Wilderness, outweigh the short term adverse impacts associated with project operations.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	2	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-2**	

Explain:

Like Alternative 5, but additional noise from biosonics will further degrade the solitude value of wilderness.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	☐	✓
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

Like Alternative 5, but compared to Alternative 5, the use of additional hazing techniques may reduce mortality of gulls because these additional techniques would be more effective at keeping gulls off the islands while bait is available.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	☐	☑
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	☑
3	On foot.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

Like Alternattive 5.

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	✓	☐	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	0	NE
Special Provisions Total Rating		**2**		

Explain:

Like Alternative 5.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	✓	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	On foot.	✓	☐	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	2	NE
Economics & Time Contraints Total Rating			**1**	

Explain:

Like Alternative 5, except: addition of bait stations will increase cost because of need to purchase bait stations, place bait stations, and maintain bait stations. However, this cost is partially offset because bait stations will be maintained by gull hazing personnel already on site. Biosonics also will add substantial cost, as much as $60,000 if certain equipment cannot be obtained on loan.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	✓	✓	☐
3	On foot.	✓	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		3	4	NE
Safety of Visitors & Workers Total Rating			**-1**	

Explain:

Like Alternative 5, except that with inclusion of bait stations and biosonics, access to more areas will be necessary, increasing risk of injury. However, the increase in this risk is not considered to be significant. Proper safety training for installation and use of bait stations will be provided to all staff conducted these activities.

Summary Ratings for Alternative 6

Wilderness Character	
Untrammeled	-3
Undeveloped	-2
Natural	0
Solitude or Primitive & Unconfined Recreation	-2
Other Features of Value	1
Wilderness Character Summary Rating	**-6**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	2
Economics & Time Constraints	1
Other Criteria Summary Rating	**3**

Safety	
Safety of Visitors & Workers	-1
Safety Summary Rating	**-1**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternatives

Alternative 7: Diphacinone-50 Conservation with bait stations, battery-operated tools, helicopter landings

Description of the Alternative

What are the details of this alternative? When, where, and how will the action occur? What mitigation measures will be taken?

Alternative 7 would be identical to Alternative 6 except for the following:

Gull hazing staff change-over at West End Island will occur about every 4 days via helicopter drop-off and pick-up. With a one-passenger helicopter, for each staff change-over, five helicopter landings would be necessary to transport personnel and supplies. Assuming an 18-week hazing period, a total of 170 helicopter landings would occur in the wilderness. The benefit of the helicopter transport of personnel and supplies would be a reduction in the numbers of marine mammals disturbed during each staff change-over and a reduction in potential for staff injuries climbing over the rugged terrain of the islands.

Component Activities

How will each of the components of the action be performed under this alternative?

Component of the Action		Activity for this Alternative
X	*Example: Transportation of personnel to the project site*	*Example: Personnel will travel by horseback*
1	Application of rodenticide.	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.
2	Transportation of personnel for mouse removal.	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.
3	Transportation of personnel for gull hazing.	By helicopter.
4	Gull hazing tools, tent camp.	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.
5	Condition of the site after project completion.	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.
6		
7		
8		
9		

Wilderness Character

What is the effect of each component activity on the qualities of wilderness character? What mitigation measures will be taken?

UNTRAMMELED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	✓	☐
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	4	NE
Untrammeled Total Rating			**-4**	

Explain:

Like Alternative 3, except for the additional effect of helicopter landings (estimate = 170 over 18 weeks) in the wilderness for drop off and pick up of personnel and supplies for gull hazing. This is a major impact to the untrammeled character of the wilderness.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.		✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.			✓
3	By helicopter.			✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.		✓	
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v			✓
6				
7				
8				
9				
Totals		0	2	NE
Undeveloped Total Rating		**-2**		

Explain:

Like Alternative 4.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	✓	✓	
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.		✓	
3	By helicopter.		✓	
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	✓		
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓		
6				
7				
8				
9				
Totals		3	3	NE
Natural Total Rating			**0**	

Explain:

Like Alternative 6, except helicopter transport of personnel to West End Island should dramatically reduce incidental disturbance to hauled-out, resting pinnipeds (sea lions and seals). Based on data from December 2012 gull hazing trials, an average of 343 pinnipeds were disturbed per helicopter trip to deliver personnel and geat to West End Islnd, including 16 animals flushed and 32 animals moved. Based on an estimated 170 trips in this alternative to transport gull hazing and bait station staff and gear , 58,272 total pinniped takes would occur, including 2,682 flushed and 22,421 moved (remainder alerted). The number of animals flushed and moved is dramatically lower than by foot transport (Alternatives 5-6).

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	✓
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	3	NE
Solitude or Primitive & Unconfined Recreation Total Rating			**-3**	

Explain:

Like Alternative 6, except that helicopter transport of personnel and supplies to West End Island for gull hazing and bait station maintenance will dramatically degrade the wilderness quality of solitude.

OTHER FEATURES OF VALUE

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	☐	✓
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

Like Alternatives 5 and 6.

Other Criteria

What is the effect of each component activity on other comparison criteria? What mitigation measures will be taken?

MAINTAINING TRADITIONAL SKILLS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☑	☐	☐
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	☐	☑
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	☑
3	By helicopter.	☐	☐	☑
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	☑
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	☐	☐	☑
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		0	0	NE
Maintaining Traditional Skills Total Rating			**0**	

Explain:

Like Alternatives 5 and 6.

SPECIAL PROVISIONS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	✓	☐	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	☐	✓
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	☐	✓
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	0	NE
Special Provisions Total Rating			**2**	

Explain:

Like Alternatives 5 and 6.

ECONOMICS & TIME CONSTRAINTS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	✓	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	☐	☐	✓
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	3	NE
Economics & Time Contraints Total Rating			**-1**	

Explain:

Like Alternative 6, except that helicopter transport to West End Island may dramatically increase cost. Change in cost will depend on whether or not it is decided to use a helicopter to search for gulls as part of the hazing efforts. If a helicopter is used and on site, additional costs for helicopter transport will be small. If a helicopter is not used and is not on site, cost will be approximately $1,550/day for eighteen weeks or $195,300.

Safety of Visitors & Workers

What is the effect of each component activity on the safety of visitors and workers? What mitigation measures will be taken?

SAFETY OF VISITORS & WORKERS

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☑
1	Primarily aerial broadcast of Diphacinone, some hand-baiting, bait stations.	☐	✓	☐
2	On foot to West End Island. If necessary, drop off by small motorized boat to other areas.	✓	✓	☐
3	By helicopter.	☐	✓	☐
4	Gull effigies, human approach, air cannons, pyrotechnics, lasers, biosonics.	☐	✓	☐
5	Invasive house mice will have been eradicated. All project equipment will have been removed; bait v	✓	☐	☐
6		☐	☐	☐
7		☐	☐	☐
8		☐	☐	☐
9		☐	☐	☐
Totals		2	4	NE
Safety of Visitors & Workers Total Rating			**-2**	

Explain:

Like Alternative 6, except that helicopter transport of personnel and supplies to West End Island for gull lhazing and bait station maintenance substantially increases the chances of an aircraft mishap, with potential for serious injury or mortality. This risk could be reduced by staff training and diligent adherence to safety protocols.

Summary Ratings for Alternative 7

Wilderness Character	
Untrammeled	-4
Undeveloped	-2
Natural	0
Solitude or Primitive & Unconfined Recreation	-3
Other Features of Value	1
Wilderness Character Summary Rating	**-8**

Other Criteria	
Maintaining Traditional Skills	0
Special Provisions	2
Economics & Time Constraints	-1
Other Criteria Summary Rating	**1**

Safety	
Safety of Visitors & Workers	-2
Safety Summary Rating	**-2**

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG STEP 2: Alternatives Not Analyzed

Alternatives Not Analyzed

What alternatives were considered but not analyzed? Why were they not analyzed?

1) Mouse control as primary method: This would not eliminate mouse impacts and is infeasible to conduct island-wide.
2) Bait stations as primary method: Infeasible due to rugged topography, disturbance impacts, safety.
3) Hand-broadcasting as primary method: Infeasible due to rugged topography, safety.
4) Trapping: Infeasible due to rugged topography, disturbance impacts, safety, extremely low likelihood of success.
5) Use of disease: Technology does not currently exist.
6) Use of biological control: Extremely low likelihood of success. Introduced species for control (e.g., cats, snakes) would likely have greater impacts on ecosystem than mice.
7) Fertility control: Technology does not currently exist.
8) Burrowing owl relocation: Owl relocation to remove their impacts on storm-petrels would not remove other impacts of mice on Farallon ecosystem. Also, obtaining federal migratory bird and California state collecting permits for translocating burrowing owls for the purpose of protecting Ashy Storm-Petrels, which would need to continue in perpetuity, are not currently possible.
9) Non-motorized boat to access offshore islets: Often rough seas, difficult, wave-swept landing conditions, and large numbers of dangerous white sharks in nearshore waters make the use of non-motorized boats extremely unsafe and infeasible.

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Alternative Comparison

Alternative 1: No Action

Alternative 2: Brodificoum 25-D Conservation

Alternative 3: Brodificoum 25-D Conservation with bait stations, battery-operated tools

Alternative 4: Brodificoum 25-D Conservation with bait stations, battery-operated tools, helicopter landings

Wilderness Character	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Untrammeled	0	0	0	3	0	3	0	4
Undeveloped	0	0	0	1	0	2	0	2
Natural	0	1	3	4	3	3	3	3
Solitude or Primitive & Unconfined Rec.	0	0	0	2	0	2	0	3
Other Features of Value	0	1	1	0	1	0	1	0
Totals	0	2	4	10	4	10	4	12
Wilderness Character Rating	**-2**		**-6**		**-6**		**-8**	

Other Criteria	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Maintaining Traditional Skills	0	0	0	0	0	0	0	0
Special Provisions	0	1	1	0	2	0	2	0
Economics & Time Constraints	0	1	4	0	3	2	2	3
Totals	0	2	5	0	5	2	4	3
Other Criteria Rating	**-2**		**5**		**3**		**1**	

Safety	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Safety of Visitors & Workers	0	1	3	4	3	4	2	4
Safety Rating	**-1**		**-1**		**-1**		**-2**	

Alternative 5:	Diphacinone-50 Conservation
Alternative 6:	Diphacinone-50 Conservation with bait stations, battery-operated tools
Alternative 7:	Diphacinone-50 Conservation with bait stations, battery-operated tools, helicopter landings
Alternative 8:	

Wilderness Character	**Alternative 5**		**Alternative 6**		**Alternative 7**		**Alternative 8**	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Untrammeled	0	3	0	3	0	4	0	0
Undeveloped	0	1	0	2	0	2	0	0
Natural	3	3	0	0	3	3	0	0
Solitude or Primitive & Unconfined Rec.	0	2	0	2	0	3	0	0
Other Features of Value	1	0	1	0	1	0	0	0
Totals	4	9	1	7	4	12	0	0
Wilderness Character Rating	**-5**		**-6**		**-8**		**0**	

Other Criteria	**Alternative 5**		**Alternative 6**		**Alternative 7**		**Alternative 8**	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Maintaining Traditional Skills	0	0	0	0	0	0	0	0
Special Provisions	1	0	2	0	2	0	0	0
Economics & Time Constraints	3	1	3	2	2	3	0	0
Totals	4	1	5	2	4	3	0	0
Other Criteria Rating	**3**		**3**		**1**		**0**	

Safety	**Alternative 5**		**Alternative 6**		**Alternative 7**		**Alternative 8**	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Safety of Visitors & Workers	3	4	3	4	2	4	0	0
Safety Rating	**-1**		**-1**		**-2**		**0**	

Project Title: Non-native Invasive House Mice on the Farallon Islands

MRDG Step 2: Decision

Refer to the **MRDG Instructions** before identifying the selected alternative and explaining the rationale for the selection.

Selected Alternative

Alternative 1:	☐ [redacted]	
Alternative 2:	☐ [redacted]	ation
Alternative 3:	☐ [redacted]	ation with bait stations, battery-operated tools
Alternative 4:	☐ [redacted]	ation with bait stations, battery-operated tools, helicopter la
Alternative 5:	☐ [redacted]	tion
Alternative 6:	☐ [redacted]	tion with bait stations, battery-operated tools
Alternative 7:	☐ [redacted]	tion with bait stations, battery-operated tools, helicopter lan
Alternative 8:	☐ [redacted]	

Explain Rationale for Selection:

At this time, there is not a Selected Alternative. This draft Wilderness MRDG will be provided in a Draft Environmental Impact Statement (EIS) analyzing alternatives for eradicating introduced, invasive house mice from the South Farallon Islands. Full and objective input from the public is encouraged on all of the alternatives analyzed in the Draft EIS. After all public comments on the Draft EIS have been received and evaluated, this Draft MRDG will be revised as necessary and an alternative selected.

If more space is needed, continue on the next page…

Explain Rationale for Selection, Continued:

Describe Monitoring & Reporting Requirements:

Approval of Prohibited Uses

Which of the prohibited uses found in Section 4(c) of the Wilderness Act are approved in the selected alternative and for what quantity?

Prohibited Use	Quantity
☐ [redacted] ort	
☐ [redacted] nt	
☐ [redacted]	
☐ [redacted]	
☐ [redacted]	
☐ [redacted]	
☐ [redacted]	
☐ [redacted]	

Record and report any authorizations of Wilderness Act Section 4(c) prohibited uses according to agency policies or guidance.

Refer to agency policies for the following review and decision authorities:

Prepared	Name	Position	
	Gerry McChesney	Refuge Manager	
	Signature		Date
Recommended	Name	Position	
	Signature		Date
Recommended	Name	Position	
	Signature		Date
Approved	Name	Position	
	Signature		Date

8.7 Appendix H – Avian Species List

Anseriformes - Screamers, Swans, Geese, and Ducks

Anatidae - Ducks, Geese, and Swans

Greater White-fronted Goose *Anser albifrons*
Emperor Goose *Chen canagica* - *
Snow Goose *Chen caerulescens*
Ross's Goose *Chen rossii*
Brant *Branta bernicla*
Cackling Goose *Branta hutchinsii*
Canada Goose *Branta canadensis*
Tundra Swan *Cygnus columbianus*
Wood Duck *Aix sponsa*
Gadwall *Anas strepera*
Eurasian Wigeon *Anas penelope*
American Wigeon *Anas americana*
Mallard *Anas platyrhynchos*
Blue-winged Teal *Anas discors*
Cinnamon Teal *Anas cyanoptera*
Northern Shoveler *Anas clypeata*
Northern Pintail *Anas acuta*
Green-winged Teal *Anas crecca*
Canvasback *Aythya valisineria*
Ring-necked Duck *Aythya collaris*
Greater Scaup *Aythya marila*
Lesser Scaup *Aythya affinis*
Harlequin Duck *Histrionicus histrionicus*
Surf Scoter *Melanitta perspicillata*
White-winged Scoter *Melanitta fusca*
Black Scoter *Melanitta americana*
Long-tailed Duck *Clangula hyemalis*
Bufflehead *Bucephala albeola*
Common Goldeneye *Bucephala clangula*
Barrow's Goldeneye *Bucephala islandica*
Common Merganser *Mergus merganser*
Red-breasted Merganser *Mergus serrator*
Ruddy Duck *Oxyura jamaicensis*

Gaviiformes - Loons

Gaviidae - Loons

Red-throated Loon *Gavia stellata*
Pacific Loon *Gavia pacifica*
Common Loon *Gavia immer*
Yellow-billed Loon *Gavia adamsii* - *

Podicipediformes - Grebes
Podicipedidae - Grebes
Pied-billed Grebe *Podilymbus podiceps*
Horned Grebe *Podiceps auritus*
Red-necked Grebe *Podiceps grisegena*
Eared Grebe *Podiceps nigricollis*
Western Grebe *Aechmophorus occidentalis*
Clark's Grebe *Aechmophorus clarkii*

Procellariiformes - Tube-nosed Swimmers
Diomedeidae - Albatrosses
Laysan Albatross *Phoebastria immutabilis*
Black-footed Albatross *Phoebastria nigripes*
Short-tailed Albatross *Phoebastria albatrus* - *

Procellariidae - Shearwaters and Petrels
Northern Fulmar *Fulmarus glacialis*
Murphy's Petrel *Pterodroma ultima*
Cook's Petrel *Pterodroma cookii*
Pink-footed Shearwater *Puffinus creatopus*
Flesh-footed Shearwater *Puffinus carneipes*
Buller's Shearwater *Puffinus bulleri*
Sooty Shearwater *Puffinus griseus*
Short-tailed Shearwater *Puffinus tenuirostris*
Manx Shearwater *Puffinus puffinus* - PV
Black-vented Shearwater *Puffinus opisthomelas*

Hydrobatidae - Storm-Petrels
Fork-tailed Storm-Petrel *Oceanodroma furcata*
Leach's Storm-Petrel *Oceanodroma leucorhoa*
Ashy Storm-Petrel *Oceanodroma homochroa*
Tristram's Storm-Petrel *Oceanodroma tristrami* - *P
Black Storm-Petrel *Oceanodroma melania*

Phaethontiformes - Tropicbirds
Phaethontidae - Tropicbirds
Red-tailed Tropicbird *Phaethon rubricauda* - *

Suliformes - Frigatebirds, Boobies, Cormorants, Darters, and Allies
Fregatidae - Frigatebirds
Magnificent Frigatebird *Fregata magnificens* - *
Great Frigatebird *Fregata minor* - *P

Sulidae - Boobies and Gannets
Masked Booby *Sula dactylatra* - *P
Brown Booby *Sula leucogaster*
Red-footed Booby *Sula sula* - *
Northern Gannet *Morus bassanus* - *

Phalacrocoracidae - Cormorants
Brandt's Cormorant *Phalacrocorax penicillatus*
Double-crested Cormorant *Phalacrocorax auritus*
Pelagic Cormorant *Phalacrocorax pelagicus*

Pelecaniformes - Pelicans, Herons, Ibises, and Allies
Pelecanidae - Pelicans
Brown Pelican *Pelecanus occidentalis*

Ardeidae - Herons, Bitterns, and Allies
American Bittern *Botaurus lentiginosus*
Great Blue Heron *Ardea herodias*
Great Egret *Ardea alba*
Snowy Egret *Egretta thula*
Cattle Egret *Bubulcus ibis*
Green Heron *Butorides virescens*
Black-crowned Night-Heron *Nycticorax nycticorax*

Threskiornithidae - Ibises and Spoonbills
White-faced Ibis *Plegadis chihi*

Accipitriformes - Hawks, Kites, Eagles, and Allies
Cathartidae - New World Vultures
Turkey Vulture *Cathartes aura*

Pandionidae - Ospreys
Osprey *Pandion haliaetus*

Accipitridae - Hawks, Kites, Eagles, and Allies
White-tailed Kite *Elanus leucurus*
Bald Eagle *Haliaeetus leucocephalus*
Northern Harrier *Circus cyaneus*
Sharp-shinned Hawk *Accipiter striatus*
Cooper's Hawk *Accipiter cooperii*
Red-tailed Hawk *Buteo jamaicensis*
Ferruginous Hawk *Buteo regalis*
Rough-legged Hawk *Buteo lagopus*
Golden Eagle *Aquila chrysaetos*

Gruiformes - Rails, Cranes, and Allies

Rallidae - Rails, Gallinules, and Coots

Black Rail *Laterallus jamaicensis*
Clapper Rail *Rallus longirostris*
Virginia Rail *Rallus limicola*
Sora *Porzana carolina*
Common Gallinule *Gallinula galeata*
American Coot *Fulica americana*

Gruidae - Cranes

Sandhill Crane *Grus canadensis*

Charadriiformes - Shorebirds, Gulls, Auks, and Allies

Charadriidae - Lapwings and Plovers

Black-bellied Plover *Pluvialis squatarola*
American Golden-Plover *Pluvialis dominica*
Pacific Golden-Plover *Pluvialis fulva*
Snowy Plover *Charadrius nivosus*
Semipalmated Plover *Charadrius semipalmatus*
Killdeer *Charadrius vociferus*
Eurasian Dotterel *Charadrius morinellus* - *PV

Haematopodidae - Oystercatchers

Black Oystercatcher *Haematopus bachmani*

Recurvirostridae - Stilts and Avocets

Black-necked Stilt *Himantopus mexicanus*
American Avocet *Recurvirostra americana*

Scolopacidae - Sandpipers, Phalaropes, and Allies

Spotted Sandpiper *Actitis macularius*
Solitary Sandpiper *Tringa solitaria*
Wandering Tattler *Tringa incana*
Greater Yellowlegs *Tringa melanoleuca*
Willet *Tringa semipalmata*
Lesser Yellowlegs *Tringa flavipes*
Upland Sandpiper *Bartramia longicauda* - *
Whimbrel *Numenius phaeopus*
Long-billed Curlew *Numenius americanus*
Bar-tailed Godwit *Limosa lapponica* - *
Marbled Godwit *Limosa fedoa*
Ruddy Turnstone *Arenaria interpres*
Black Turnstone *Arenaria melanocephala*

Surfbird *Aphriza virgata*
Red Knot *Calidris canutus*
Sanderling *Calidris alba*
Semipalmated Sandpiper *Calidris pusilla*
Western Sandpiper *Calidris mauri*
Little Stint *Calidris minuta* - *
Least Sandpiper *Calidris minutilla*
Baird's Sandpiper *Calidris bairdii*
Pectoral Sandpiper *Calidris melanotos*
Sharp-tailed Sandpiper *Calidris acuminata*
Rock Sandpiper *Calidris ptilocnemis*
Dunlin *Calidris alpina*
Buff-breasted Sandpiper *Tryngites subruficollis*
Ruff *Philomachus pugnax*
Short-billed Dowitcher *Limnodromus griseus*
Long-billed Dowitcher *Limnodromus scolopaceus*
Wilson's Snipe *Gallinago delicata*
Wilson's Phalarope *Phalaropus tricolor*
Red-necked Phalarope *Phalaropus lobatus*
Red Phalarope *Phalaropus fulicarius*

Laridae - Gulls, Terns, and Skimmers

Black-legged Kittiwake *Rissa tridactyla*
Sabine's Gull *Xema sabini*
Bonaparte's Gull *Chroicocephalus philadelphia*
Laughing Gull *Leucophaeus atricilla*
Franklin's Gull *Leucophaeus pipixcan*
Heermann's Gull *Larus heermanni*
Mew Gull *Larus canus*
Ring-billed Gull *Larus delawarensis*
Western Gull *Larus occidentalis*
California Gull *Larus californicus*
Herring Gull *Larus argentatus*
Thayer's Gull *Larus thayeri*
Glaucous-winged Gull *Larus glaucescens*
Glaucous Gull *Larus hyperboreus*
Caspian Tern *Hydroprogne caspia*
Common Tern *Sterna hirundo*
Arctic Tern *Sterna paradisaea*
Forster's Tern *Sterna forsteri*
Elegant Tern *Thalasseus elegans*

Stercorariidae - Skuas

South Polar Skua *Stercorarius maccormicki*

Pomarine Jaeger *Stercorarius pomarinus*
Parasitic Jaeger *Stercorarius parasiticus*
Long-tailed Jaeger *Stercorarius longicaudus*

Alcidae - Auks, Murres, and Puffins
Common Murre *Uria aalge*
Thick-billed Murre *Uria lomvia* - *
Pigeon Guillemot *Cepphus columba*
Marbled Murrelet *Brachyramphus marmoratus*
Scripps's Murrelet *Synthliboramphus scrippsi*
Craveri's Murrelet *Synthliboramphus craveri*
Ancient Murrelet *Synthliboramphus antiquus*
Cassin's Auklet *Ptychoramphus aleuticus*
Rhinoceros Auklet *Cerorhinca monocerata*
Horned Puffin *Fratercula corniculata*
Tufted Puffin *Fratercula cirrhata*

Columbiformes - Pigeons, and Doves
Columbidae - Pigeons and Doves
Rock Pigeon *Columba livia* - I
Band-tailed Pigeon *Patagioenas fasciata*
Eurasian Collared-Dove *Streptopelia decaocto* - I
White-winged Dove *Zenaida asiatica*
Mourning Dove *Zenaida macroura*

Cuculiformes - Cuckoos and Allies
Cuculidae - Cuckoos, Roadrunners, and Anis
Yellow-billed Cuckoo *Coccyzus americanus*
Black-billed Cuckoo *Coccyzus erythropthalmus* - *

Strigiformes - Owls
Tytonidae - Barn Owls
Barn Owl *Tyto alba*

Strigidae - Typical Owls
Great Horned Owl *Bubo virginianus*
Burrowing Owl *Athene cunicularia*
Long-eared Owl *Asio otus*
Short-eared Owl *Asio flammeus*
Northern Saw-whet Owl *Aegolius acadicus*

Caprimulgiformes - Goatsuckers, Oilbirds, and Allies
Caprimulgidae - Goatsuckers
Lesser Nighthawk *Chordeiles acutipennis*

Common Nighthawk *Chordeiles minor*
Common Poorwill *Phalaenoptilus nuttallii*

Apodiformes - Swifts, and Hummingbirds
Apodidae - Swifts
Black Swift *Cypseloides niger*
Chimney Swift *Chaetura pelagica*
Vaux's Swift *Chaetura vauxi*
White-throated Swift *Aeronautes saxatalis*

Trochilidae - Hummingbirds
Ruby-throated Hummingbird *Archilochus colubris* - *
Black-chinned Hummingbird *Archilochus alexandri*
Anna's Hummingbird *Calypte anna*
Costa's Hummingbird *Calypte costae*
Rufous Hummingbird *Selasphorus rufus*
Allen's Hummingbird *Selasphorus sasin*
Calliope Hummingbird *Selasphorus calliope*

Coraciiformes - Rollers, Motmots, Kingfishers, and Allies
Alcedinidae - Kingfishers
Belted Kingfisher *Ceryle alcyon*

Piciformes - Puffbirds, Jacamars, Toucans, Woodpeckers, and Allies
Picidae - Woodpeckers and Allies
Lewis's Woodpecker *Melanerpes lewis*
Acorn Woodpecker *Melanerpes formicivorus*
Yellow-bellied Sapsucker *Sphyrapicus varius*
Red-naped Sapsucker *Sphyrapicus nuchalis*
Red-breasted Sapsucker *Sphyrapicus ruber*
Northern Flicker *Colaptes auratus*

Falconiformes - Caracaras and Falcons
Falconidae - Caracaras and Falcons
American Kestrel *Falco sparverius*
Merlin *Falco columbarius*
Peregrine Falcon *Falco peregrinus*
Prairie Falcon *Falco mexicanus*

Passeriformes - Passerine Birds
Tyrannidae - Tyrant Flycatchers
Olive-sided Flycatcher *Contopus cooperi*
Western Wood-Pewee *Contopus sordidulus*
Eastern Wood-Pewee *Contopus virens* - *PA

Yellow-bellied Flycatcher *Empidonax flaviventris* - *
Alder Flycatcher *Empidonax alnorum* - *
Willow Flycatcher *Empidonax traillii*
Least Flycatcher *Empidonax minimus*
Hammond's Flycatcher *Empidonax hammondii*
Gray Flycatcher *Empidonax wrightii*
Dusky Flycatcher *Empidonax oberholseri*
Pacific-slope Flycatcher *Empidonax difficilis*
Black Phoebe *Sayornis nigricans*
Eastern Phoebe *Sayornis phoebe*
Say's Phoebe *Sayornis saya*
Ash-throated Flycatcher *Myiarchus cinerascens*
Great Crested Flycatcher *Myiarchus crinitus* - *
Brown-crested Flycatcher *Myiarchus tyrannulus*
Sulphur-bellied Flycatcher *Myiodynastes luteiventris* - *PV
Tropical Kingbird *Tyrannus melancholicus*
Cassin's Kingbird *Tyrannus vociferans*
Western Kingbird *Tyrannus verticalis*
Eastern Kingbird *Tyrannus tyrannus*
Scissor-tailed Flycatcher *Tyrannus forficatus*

Laniidae - Shrikes
Brown Shrike *Lanius cristatus* - *P
Loggerhead Shrike *Lanius ludovicianus*
Northern Shrike *Lanius excubitor*

Vireonidae - Vireos
White-eyed Vireo *Vireo griseus* - *PA
Bell's Vireo *Vireo bellii*
Yellow-throated Vireo *Vireo flavifrons*
Plumbeous Vireo *Vireo plumbeus*
Cassin's Vireo *Vireo cassinii*
Blue-headed Vireo *Vireo solitarius* - *
Hutton's Vireo *Vireo huttoni*
Warbling Vireo *Vireo gilvus*
Philadelphia Vireo *Vireo philadelphicus*
Red-eyed Vireo *Vireo olivaceus*
Yellow-green Vireo *Vireo flavoviridis* - *

Corvidae - Crows and Jays
Clark's Nutcracker *Nucifraga columbiana*
American Crow *Corvus brachyrhynchos*
Common Raven *Corvus corax*

Alaudidae - Larks
Horned Lark *Eremophila alpestris*

Hirundinidae - Swallows
Purple Martin *Progne subis*
Tree Swallow *Tachycineta bicolor*
Violet-green Swallow *Tachycineta thalassina*
Northern Rough-winged Swallow *Stelgidopteryx serripennis*
Bank Swallow *Riparia riparia*
Cliff Swallow *Petrochelidon pyrrhonota*
Barn Swallow *Hirundo rustica*

Sittidae - Nuthatches
Red-breasted Nuthatch *Sitta canadensis*
White-breasted Nuthatch *Sitta carolinensis*
Pygmy Nuthatch *Sitta pygmaea*

Certhiidae - Creepers
Brown Creeper *Certhia americana*

Troglodytidae - Wrens
Rock Wren *Salpinctes obsoletus*
Canyon Wren *Catherpes mexicanus*
House Wren *Troglodytes aedon*
Pacific Wren *Troglodytes pacificus*
Winter Wren *Troglodytes hiemalis* - *PA
Marsh Wren *Cistothorus palustris*
Bewick's Wren *Thryomanes bewickii*

Polioptilidae - Gnatcatchers and Gnatwrens
Blue-gray Gnatcatcher *Polioptila caerulea*

Cinclidae - Dippers
American Dipper *Cinclus mexicanus*

Regulidae - Kinglets
Golden-crowned Kinglet *Regulus satrapa*
Ruby-crowned Kinglet *Regulus calendula*

Phylloscopidae - Leaf Warblers
Dusky Warbler *Phylloscopus fuscatus* - *
Arctic Warbler *Phylloscopus borealis* - *P

Megaluridae - Grassbirds
Lanceolated Warbler *Locustella lanceolata* - *P

Muscicapidae - Old World Flycatchers
Red-flanked Bluetail *Tarsiger cyanurus* - *P
Northern Wheatear *Oenanthe oenanthe* - *

Turdidae - Thrushes
Western Bluebird *Sialia mexicana*
Mountain Bluebird *Sialia currucoides*
Townsend's Solitaire *Myadestes townsendi*
Veery *Catharus fuscescens* - *P
Gray-cheeked Thrush *Catharus minimus* - *
Swainson's Thrush *Catharus ustulatus*
Hermit Thrush *Catharus guttatus*
American Robin *Turdus migratorius*
Varied Thrush *Ixoreus naevius*

Mimidae - Mockingbirds and Thrashers
Gray Catbird *Dumetella carolinensis*
Northern Mockingbird *Mimus polyglottos*
Sage Thrasher *Oreoscoptes montanus*
Brown Thrasher *Toxostoma rufum*
Bendire's Thrasher *Toxostoma bendirei*

Sturnidae - Starlings
European Starling *Sturnus vulgaris* - I

Motacillidae - Wagtails and Pipits
Eastern Yellow Wagtail *Motacilla tschutschensis* - *P
White Wagtail *Motacilla alba* - *P
Olive-backed Pipit *Anthus hodgsoni* - *P
Red-throated Pipit *Anthus cervinus*
American Pipit *Anthus rubescens*
Sprague's Pipit *Anthus spragueii*

Bombycillidae - Waxwings
Bohemian Waxwing *Bombycilla garrulus*
Cedar Waxwing *Bombycilla cedrorum*

Ptilogonatidae - Silky-flycatchers
Phainopepla *Phainopepla nitens*

Calcariidae - Longspurs and Snow Buntings
Lapland Longspur *Calcarius lapponicus*
Chestnut-collared Longspur *Calcarius ornatus*

Smith's Longspur *Calcarius pictus* - *PV
Snow Bunting *Plectrophenax nivalis* - *

Parulidae - Wood-Warblers
Ovenbird *Seiurus aurocapilla*
Worm-eating Warbler *Helmitheros vermivorum* - *
Louisiana Waterthrush *Parkesia motacilla* - *
Northern Waterthrush *Parkesia noveboracensis*
Golden-winged Warbler *Vermivora chrysoptera* - *
Blue-winged Warbler *Vermivora cyanoptera* - *
Black-and-white Warbler *Mniotilta varia*
Prothonotary Warbler *Protonotaria citrea*
Tennessee Warbler *Oreothlypis peregrina*
Orange-crowned Warbler *Oreothlypis celata*
Lucy's Warbler *Oreothlypis luciae*
Nashville Warbler *Oreothlypis ruficapilla*
Virginia's Warbler *Oreothlypis virginiae*
Connecticut Warbler *Oporornis agilis* - *
MacGillivray's Warbler *Geothlypis tolmiei*
Mourning Warbler *Geothlypis philadelphia* - *
Kentucky Warbler *Geothlypis formosa*
Common Yellowthroat *Geothlypis trichas*
Hooded Warbler *Setophaga citrina*
American Redstart *Setophaga ruticilla*
Cape May Warbler *Setophaga tigrina* - *
Cerulean Warbler *Setophaga cerulea* - *
Northern Parula *Setophaga americana*
Magnolia Warbler *Setophaga magnolia*
Bay-breasted Warbler *Setophaga castanea*
Blackburnian Warbler *Setophaga fusca*
Yellow Warbler *Setophaga petechia*
Chestnut-sided Warbler *Setophaga pensylvanica*
Blackpoll Warbler *Setophaga striata*
Black-throated Blue Warbler *Setophaga caerulescens*
Palm Warbler *Setophaga palmarum*
Pine Warbler *Setophaga pinus* - *
Yellow-rumped Warbler *Setophaga coronata*
Yellow-throated Warbler *Setophaga dominica*
Prairie Warbler *Setophaga discolor*
Grace's Warbler *Setophaga graciae* - *
Black-throated Gray Warbler *Setophaga nigrescens*
Townsend's Warbler *Setophaga townsendi*
Hermit Warbler *Setophaga occidentalis*
Golden-cheeked Warbler *Setophaga chrysoparia* - *

Black-throated Green Warbler *Setophaga virens*
Canada Warbler *Cardellina canadensis*
Wilson's Warbler *Cardellina pusilla*
Red-faced Warbler *Cardellina rubrifrons* - *
Yellow-breasted Chat *Icteria virens*

Emberizidae - Emberizids

Green-tailed Towhee *Pipilo chlorurus*
Spotted Towhee *Pipilo maculatus*
Rufous-crowned Sparrow *Aimophila ruficeps*
Cassin's Sparrow *Peucaea cassinii* - *
American Tree Sparrow *Spizella arborea*
Chipping Sparrow *Spizella passerina*
Clay-colored Sparrow *Spizella pallida*
Brewer's Sparrow *Spizella breweri*
Field Sparrow *Spizella pusilla* - *P
Black-chinned Sparrow *Spizella atrogularis*
Vesper Sparrow *Pooecetes gramineus*
Lark Sparrow *Chondestes grammacus*
Black-throated Sparrow *Amphispiza bilineata*
Sage Sparrow *Artemisiospiza belli*
Lark Bunting *Calamospiza melanocorys*
Savannah Sparrow *Passerculus sandwichensis*
Grasshopper Sparrow *Ammodramus savannarum*
Baird's Sparrow *Ammodramus bairdii* - *
Le Conte's Sparrow *Ammodramus leconteii* - *
Nelson's Sparrow *Ammodramus nelsoni*
Fox Sparrow *Passerella iliaca*
Song Sparrow *Melospiza melodia*
Lincoln's Sparrow *Melospiza lincolnii*
Swamp Sparrow *Melospiza georgiana*
White-throated Sparrow *Zonotrichia albicollis*
Harris's Sparrow *Zonotrichia querula*
White-crowned Sparrow *Zonotrichia leucophrys*
Golden-crowned Sparrow *Zonotrichia atricapilla*
Dark-eyed Junco *Junco hyemalis*
Little Bunting *Emberiza pusilla* - *P

Cardinalidae - Cardinals and Allies

Hepatic Tanager *Piranga flava*
Summer Tanager *Piranga rubra*
Scarlet Tanager *Piranga olivacea*
Western Tanager *Piranga ludoviciana*
Rose-breasted Grosbeak *Pheucticus ludovicianus*

Black-headed Grosbeak *Pheucticus melanocephalus*
Blue Grosbeak *Passerina caerulea*
Lazuli Bunting *Passerina amoena*
Indigo Bunting *Passerina cyanea*
Painted Bunting *Passerina ciris*
Dickcissel *Spiza americana*

Icteridae - Blackbirds

Bobolink *Dolichonyx oryzivorus*
Red-winged Blackbird *Agelaius phoeniceus*
Tricolored Blackbird *Agelaius tricolor*
Western Meadowlark *Sturnella neglecta*
Yellow-headed Blackbird *Xanthocephalus xanthocephalus*
Rusty Blackbird *Euphagus carolinus* - *
Brewer's Blackbird *Euphagus cyanocephalus*
Common Grackle *Quiscalus quiscula* - *
Great-tailed Grackle *Quiscalus mexicanus*
Brown-headed Cowbird *Molothrus ater*
Orchard Oriole *Icterus spurius*
Hooded Oriole *Icterus cucullatus*
Bullock's Oriole *Icterus bullockii*
Baltimore Oriole *Icterus galbula*
Scott's Oriole *Icterus parisorum*

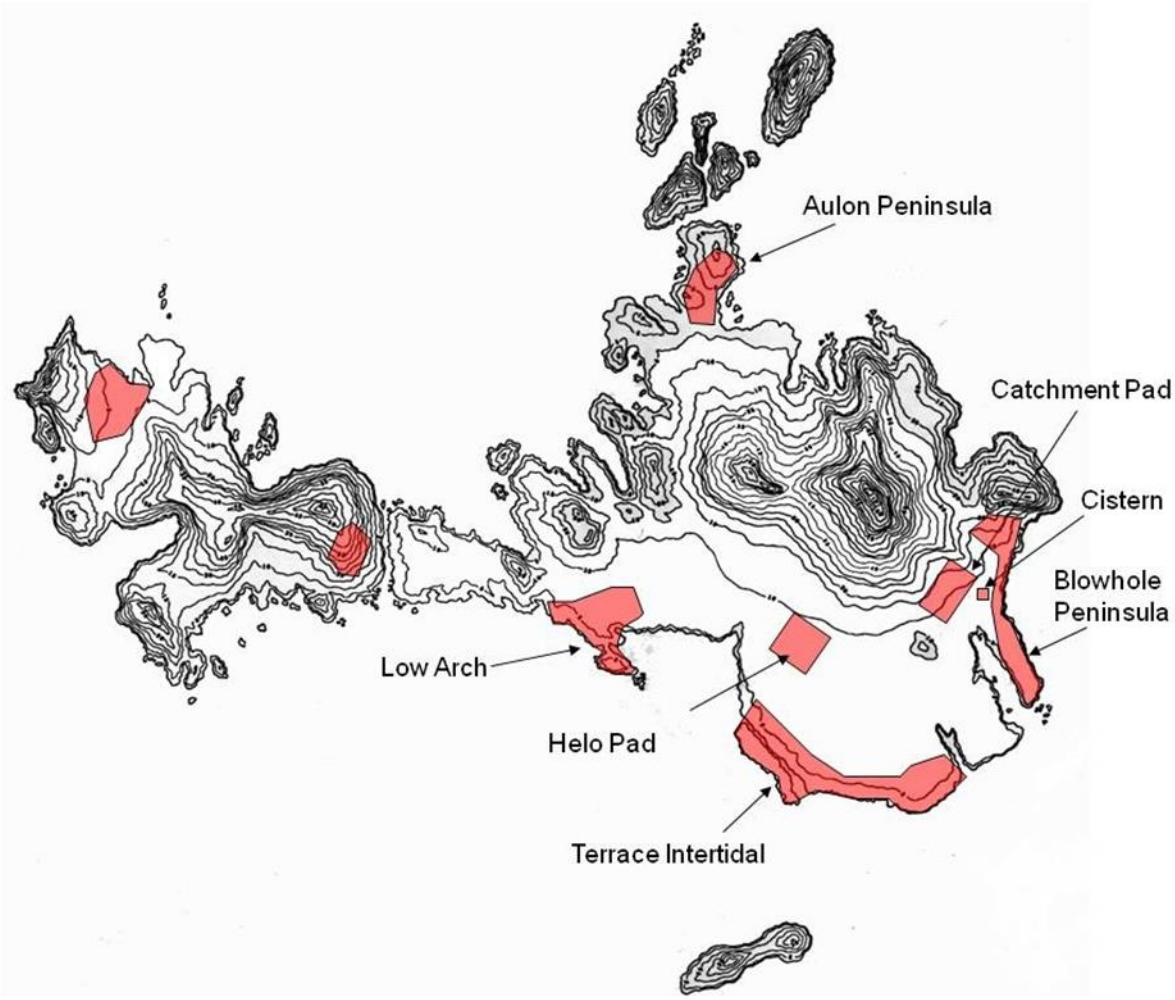
Fringillidae - Fringilline and Cardueline Finches and Allies

Common Rosefinch *Carpodacus erythrinus* - *P
Purple Finch *Haemorhous purpureus*
Cassin's Finch *Haemorhous cassinii*
House Finch *Haemorhous mexicanus*
Red Crossbill *Loxia curvirostra*
Common Redpoll *Acanthis flammea* - *
Pine Siskin *Spinus pinus*
Lesser Goldfinch *Spinus psaltria*
Lawrence's Goldfinch *Spinus lawrencei*
American Goldfinch *Spinus tristis*
Evening Grosbeak *Coccothraustes vespertinus*

Passeridae - Old World Sparrows

House Sparrow *Passer domesticus* - I

8.8 Appendix I – Map of Western Gull Roosting Sites



8.9 Appendix J – Intertidal Species List

Farallon Islands – Invertebrates (231 taxa) and Fishes (8 taxa), 6/26/12

ANNELIDA: ragworms, earthworms and leeches
Arabella iricolor
Dodecaceria fewkesi
Nereis guberi
Phyllochaetopterus prolifica
Serpula vermicularis
Spirorbis borealis
Thelepus crispus

ARTHROPODA: insects, arachnids, and crustaceans
Acanthomysis sp.
Achelia chelata
Achelia spinoseta
Allorchestes anceps
Alpheus dentipes
Ammothea hilgendorfi
Anatanais normani
Balanus amphitrite
Balanus glandula
Balanus nubilus
Caprella anomala
Caprella californica
Chthamalus dalli
Cirolana harfordi
Elasmopus serricatus
Exosphaeroma inornata
Fabia subquadrata
Gnorimosphaeroma sp.
Hemigrapsus nudus
Hyale grandicornis
Ianiropsis kincaidi
Idotea fewkesi
Idotea resecata
Idotea schmitti
Idotea stenops
Idotea urotoma
Idotea wosnesenskii
Lecythorychus hilgendorfi
Ligia occidentalis
Ligia pallasii

Limnoria algarum
Littorophiloscia richardsonae
Lophopanopeus leucomanus
Melita californica
Nymphopsis spinosissima
Oedignathus inermis
Pachygrapsus nudus
Pagurus hirsutiusculus
Pagurus samuelensis
Paracerceis cordata
Parallorchestes ochotensis
Paraxanthia taylorii
Pollicipes polymerus
Polycheria osborni
Porcellio americanus
Pugettia gracilis
Pugettia product
Romalean antennarius
Romalean magister
Romalean productus
Scyra acutifrons
Scyra acutifrons
Semibalanus cariosus
Tetraclita rubescens
bryozoan (unid.)
Eurystomella bilabiata
Flustrellidra corniculata

CNIDARIA: corals, sea anemones, jellyfish, sea pens, sea pansies, sea wasps, and tiny freshwater hydra
Allopora porphyra
Anthopleura elegantissima
Anthopleura sola
Anthopleura xanthogrammica
Aurelia aurita
Balanophyllia elegans
Corynactis californica
Epiactis prolifera
Obelia sp.
Stylantheca prophyra
Symplectuscyphus turgida
Tethya aurantia
Urticina crassicornis
Urticina lofotensis
Amphiodia occidentalis
Amphipholis squamata
Dermasterias imbricata

Henricia leviuscula
Leptasterias hexactis
Leptasterias puscilla

ECHINODERMATA: starfish, sand dollars, crinoids, sea urchins, sea cucumbers, and brittle stars
Loxorhyncus crispatus
Ophiopholis aculeata
Ophiothrix spiculata
Patiria miniata
Pisaster giganteus
Pisaster ochraceus
Pycnogonum stearnsi
Pycnopodia helianthoides
Strongylocentrotus droebachiensis
Strongylocentrotus franciscanus
Strongylocentrotus purpuratus

ENTOPROCTA: entoprocts, goblet worms, and kamptozoans
Barentsia benedeni

HYDROIDA: the subclass Leptolinae (or Hydroidolina) which also includes the colonial jellies of the Siphonophora which were not part of the Hydroida
Abietinaria sp.
Aglaophenia inconspicua
hydrozoans (brown, unid.)
Amphissa columbiana
Acmaea mitra
Alia tuberosa
Amphissa versicolor
Anisodoris noblis
Balcis thersites
Barleeia haliotiphila
Barleeia subtenuis
Berthella californica
Cadlina luteomarginata
Cadlina modesta
Calliostoma annulatum
Calliostoma canaliculatum
Calliostoma ligatum
Chama arcana
Chlorostoma brunnea
Chlorostoma funebralis
Corolla spectabilis (Pteropod)
Crassaderma giganteus
Crepidula adunca

Crepidula perforans
Crepipatella lingulata
Cryptochiton stelleri
Cryptomya californica
Cyanoplax dentiens
Cymakra aspera

MOLLUSCA: mollusks
Diodora aspera
Diplodonta orbella
Dirona picta
Epitonium tinctum
Flabellina trilineata
Gastropod (unid.)
Granulina margaritula
Haliotis racherodii
Haliotis rufescens
Hermissenda crassicornis
Hiatella arctica
Hipponix craniodes
Irus lamellifer
Ischnochiton regularis
Katharina tunicata
Kellia laperousii
Lacuna cistula
Lacuna marmorata
Lacuna porrecta
Lacuna unifasciata
Lasaea subviridis
Lirobittium purpureum
Lirobittium schrichtii
Littorina keenae
Littorina planaxis
Littorina scutulata
Littorina sitkana
Lottia asmi
Lottia digitalis
Lottia gigantea
Lottia insessa
Lottia instabilis
Lottia limantula
Lottia pelta
Lottia persona
Lottia persona
Lottia scabra
Lottia scutum
Lottia strigatella

Lottia triangularis
Megatebennus bimaculatus
Milneria minima
Modiolus capax
Modiolus carpenti
Mopalia ciliata
Mopalia muscosa
Musculus pygmaeus
Mytilus californianus
Nassarius mendicus
Nucella canaliculata
Nucella emarginata
Nuttallina californica
Ocinebrina atropurpurea
Ocinebrina interfossa
Ocinebrina lurida
Octopus dofleini
Octopus rubescens
Odostomia sp.
Okenia rosacea
Onchidella borealis
Opalia wroblewskyi
Palciphorella velatta
Penitella conradi
Petaloconchus montereyensis
Petricola carditoides
Philobrya setosa
Protothaca staminea
Tonicella lineata
Tonicella lokii
Transennella tantilla
Trimusculus reticulatus
Triopha catalinae
Triopha maculata

PORIFERA: sponges
Acarnus erithacus
Anaata spongigartina
Antho lithophoenix
Aplysilla glacialis
Aplysilla polyraphis
Axocielita originalis
Clathria sp.
Geodia mesotriaence
Halichondria panicea
Haliclona sp.
Higginsia sp.

Leucandra heathi
Leucilla nuttingi
Leucosolenia eleanor
Lissodendoryx topsenti
Mycale psila
Myxilla incrustans
Porifera (unid.)
Scypha sp.
Stelletta clarella
Suberites sp.
Tedania gurjanovae

SIPUNCULIDA: bilaterally symmetrical, unsegmented marine worms
peanut worm (unid.)
Phascolosoma agassizii

TUNICATA
Aplidium californicum
Archidistoma eudistoma
Archidistoma ritteri
ascidian (biege, unid.)
Cystodytes lobatus
Didemnum carnulentum
Pycnoclayella stanleyi
Ritterella aequalisphonis
Styela montereyensis

VERTEBRATA: jawless fishes, bony fishes, sharks and rays, amphibians, reptiles, mammals, and birds
Clinocottus acuticeps
Clinocottus embryum
Clinocottus recalvus
Gobiesox maendricus
Oligochinus lighti
Oligocottus maculosus
Oligocottus synderi
Xiphister mucosus

CHLOROPHYTA: All the green algae within the green plants (Viridiplantae)
Acrosiphonia coalita
Blidingia minima var. vexata
Bryopsis corticulans
Cladophora columbiana
Cladophora graminea
Codium fragile
Codium setchellii

Derbesia marina
Endophyton ramosum
Entocladia viridis
Prasiola meridionalis
Ulothrix flacca
Ulva californica
Ulva clathrata
Ulva compressa
Ulva flexuosa
Ulva intestinalis
Ulva lactuca
Ulva lobata
Ulva taeniata
Urospora sp.

HETEROKONTOPHYTA: major line of eukaryotes
Alaria marginata
Analipus japonicus
Colpomenia peregrina
Compsonema serpens
Costaria costata
Desmarestia herbacea
Desmarestia munda
Dictyoneurum californicum
Egregia menziesii
Hinksia sandriana
Laminaria ephemera
Laminaria setchellii
Laminaria sinclairii
Leathesia difformis
Macrocystis pyrifera
Melanosiphon intestinalis
Nereocystis luetkeana
Petalonia fascia
Petrospongium rugosum
Pterygophora californica
Pylaiella sp.
Ralfsia sp.
Scytosiphon dotyii
Scytosiphon lomentaria
Spongonema tomentosum
Stephanocystis osmundacea
Streblonema sp.

RHODOPHYTA: red algae
Acrochaetium porphyrae
Acrochaetium sp.

Ahnfeltiopsis leptophylla
Ahnfeltiopsis linearis
Anotrichium furcellatum
Antithamnion dendroidum
Audouinella subimmersa
Bangia sp.
Bornetia californica
Bossiella dichotoma
Bossiella plumosa
Bossiella schmittii
Branchioglossum bipinnatifidum
Branchioglossum undulatum
Calliarthron tuberculosum
Callithamnion biseriatum
Callophyllis crenulata
Callophyllis flabellulata
Callophyllis heanophylla
Callophyllis linearis
Callophyllis obtusifolia
Callophyllis pinnata
Callophyllis violacea
Centroceras clavulatum
Ceramium gardneri
Ceramium pacificum
Chondracanthus canaliculatus
Chondracanthus corymbiferus
Chondracanthus exasperatus
Chondracanthus harveyanus
Chondracanthus spinosus
Clathromorphum parcum
Constantinea simplex
Corallina chilensis
Corallina vancouveriensis
Corallophila eatonianum
Cryptopleura corallinara
Cryptopleura lobulifera
Cryptopleura ruprechtiana
Cryptopleura violacea
Cumagloia andersonii
Delesseria decipiens
Dilsea californica
Endocladia muricata
Erythrophyllum delesserioides
Erythrotrichia carnea
Farlowia compressa
Farlowia conferta
Farlowia mollis

Faucheocolax attenuata
Gelidium coulteri
Gelidium robustum
Gloiocladia laciniata
Goniotrichopsis sublittoralis
Gracilariophila oryzoides
Gracilariopsis andersonii
Grateloupia californica
Grateloupia filicina
Griffithsia pacifica
Gymnogongrus chiton
Halosaccion glandiforme
Halymenia schizymenioides
Herposiphonia parva
Herposiphonia plumula
Hildenbrandia occidentalis
Hymenena flabelligera
Hymenena multiloba
Janczewskia gardneri
Leachiella pacifica
Lithophyllum dispar
Lithophyllum dispar
Lithothrix aspergillum
Maripelta rotata
Mastocarpus jardinii
Mastocarpus papillatus
Mazzaella affinis
Mazzaella californica
Mazzaella flaccida
Mazzaella leptorhynchos
Mazzaella linearis
Mazzaella oregona
Mazzaella parksii
Mazzaella rosea
Mazzaella splendens
Mazzaella volans
Melobesia marginata
Melobesia mediocris
Membranoptera dimorpha
Mesophyllum lamellatum
Microcladia borealis
Microcladia coulteri
Myriogramme spectabilis
Myriogramme variegata
Neogastroclonium subarticulatum
Neoptilota densa
Neoptilota hypnoides

Neorhodomela larix
Nienburgia andersoniana
Odonthalia floccosa
Opuntiella californica
Osmundea spectabilis
Peyssonnelia sp.
Peyssonneliopsis epiphytica
Phycodrys setchellii
Pikea californica
Pikea pinnata
Pleonosporium vancouverianum
Plocamium pacificum
Plocamium violaceum
Polyneura latissima
Polysiphonia hendryi
Polysiphonia pacifica
Prionitis lanceolata
Prionitis linearis
Prionitis sternbergii
Pseudolithophyllum neofarlowii
Pterochondria woodii
Pterocladia caloglossoides
Pterosiphonia baileyi
Pterosiphonia bipinnata
Pterosiphonia dendroidea
Pterothamnion villosum
Ptilota filicina
Ptilothamnionopsis lejolisea
Pugetia fragilissima
Pyropia gardneri
Pyropia lanceolata
Pyropia nereocystis
Pyropia perforata
Rhodochorton purpureum
Rhodymenia californica
Rhodymenia callophyllidoides
Rhodymenia pacifica
Rhodymeniocolax botryoides
Sahlingia subintegra
Sarcodiotheca gaudichaudii
Schimmelmannia plumosa
Scinaia confusa
Smithora naiadum
Stenogramma interrupta
Stylonema alsidii
Tiffaniella snyderae
Weeksia reticulata

MAGNOLIOPHYTA: flowering plants
Phyllospadix scouleri

8.10 Appendix K – Maps of Pinniped Haul-out Sites

Figure 1: Elephant seal haulout locations on the South Farallon Islands

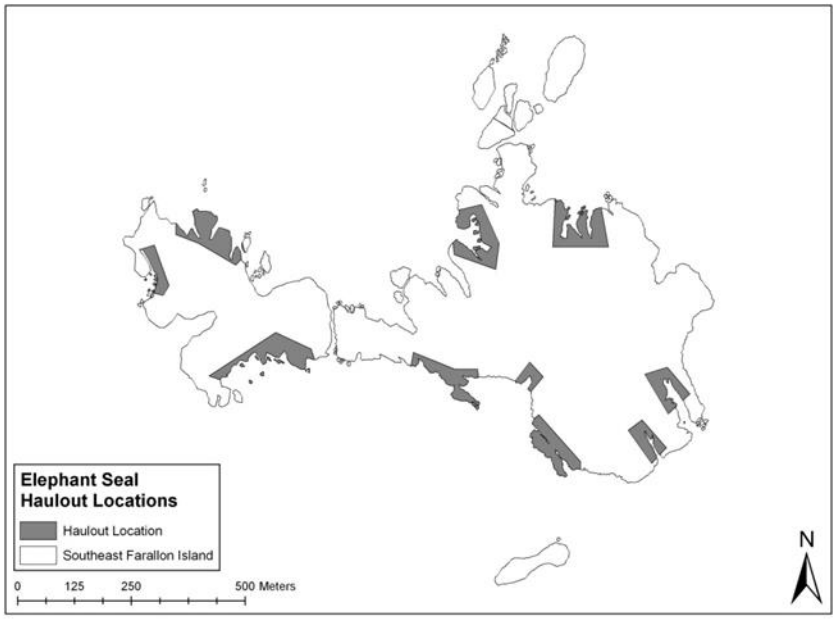


Figure 2: Harbor seal haulout locations on the South Farallon Islands.

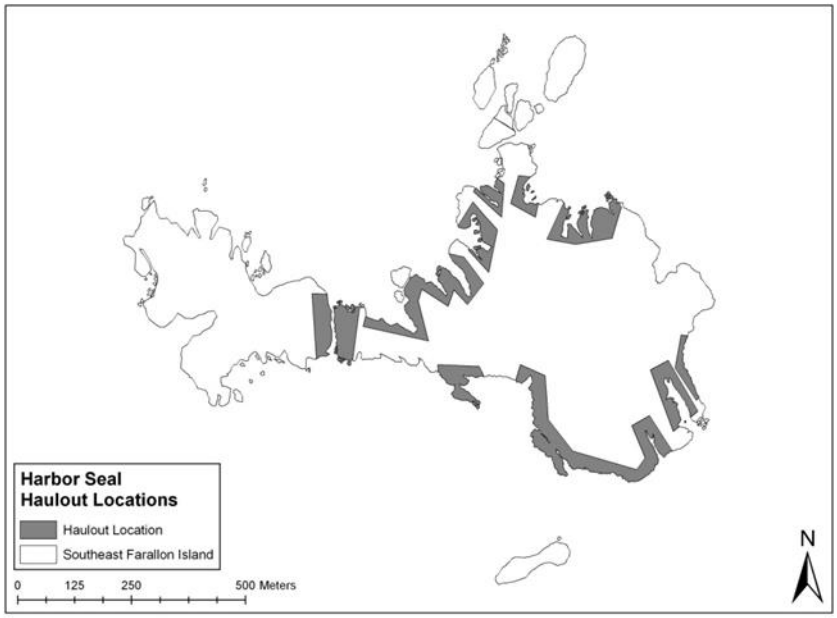


Figure 3: Steller sea lion haulout locations on the South Farallon Islands.

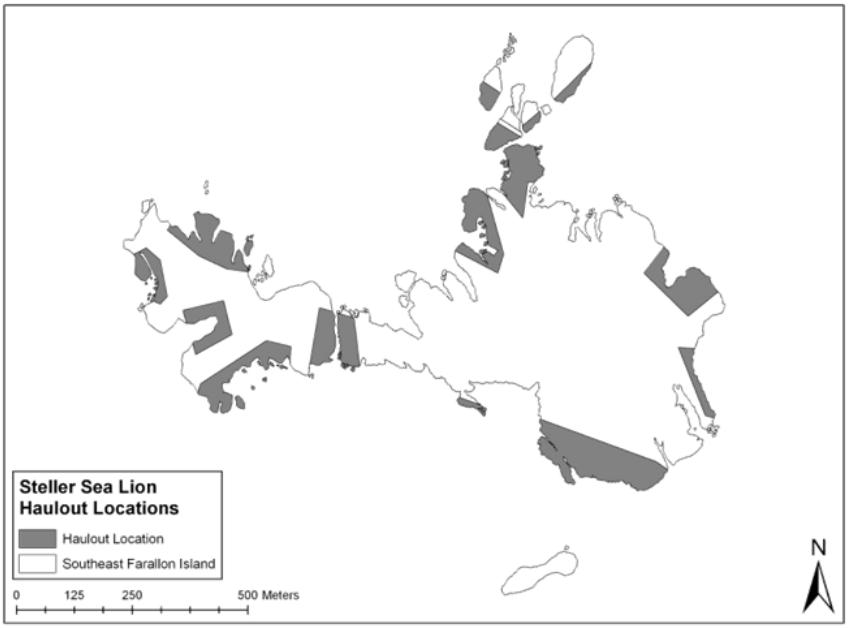


Figure 4: California sea lion haulout locations on the South Farallon Islands.

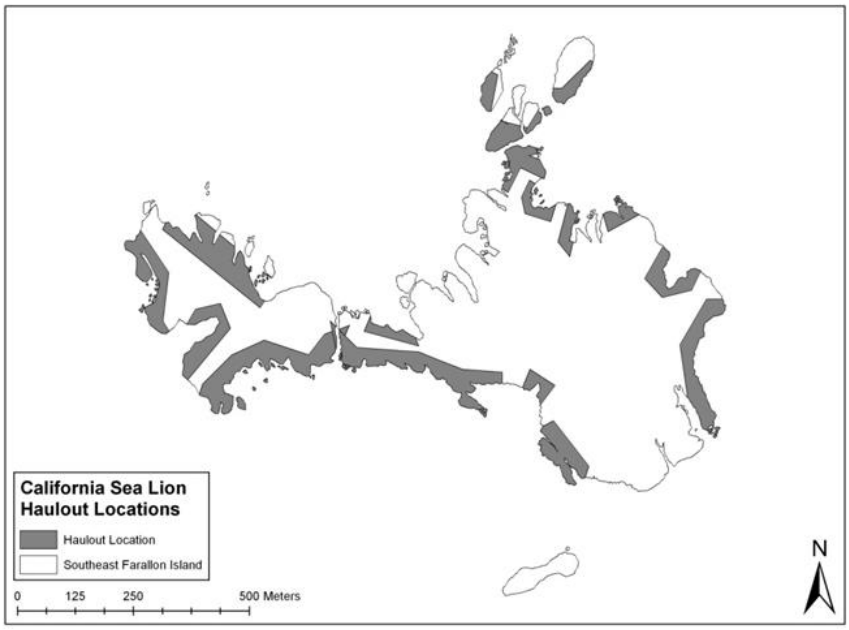
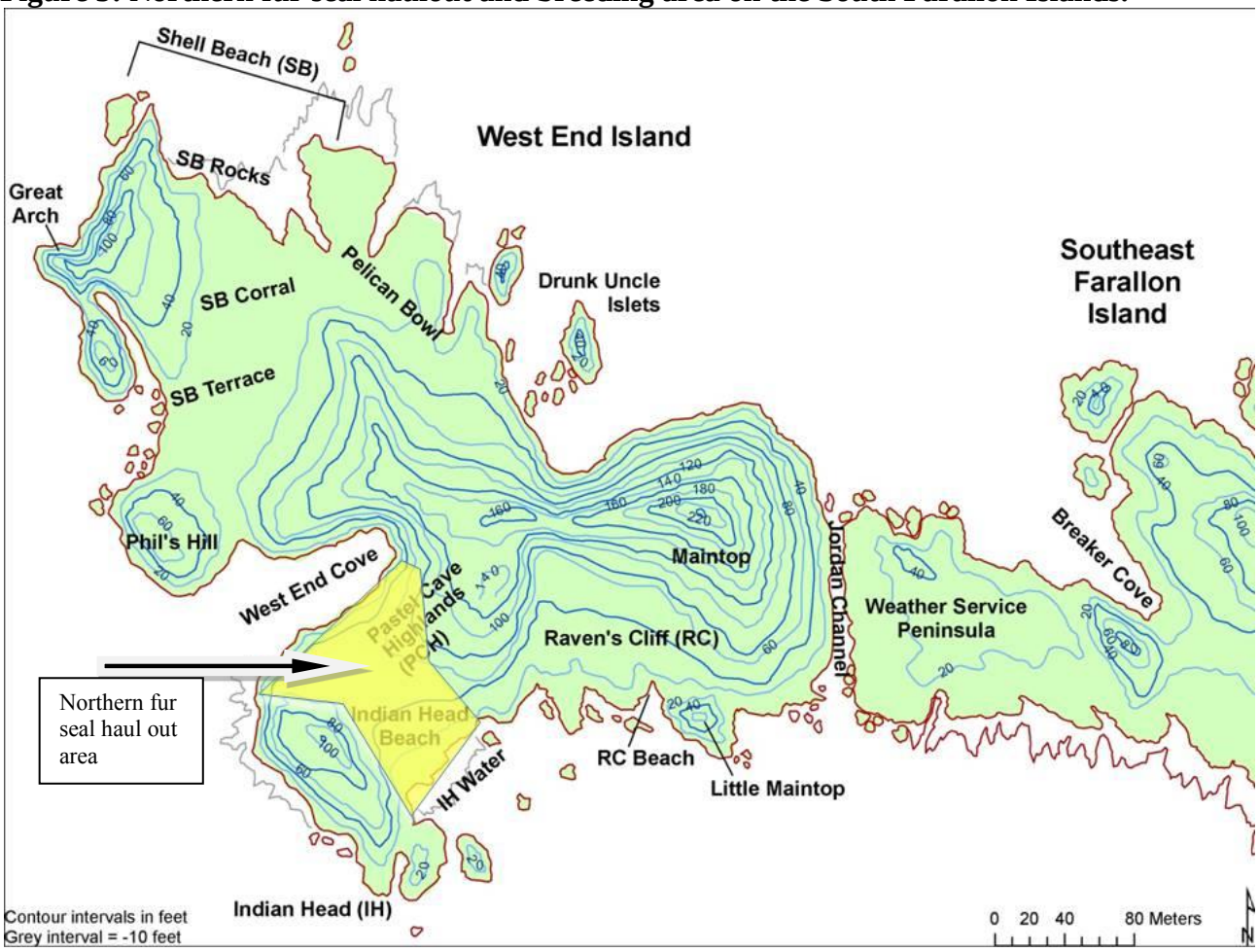


Figure 5: Northern fur seal haulout and breeding area on the South Farallon Islands.



8.11 Appendix L – Plant Species List

Farallones Plant List

Scientific Name	Common Name
Amaranthus deflexus	Large-fruit amaranth
Amsinckia spectabilis	Sea-side fiddleneck
Anagallis arvensis	Red pimpernel
Anagallis arvensis f. caerulea	
Apium graveolens	Celery family
Atriplex sp. (hortensis?)	Saltbush
Avena fatua	Common wild oat
Brassica oleracea	Wild cabbage
Baccharis pilularis	Coyote brush
Bromus carinatus var. maritimus	Seaside brome
Bromus diandrus	Great brome
Cakile maritima	European searocket
Calandrinia ciliata	Fringed redmaids
Cerastium viscosum	Sticky chickweed
Chenopodium murale	Nettle-leaved goosefoot
Cirsium vulgare	Bull thistle
Claytonia perfoliata	Miner's lettuce
Coprosma repens	Taupata
Coronopus didymus	Lesser swine-cress
Cotula australis	Southern waterbuttons
Crassula erecta	Sand pygmyweed
Cupressus macrocarpa	Monterey cypress
Cymbalaria murale	
Daucus Carota	Queen Anne's lace
Ehrharta erecta	Panic veldtgrass
Erigeron glaucus	Seaside fleabane
Erodium cicutarium	Redstem filaree
Erodium moschatum	Musky stork's bill
Geranium molle	Dovefoot geranium
Gnaphalium luteo-album	Jersey cudweed
Grindelia nana var. integrifolia	Idaho gumweed
Heliotropium curassavicum	Seaside heliotrope
Hordeum leporinum	Hare barley
Hypochoeris glabra	
Juncus bufonius	Toad rush
Juncus patens	Spreading rush
Lasthenia minor	Coastal goldfields

Lavatera arborea	Tree mallow
Leontodon leysseri	Lesser hawkbit
Lycopersicum esculentum	Tomato
Malva parviflora	Cheeseweed mallow
Medicago hispida	Burclover
Melilotus indicus	Annual yellow sweetclover
Melilotus sp.	Sweet-clover
Mesembrianthemum chilense	
Montia hallii	Annual water minorslettuce
Oxalis corniculata	Creeping woodsorrel
Oxalis suksdorfi	Suksdorf woodsorrel
Phyllospadix torreyi	Torrey's surfgrass
Pinus radiata	Monterey pine
Plagyobothrys reticulatus	
Plantago coronopus	Buckhorn plantain
Poa annua	Annual bluegrass
Polycarpon tetraphyllum	Four-leaved allseed
Polypogon monspeliensis	Annual rabbitsfoot grass
Portulaca oleracea	Little hogweed
Psilocarphus tenellus	Slender woolyheads
Raphanus sativus	Cultivated radish
Rumex Acetosella	Common sheep sorrel
Rumex crispus	Curly dock
Sagina occidentalis	Western pearlwart
Senecio vulgaris	Old-man-in-the-spring
Sisymbrium orientale	Indian hedgemustard
Solanum furcatum	Forked nightshade
Sonchus asper	Spiny sowthistle
Sonchus oleraceus	Common sowthistle
*Sonchus sp.***	Daisy family
Spergularia macrotheca	Sticky sandspurry
Spergularia marina	Salt sandspurry
Spergularia media	Media sandspurry
Stellaria media	Chickweed
Tetragonia tetragonioides	New Zealand spinach
Trifolium fucatum	Bull clover
Trifolium incarnatum	Crimson clover
Trifolium variegatum	Whitetip clover
Trifolium sp.	Pea family
Urtica urens	Dwarf nettle

Vulpia bromoides	Brome fescue
Zantedeschia aethiopica	Calla lily

8.12 Appendix M – Three Species Model

prbo

Modeling the Impacts of House Mouse Eradication on Ashy Storm-Petrels on Southeast Farallon Island

Report to the U.S. Fish and Wildlife Service

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July 2013

Any reference to or use of this report or any portion thereof shall include the following citation:

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For further information contact the director of the California Current at marinedirector@prbo.org or PRBO Conservation Science, 3820 Cypress Drive #11,

Executive Summary

- This study provides quantitative estimates of the anticipated benefit to Ashy Storm-Petrels from proposed house mouse eradication on the South Farallon Islands.
- The objective of this study was to examine the ecological relationships between Farallon House Mouse abundance, Burrowing Owl abundance, Ashy Storm-Petrel predation by Burrowing Owls, and Ashy Storm-Petrel annual survival.
- Indices of House Mouse abundance, Burrowing Owl abundance, and Ashy Storm-Petrel predation by owls each showed a clear and distinctive seasonal pattern. Owls arrive at the island in the fall when mice are abundant. The owls then switch to preying upon storm-petrels after the mouse population crashes in December and January. There is a sharp peak observed in predation on Ashy Storm-Petrels by Burrowing Owls in February and March, during storm-petrel pre-breeding attendance.
- On a monthly basis, owl predation on storm-petrels is strongly positively related to Burrowing Owl abundance and strongly negatively related to House Mouse abundance, consistent with the view that mice are the primary prey and Ashy Storm-Petrels the secondary prey.
- Burrowing Owl abundance and predation on storm-petrels have increased in recent years, with especially high levels of both parameters in recent years. Annual variation in owl abundance and predation on storm-petrels are highly positively and significantly correlated.
- In assessing recent storm-petrel population index trends from 2000 to 2012, we evaluated twelve different models to determine the best parameterization describing the change in population index over time, as determined by AIC. The preferred model was a two part linear spline with a change point between 2006 and 2007.This break is consistent with the observed recent increase in Burrowing Owl numbers. Prior to the change point, the storm-petrel population index had increased significantly ($p < 0.001$). After the change point there was a significant change in trend ($p = 0.002$), resulting in a linear decrease in population ($p = 0.095$).
- As the best-fit negative linear population trend of 7.19% annual decrease (“Observed Steep Decline” scenario – Scenario A) was not statistically significant, we also assessed the sensitivity of our modeling results by considering two other scenarios: a “Moderate Decline” scenario – Scenario B - of 3.36% annual decline, and a “Near Stable” scenario – Scenario C - of 0.63% annual increase. We used these scenarios for modeling plausible future population trends.

- Capture-recapture analyses reveal a strong and significant effect of Burrowing Owl abundance on annual Ashy Storm-Petrel adult survival. Results of the survival analysis indicate that a 50% reduction in owl abundance can be expected to increase overall annual survival by 2.64 to 4.92%, depending on the scenario assessed.
- We estimate the change in population trend of Ashy Storm-Petrels as a result of anticipated reductions in Burrowing Owl predation on SEFI, using a population-dynamic model. A 50% reduction in Burrowing Owl abundance can be expected to change population growth rates by 2.3-3.9% depending on whether we assume Scenarios A or C, with Scenario B values in between. This corresponds to changing a population that is strongly declining to weakly declining (7.19% annual decline to 3.26%, Scenario A) or from near-stable to increasing (0.63% increase per year to 2.90% increase, Scenario C). Under Scenario B, population trajectory would change from declining at 3.36% per year to nearly stable at 0.22% decline per year. With a 71.5% reduction in the Burrowing Owl abundance index, population growth rates change by 3.1-5.3%, depending on the scenario. This greater reduction results in larger population benefits for storm-petrels (resulting in 1.88% annual decline under Scenario A and 3.69% annual increase under Scenario C.
- In summary, reduction in Burrowing Owl abundance has strong positive population impacts in all scenarios examined. Under Scenario A, the “Observed Steep Decline” scenario, rates of decline are substantially reduced, under Scenario B, the “Moderate Decline” scenario, the population trends change from moderate decline to stable or slight annual increase, and under Scenario C, the “Near Stable” scenario rates of annual population change from a very weak increase to a strong increase after owl reduction, a nearly five-fold increase in the net population growth rate.
- Reducing Burrowing Owl abundance, through elimination of their house mouse prey, will have a long term, substantial and significant effect in reducing overall Ashy Storm-Petrel mortality and promoting stable or increasing future population trends.

Introduction

Colonially breeding seabird populations worldwide face major threats, including climate change, habitat loss, overharvesting and bycatch, invasive species, pollution, and disease (Wilcove et al. 1998). When compared with other birds, seabirds produce few young per year; they breed at an older age and have higher adult survival (Weimerskirch 2002). For extremely long lived, low-fecundity species such as those in the order Procellariformes, the storm-petrels, shearwaters, and albatrosses etc. adult survival is the key demographic parameter in determining population growth or decline (Nur & Sydeman 1999). Management actions to counter threats to seabird survival can be difficult to implement, but one example where direct conservation action has had success is the elimination of introduced species impacting seabird colonies (review in Mulder et al. 2011).

Natural resource managers are primarily concerned with the often severe and obvious effects of predators on island-breeding seabird species, where the introduced predator decreases the abundance of prey species and can cause population declines (Schoener and Spiller 1996, Krajick et al. 2005). In addition, indirect interactions may exacerbate predation on prey species of concern. One example is hyper-predation, where there is an enhanced predation pressure on a secondary prey, due to either an increase in the abundance of a predator population that displays a numerical response to the primary prey, which itself may be an introduced species, or there is enhanced predation pressure due to a sudden decline in the abundance or availability of the primary prey (Howald et al. 2007). In both cases, with and without indirect effects, we have predation by a predator on a prey where the level of predation on the prey species of concern is determined by a third species. An example is Allen Cay Mice in the British Virgin Islands, which were recently eradicated as they were facilitating populations of Barn Owls to depredate Audubon's Shearwaters (Island Conservation 2012).

In this study, we analyze field data and develop statistical and population models to understand the inter-relationships among three species: an invasive rodent (House Mouse, Mus musculus), a native predator (Burrowing Owl, Athene cunicularia), and a seabird of conservation concern (Ashy Storm-Petrel, Oceanodroma homochroa) on Southeast Farallon Island, California (SEFI). In addition to examining variation in abundance among the three species over time, we also analyze field data on predation intensity by owls on the Ashy Storm-Petrel. Using a long-term mist-netting study of the Ashy Storm-Petrel on SEFI (Bradley et al. 2011), we estimate the change in an index of

adult survival with respect to variation in the abundance of Burrowing Owls. We then construct a population dynamic model that accounts for current population trends and estimate the change in future population trends that is expected given a reduction in owl predation activity.

The two primary objectives of this study are to:

1. Demonstrate the ecological relationships between House Mouse abundance, Burrowing Owl abundance, owl predation of Ashy Storm-Petrels, and Ashy Storm-Petrel annual survival.
2. Quantify the expected change in Ashy Storm-Petrel adult survival and consequent change in Ashy Storm-Petrel population trends as a result of anticipated reductions in Burrowing Owl predation on the South Farallon Islands.

Focal Species

House Mice

House mice are one of the most widespread invasive mammals on earth; amongst vertebrates the breadth of their global distribution is second only to that of humans (Bronson 1979; Brooke and Hilton 2002). In island ecosystems, house mice have been shown to have significant impacts on plant, invertebrate, and seabird communities (Angel et al. 2009). Despite this, there has been little conservation action devoted to mice on islands, relative to other introduced mammals (Wanless et al. 2007; Howald et al. 2007, Wanless et al. 2012). House mice were introduced to the South Farallon Islands sometime during the 1800's (Ainley and Boekelehide 1990). Despite over 40 years of continuous study of breeding seabirds on the Farallones, there is little evidence of direct effects of mice on breeding seabirds – though nest predation by mice is challenging to document. Mice on islands are known to directly depredate seabird eggs and chicks of several species (Mulder et al. 2011).

Burrowing Owls

The Burrowing Owl is found in the interior of California and other western States (Gervais et al. 2008). They arrive on the Farallones on their southbound fall migration (DeSante and Ainley 1980) starting in September. The arrival of migrating or dispersing landbirds onto the Farallones is not uncommon; over 400 different landbird species have been recorded on the islands since 1968 (Richardson et al. 2003). Most landbirds that arrive on the Farallones depart within a few days (DeSante and Ainley 1980). However, Burrowing Owl arrival in fall occurs at the time the house mouse population is

at its annual peak (Irwin 2006; also see Figure 2 - Results). Some Burrowing Owls now remain on the islands for up to several months, subsisting primarily on a diet of mice in the fall (Mills 2006; PRBO, unpubl. data). As we demonstrate in this study, in the winter months, the mouse population declines rapidly, severely reducing their availability as prey items for Burrowing Owl. Consequently, Burrowing Owl switch to alternative prey sources (Mills 2006; PRBO, unpubl. data). Adult storm-petrels, which begin to arrive on the islands starting in mid-winter to visit breeding sites and engage in courtship activity, and are nocturnal like the owls, become a major alternative prey item for the owls through the late winter and spring. Some owls die on the island during the winter (PRBO, unpubl. data). By May, all surviving Burrowing Owls have departed the island for their breeding grounds (this study). Burrowing Owls do not breed on the Farallon islands.

Ashy Storm-Petrel

The Ashy Storm-Petrel is a seabird species of major conservation concern. This small (~42 g), colonially breeding species is endemic to waters of the California Current, along the coast of California and Mexico (Spear & Ainley 2007), with breeding populations concentrated at the Farallon and Channel Islands (Carter et al. 2008). Sydeman et al. (1998a, 1998b) estimated a 44% decline in breeders, with a 95% confidence interval of 22-66% decline, in the population from 1972 to 1992 at Southeast Farallon Island (SEFI). The South Farallon Islands represents the largest colony for this species, with perhaps 50% of the world population (Carter et al. 2008). Due to major population declines, threats from colony predation, and at-sea mortality (e.g., from oil spills), the species has been listed as a California Species of Special Concern for many years (Carter et al. 2008) and was recently petitioned for listing under the Endangered Species Act. The Ashy Storm-Petrel is currently listed as “Endangered” by IUCN (2012) (http://www.iucnredlist.org/apps/redlist/details/106003987/0) due to its restricted geographic range, small population size, and apparent declines (Sydeman et al. 1998a, Ainley and Hyrenbach 2010).

The Ashy Storm-Petrel has been the subject of much study on the Farallon Islands (Ainley et al. 1990, Ainley 1995, Sydeman et al. 1998a). PRBO has conducted two previous Population Viability Analyses (PVA), one that considered only the South Farallon Islands population (Sydeman et al. 1998b) and the second that expanded the geographic scope to include the Channel Islands population as well (Nur et al. 1999a). As part of the PVAs, Sydeman et al. (1998b) and Nur et al. (1999a) developed a population dynamic model that synthesized the best available demographic information

on the Farallon population and accounted for observed population trends. Here we update the model developed by Nur et al. (1999a) based on the most recent observations and analysis of data since 1997. In particular, we analyze variation in annual survival of the Ashy Storm-Petrel, based on standardized mist netting that has been conducted continuously since 1992, with specific focus on estimating the effect of Burrowing Owl predation on Ashy Storm-Petrel survival during the period 2000 to 2012.

Methods

Field Data Collection

House Mice Abundance

House mice abundance was determined through monthly trapping success on 4 transect lines spread across island habitats (Irwin 2006). Trapping was conducted monthly for 3 nights between March 2001 to March 2004, and again from December 2010 to March 2012. Both sampling efforts used the same transects, each with 7 traps per transect. For the 2010-2012 effort 5 additional traps were added on a Lighthouse Hill transect. Trapping efforts used D-Con snap traps baited with peanut butter and oats. Trapping success was determined as the proportion of house mouse captures for the 84 (2001-2004) or 99 (2010-2012) traps set per monthly session.

Mistnetting of Ashy Storm-Petrels

Southeast Farallon Island is the largest of the 39 hectare South Farallon Islands, located approximately 48 km west of San Francisco, CA (Figure 1). As part of this study, we present an index of variation in population size based on statistical analysis of standardized mist-net captures. We use the population index to estimate change over time in the adult population of Ashy Storm-Petrels from 2000 to 2012.

We also estimate adult survival, specifically in relation to Burrowing Owl abundance (see “Statistical Analysis”) based on the same set of captured and recaptured Ashy Storm-Petrels. Survival analyses presented here are based on capture-mark-recapture data of uniquely banded individuals. The survival analyses focus on 2000 to 2011 because of our focus on more recent years, and that the standardized Burrowing Owl abundance index was only available as of January 2000 (see below).

Mist-netting was conducted for 3 hours each netting session (from 22:30 – 01:30), with one or more sessions per month, as part of an on-going capture mark-recapture study. Two mist net sites were used (Lighthouse Hill [LHH] and Carpentry Shop [CS]; Figure 1)

that differ in characteristics such as exposure, proximity to primary breeding habitat, proximity to the shoreline, and bird density. Nets were only opened if there was less than 10 knots of wind and little or no moon visible, as strong winds and moonlight reduce the ability of nets to capture birds and make it easier for birds to avoid the net. The goal was to conduct one session at each site once per month from April to August, weather permitting. Net location and net type were kept constant at these two sites for the duration of the study, using one 12 m long, 4 shelf nylon mist net (Avinet Inc.) with 30 mm mesh and a height of 2.6 m. Birds were banded with incoloy or stainless steel metal leg bands (size 1b) with unique numbers assigned by the US Geological Survey's Bird Banding Laboratory. LHH site is south-facing, approximately half-way up Lighthouse Hill (~50 m elevation), and surrounded by a large amount of storm petrel breeding habitat and known high density of breeding sites (Sydeman et al. 1998a, PRBO unpublished). CS site is east facing, adjacent to the ocean (~6 m elevation), in an area of less storm-petrel breeding habitat, apparently fewer breeding birds and has lower capture rates than LHH (Sydeman et al. 1998a). We restricted our analyses to the period between April 1st and August 15th, as this time period had relatively standardized effort across the entire time series 1992-2012, as well as matching periods of regular Ashy Storm-Petrel colony attendance (Ainley et al. 1990). Egg-laying by Ashy Storm-petrels typically commences in May (Ainley et al. 1990).

Social attraction, in the form of broadcast recordings of Ashy Storm-Petrel calls, was used during all net sessions to increase the chance of Ashy Storm-Petrel captures at the netting sites. A portable cassette tape player was placed at the base of the middle of the mist net and broadcast at a volume of ~65db throughout the netting sessions. The main calls on the tape were "flight calls," but in the background low frequency burrow "purring calls" and "rasping calls" are present (Ainley 1995). The flight call rate was approximately 0.44 calls per second or 26.5 calls per minute.

Ashy Storm-Petrel reproductive success

Ashy Storm-Petrel reproductive success (number of chicks fledged per pair) was determined for a sample of birds breeding in rock crevices in accessible habitat. In the absence of other data we assume similar reproductive success between accessible and inaccessible habitats, Clutch size for Ashy Storm-Petrel is 1 and birds can relay after failed breeding attempts (Ainley 1995). Beginning 5 May in each year, from 1992 to 2011, we checked all previously occupied breeding sites every 5 days to determine nest contents. All occupied sites were monitored for reproductive success, with a goal of at least 40 sites monitored each season. New sites were added annually during the

breeding season by confirmed breeding of birds which responded to Ashy Storm-Petrel calls played during the day. Sites that had not been occupied for at least consecutive 5 years were dropped from further study. We used a flashlight and, starting in 2007, a small camera ("See Snake") to carefully and thoroughly examine each site. The camera allowed for increased sample size from 2007-2011, doubling the number of active sites we could follow. Once an egg was found or an adult was observed in incubation posture for two consecutive checks, the site was left undisturbed for 8 checks (40 days) before returning to check for hatch. Once a hatched chick was confirmed, the site was left undisturbed for an additional 8 checks. After the second skip period, we resumed checking the site every five days until the chick fledged. The "skip" periods help to reduce potential disturbance to incubating adults and young chicks. Chicks that were fully feathered and disappeared from their nesting crevice after 60 days of age were assumed to have fledged (Ainley et al.1990). Reproductive Success was determined with respect to all attempts of a pair (including relays).

Ashy Storm-Petrel predation index

We developed an index of predation on Ashy Storm-Petrel from January 2003 to April 2012. Before 2003, data were not collected in a sufficiently systematic and standardized fashion. For each month beginning in 2003, we counted the number of depredated wings based on repeated, standardized surveys conducted every 5 days from March to August, supplemented by incidental collections throughout the year. Incidental collections were based on access to areas visited as part of long term studies at approximately the same time across all years. Thus, effort in September to February may not have been the same as in March to August but the effort was consistent from one year to the next. Identified remains were allocated to either Western Gull or Burrowing Owl, or were classified as unknown predator. Storm petrels depredated by Western Gulls are ingested whole, with the regurgitated wings congealed in digestive juices. This is in sharp contrast to storm-petrels consumed by Burrowing Owls, where wings are removed from the body before consumption and left unadulterated. Only remains positively identified as being caused by owls were used in this analysis. There is no evidence to suggest that predation rates on storm-petrels would differ in unsampled inaccessible areas.

Burrowing Owl abundance index

An index of Burrowing Owl abundance was determined based on daily observations of accessible areas from January 2000 to April 2012, as well as detailed roost surveys of Burrowing Owls conducted every 3 days from 2010 to 2012. As part of daily Farallon

monitoring operations, island biologists searched the island for non-breeding birds and tally a total in the daily journal (Desante and Ainley 1980, Richardson et al. 2003). While effort varies through the year (i.e. ~8 hours in the fall and ~3 hours in the winter; owls are absent or rare May-August), effort is relatively consistent across years. However, to reduce effects of variation in daily sightings of owls, and allow for the fact that daily survey effort in earlier years was lower than in more recent years, we developed a robust and conservative index of Burrowing Owl abundance. The index was the maximum number of owls seen on a single day calculated for each month– as obtained by daily surveys throughout the time series and supplemented by roost surveys in recent years. Excluding May to August, when Burrowing Owl were absent or rare, the index varied from 1 to 10 in most months (mean = 2.85, SD = 2.78). During the four months from May to August each year, the monthly index was 0 (in 90% of the cases) or 1 (the other 10%).

A preliminary analysis indicated that the most consistent monthly metric of owl abundance was the maximum number of owls estimated to be on the island at any one time rather than mean or minimum per month; the maximum monthly value was more closely related to Ashy Storm-Petrel predation than were mean or minimum monthly values (see below).

For Ashy Storm-Petrel survival analyses, we examined several annual indices of Burrowing Owl abundance that differed with respect to which months were included. The most comprehensive measure was the mean of monthly maximum values calculated for the months of September to April; Burrowing Owls were almost entirely absent during the months of May to August. The September - April measure showed a significant relationship with respect to Ashy Storm-Petrel survival (see below), and its effect was stronger than other Burrowing Owl abundance metrics (e.g., for January-April). In any case, all Burrowing Owl abundance metrics examined were highly correlated with each other and thus population modeling results presented here are not sensitive to which metric was chosen.

Statistical Analysis

Negative Binomial Regression Modeling for Population Index

We used negative binomial regression to analyze capture rates of Ashy Storm-Petrel in order to construct a population size index. Negative binomial regression allows for non-linear relationships and residuals that are not normally distributed, as was the case in this study. This method is especially suitable for count data, and is more suitable than

Poisson regression as it accounts for over-dispersion. That is, the variance exceeds the mean, as is common in ecological studies (Carmen and Trivedi 1998; Hilbe 2007). Note that negative binomial regression models the natural logarithm ln(Y) in relation to a set of predictor variables, where, in this case Y = count variable; in other words, negative binomial regression uses a log-link function. No log-transformation is required prior to analysis; the analysis is carried out on Y with residuals assumed to be negative-binomially distributed.

We employed negative binomial regression (using program STATA 10.0) to model the dependent variable while controlling for variation in: hours of netting effort in a session, number of days spent netting at a site in a given year, Day of Year, (Day of Year)2, to allow for a quadratic seasonal effect, and site. In particular, we included "Year" as a categorical variable (i.e., as a factor) in order to derive year-specific estimates for the count variable, which was the goal of this analysis. The final full model included the two effort variables, the two date variables, site, and year as a categorical variable. This model was preferred by Akaike information criterion (AIC), used as a measure of goodness of fit, to models that had only a subset of these variables, i.e., the inclusion of each variable was justified with respect to AIC. This approach assumes that capture probability did not vary among years, other than that due to variation in the other predictor variables.

From the preferred model we estimated the year-specific effect for each year. The coefficient for the base year (2000) was set at 0.0, and the other coefficients were estimated as the difference in ln(counts) for that year relative to the base-year (2000), after controlling for the other variables. For illustration purposes only, we graph the natural log values as the year-specific coefficient plus 1, in order to avoid negative values. For the purposes of analyzing trend, however, we analyzed the ln-transformed values without addition of 1.

<u>Analysis of Ashy Storm-Petrel Population Trends</u>

To obtain a recent estimate of population change for use in the population model, we performed a set of regression analyses of ln-transformed population index values (see above), comparing multiple models. In the simplest case, linear regression, the coefficient for a given time period, once back-transformed, estimates the constant proportional change for the specified time period (Nur et al. 1999b). Our prime objective was not to characterize historical change but to estimate population trend during the most recent period to then use in modeling the expected trajectory in the near future, during the period when mouse

eradication is presumed to occur. We assessed 12 models to describe the previous 13 years of population ln-based index values, including a constant, linear, quadratic, cubic, inverse(year), and ln(year). We restricted our analyses to the period 2000-2012, with 2012 the most recent year for which we had data. We did not model population trends before 2000 for two reasons: 1) oceanographic conditions in the 1990's were much different from that experienced in the period 2000-2012 (Peterson and Schwing 2003, Doney et al. 2012), and so of questionable relevance for future projections, and 2) mouse, owl abundance and owl-predation data were not available prior to 2000.
In addition to the six models listed above, we also assessed 6 models of linear splines to determine whether an apparent change in trend occurred, from linear increasing to linear decreasing trend, during the period between 2005 and 2008. We chose this period as the wide data range where a possible change in trend may have occurred, after initial data examination (see Results). The 6 models examined assessed all possible change points in that period, with the change point occurring in a given year, or the change occurring between 2 years. We tested change points at 2005, 2006 and 2007; and half-way between 2005 and 2006, 2006 and 2007, and 2007 and 2008. AIC values were used to determine the best fit model. We then used the best fit model to model the trajectory for the most recent period, in this case a negative linear trend from 2007 to 2012, with the change in trend occurring between 2006 and 2007 (see Results). As presented below, the best estimated trend for 2007 to 2012 was that of a steep decline.

However, because of considerable uncertainty around the estimated trend value, we assessed sensitivity of our analyses to the assumption of this "Observed Steep Decline" trend, described subsequently as Scenario A. We considered two alternatives to Scenario A: first, a moderate decline equal to the estimated slope coefficient plus 1 standard error (i.e., a decline of about one-half the magnitude of the observed decline) - Scenario B - and second a "near stable" scenario – Scenario C, in which the trend was equal to the observed coefficient plus 2 standard errors. In other words, we examined **three scenarios** with regard to future population trajectory: A) a steep decline (results of the best-supported population trend model for the period 2000-2012), B) a moderate decline, and C) a near-stable, slightly increasing trend.

<u>Calculation of an Ashy-Storm Petrel Population Estimate</u>

We estimated the current Farallon Ashy Storm-Petrel population size from the negative binomial regression analysis of mist-netting using year-specific estimates for each of the 3 most recent years, 2010, 2011, and 2012. Results from 3 most recent years is, in our view, more robust than relying on results from a single year We determined the weighted 3-year mean (calculated in natural log values) and then backtransformed it. Weighting was based on the inverse of the standard error of the annual estimate (Kutner et al. 2004). To estimate the current number of breeders on SEFI, we used the estimated proportional change from 1992 to 2010-2012 and multiplied that by 2660, the number of breeders estimated by Sydeman et al. (1998b). All breeder estimates are rounded to the closest even number of individuals.

To obtain a 95% Confidence Interval (CI) around this 3-year estimate of proportional population change, we followed several steps. First, we calculated the mean annual standard error from the standard errors around the annual, year-specific coefficients obtained from the negative binomial regression analysis using output from 2010-2012. Second, we obtained the “3-year mean SE” by dividing the mean annual SE by the square-root of n, where n = number of years used to obtain the mean standard error, i.e., n = 3. Third, we constructed an approximate 95% CI as estimated population change (in ln-units) plus or minus 2 times the “3-year mean SE.” The upper and lower CI bounds were then backtransformed to obtain upper and lower estimates of proportional change.

Statistical Estimation of Effects of Burrowing Owls on Survival of Ashy Storm-Petrels

We used the package RMARK (Laake et al. 2012) to analyze Ashy Storm-Petrel capture-recapture data and thus estimate survival and recapture probabilities and effects of covariates on these. Our goal was to obtain reliable estimates of survival probability, not to estimate recapture probability. However, in order to obtain the former, we needed to obtain reliable estimates of recapture probability (Cooch et al. 1996). We constructed a capture history table that included all Ashy Storm-Petrels captured between years 2000 and 2012, maximizing overlap between our Ashy Storm-Petrel mistnetting and Burrowing Owl abundance datasets. The following covariates of survival were included in the set of competing models we evaluated: Burrowing Owl abundance index (described elsewhere in this Report), capture site (LHH vs. CS), Southern Oscillation Index values in winter (SOI), and all possible combinations of these three variables. To model recapture probabilities, we considered the following covariates:

site, effort (net hours per year), SOI, and all combinations of these three variables. We also modeled year-specific variation in survival (with year as a factor, not as a continuous covariate), but for the population modeling component of this study we were concerned only with estimates reflecting specific covariates, especially Burrowing Owl abundance.

The SOI influence on Ashy Storm-Petrel survival was included in our survival models because January-March SOI has been shown previously to predict Cassin's Auklet (*Ptychoramphus aleuticus*) adult survival on the Farallones (Lee et al. 2007, Nur et al. 2011). We therefore expected Ashy Storm-Petrel may also respond to the biophysical effects associated with winter SOI. We included SOI in the recapture models because we wanted to ascertain the influence of SOI on the behavior of the birds. For example, it is possible that, under some large-scale climatic conditions, birds may be more likely or less likely to attempt to breed on the Farallones in a given year, thus influencing their chances of re-capture. SOI values from http://www.cgd.ucar.edu/cas/catalog/climind/SOI.signal.ascii were obtained on a monthly basis. We summarized the SOI values from two intervals that we suspected may best reflect the influence of the large-scale climatic conditions on Ashy Storm-Petrel survival and recapture in the Farallones: the period from December to February and the period from January to March, both prior to the initiation of egg-laying. In a preliminary analysis, the latter period's SOI showed a stronger effect on survival and recapture probabilities, so we used it in our final models.

We included capture site in the estimation of recapture probability because there may be differences in the capture probabilities for these two sites, which differ in a number of respects (see above). Differences between sites may be reflected in the composition of transients vs. true resident birds. Transient birds have low fidelity to the vicinity of the trapping location; they are non-breeders and thus are unlikely to be recaptured in subsequent years (Nur et al. 1993). If transients are more common at one site compared to the other site, this will be reflected in differences in site-specific capture probabilities. Any method that can improve our estimate of recapture probability will also improve our ability to estimate survival. However, our goal in the capture-recapture analysis was not to estimate absolute survival probability but rather the relative difference in survival probability, especially in relation to differences in Burrowing Owl abundance. For this reason, we included site in modeling recapture probability and survival probability (Cooch et al. 1996).

Burrowing Owl abundance was estimated by averaging "maximum owls per month" over a specified period of months. We considered several different time periods, but the two time periods that were both statistically predictive and ecologically meaningful were: (1) September to April, the 8 months during which Burrowing Owls are on the island and (2) just January to April. The justification for considering the latter is that owl predation on Ashy Storm-Petrels is almost entirely confined to these four months (see Figure 2 below). We evaluated a total of 128 models: First, we ran 64 models with various combinations of 0 to 3 covariates for survival (site, Burrowing Owl abundance, SOI) and 0 to 3 covariates for recapture probability (site, netting hours, SOI), for which the Burrowing Owl abundance metric was the September to April mean monthly value. Second, we ran another set of 64 models in which the Burrowing Owl abundance metric was the January to April metric instead of September to April. We chose the top model among the 128 examined, i.e., the one that optimized AIC, and use these results for inclusion in the predictive population dynamic model. Specifically, the statistical model results were used to indicate the change in logit survival with a change in Burrowing Owl abundance (logit survival is the dependent variable used in capture-recapture analyses; Cooch et al.1996). The change in logit survival was converted into a change in absolute survival and this was used in the population model; note that:

$$\text{logit survival} = \ln[(\text{survival probability})/(1\text{-survival probability})].$$

Population Modeling of Ashy Storm-Petrels

Overview and Approach Used

To assess and quantify the impact of a change in Burrowing Owl abundance and predation on Ashy Storm-Petrel, we developed a deterministic population dynamic model for the Farallon Island population, building on previous modeling by Nur et al. (1999a) for this same population.

Our modeling approach was to first construct a population dynamic model that could best account for recent, observed Ashy Storm-Petrel population trends on SEFI, given field observations, previous studies, and the scientific literature. The estimation of recent population trend (during the period 2000-2012) is described in this report. However, to allow for uncertainty regarding estimates of recent trend and therefore uncertainty about population trends in the near future, we consider three scenarios that span a range of plausible trends, based on our statistical analysis of the mistnetting index: A) steep decline, B) moderate decline, and C) near-stable. For each trend

scenario, we developed a population-dynamic model that reproduced the presumed trend. To do so, we derived three different estimates of baseline (current) survival in the absence of mouse eradication (described below), one for each population-trend model. We then incorporated changes in adult survival associated with presumed changes in Burrowing Owl abundance on the Farallon Islands with respect to these three trend scenarios. These presumed changes in Burrowing Owl abundance in turn reflect the likely consequences of proposed mouse eradication. The next step was to model the population dynamics of Ashy Storm-Petrels, given the presumed, statistically estimated, changes in survival resulting from reduction in Burrowing Owl predation, considering the three possible baseline (pre-eradication) trend scenarios.

The changes in adult survival were directly estimated from the statistical analysis of the 13-year dataset (capture histories from 2000 to 2012) during which time we had independent estimates of Burrowing Owl abundance on a monthly and annual basis. Thus, the pre-eradication parameter values used were derived from population dynamic models that reflects scenarios consistent with recently observed population trends; the postulated post-eradication parameter values reflect, in addition, our statistical analysis of the effect of Burrowing Owls on Ashy Storm-Petrel population dynamics.

<u>Parameters of the “Current Population Dynamic Model”</u>

There are six important demographic processes that a seabird population dynamic model needs to incorporate (Nur & Sydeman 1999). The first two concern survival, the next three are components of reproductive success, and the sixth is the balance between emigration and immigration. We discuss each in turn.

i) **Survival of adults.** Nur et al. (1999a) determined that a stable population of Ashy Storm-Petrels would require an adult survival rate of 89.2%. We did not use this value, but instead adjusted survival values of adults to produce three trend scenarios: (A) a population that exhibited the same population trajectory as has recently been observed (a decline of approximately 7.2% per year, see “Results”), (B) a moderate decline (of approximately 3.4% per year) and (C) a near-stable population (increase of approximately 0.6% per year).

ii) **Survival of juveniles and subadults.** We followed Nur et al. (1999a), who in turn followed Ainley et al. (2001), and estimated survival of first-year, second-year, and third-year individuals as a fixed percentage of adult survival. The percentages used by Nur et al. (1999a) were: 72%, 86%, and 98% of the adult

value. By the fourth year of life, Ashy Storm-Petrels have begun breeding, and so we assumed that survival in their fourth year reached adult levels.

iii) **Reproductive Success** is the number of young reared to fledging per breeding pair per year. It is conditional on a pair actually breeding. Field methods for determining annual reproductive success are described elsewhere in this report. For the population modeling, we used the mean reproductive success observed for this population over the last 10 years (2002-2011).

iv) **Probability of Breeding Among Experienced Breeders.** Ainley et al. (1990) reported that over a 12 year period on SEFI, an egg was laid in 92% of crevices that were occupied by Ashy Storm-Petrels. We follow Nur et al. (1999a) and use this value, assuming that all individuals who have bred before return to the colony, assuming they have survived. We believe this assumption is valid as there are no available data to suggest otherwise.

v) **Probability of Breeding for the First Time.** No field data are available to estimate this parameter for this species (Ainley 1995). Here we followed Nur et al. (1999a) who relied on a field study of the closely related Leach's Storm-Petrel (*O. leucorhoa*). Nur et al. (1999a) assumed that, for the Farallon Ashy Storm-Petrel population, 10% of four-year olds, 50% of five-year olds, 90% of six-year olds, and 100% of seven-year olds were capable of breeding. This does not mean that, for example, 100% of seven year olds bred, but rather that by age 7, Ashy Storm-Petrel breeding probability reached 100% of the adult value for breeding, 92% (see above). Thus, our model assumes that most Ashy Storm-Petrels first bred at ages 5 or 6, but a few earlier (age 4) or later (age 7 or later).

vi) **Balance between Emigration and Immigration.** The closest significant breeding population relative to the Farallon Islands is on the Channel Islands, at least 420 km away (Carter et al. 2008). There have been only a few records of banded birds from the Channel Islands being recaptured on the Farallones and vice versa (Nur et al. 1999a,USGS unpublished, PRBO unpublished). From 1992 to 1997, less than 1% of all recaptured individuals on SEFI were known to have been first banded on the Channel Islands. These individuals might be dispersing widely during the subadult, pre-breeding period, as has been observed with wide ranging vagrant storm petrel species detected on SEFI (Tristram's Storm-Petrel O.tristrami- Warzybok et al. 2009, Fork-tailed Storm-Petrel O.furcata – PRBO unpublished), but which then return to their natal colonies when they reach maturity (Nur & Sydeman 1999). Wide ranging

behavior of immature storm petrels of multiple species has been well documented (Mainwood 1976, Love 1978, Furness and Baillie 1981, Fowler et al. 1982). Nur et al. (1999a) estimated that the actual dispersal rate was 1.6%, which is still a low rate of immigration. In the population dynamic model we allow for some immigration and emigration but assume that immigration equals emigration; that is, that dispersal is balanced. The empirical evidence indicates that emigration from the Farallones to the Channel Islands is also very low, an inference supported by genetic studies (Girman et al. 1999). If dispersal is not balanced, then population dynamic results would be affected.

Additional assumptions

We assumed no maximum longevity. Ashy Storm-Petrels from SEFI show a maximum observed longevity of 35 years (Bradley and Warzybok 2003). North American Leach's Storm-Petrels have been observed to live at least to age 36 years (Huntington et al. 1996). Though we assumed no maximum life span, we also assumed that older adults (beyond prime breeding age) displayed slightly lower adult survival rates, consistent with other studies of seabirds (Pyle et al. 1997, Nur et al.1999a). Model results were robust to the assumption of maximum age because few adults are expected to survive beyond age 36.

We assumed no density dependence. Population density for this species is low, especially when compared to other seabirds on the Farallones. In any case, there is no evidence of density dependent reproductive success or survival for any petrel species. We did not differentiate between males and females. The species is monogamous, and so reproductive success of one sex equals that of the other sex. No sex-specific information is available regarding survival or age of first breeding for this species.

Starting Population Size

As this analyses focused on changes in trends, we depicted population modeling results, with and without impacts of mouse eradication, by setting relative population size in Year 0 to 1.0. Year 0 corresponds to the year in which Burrowing Owl abundance is reduced, presumably a result of mouse eradication. Thus, for example, a change in relative population size from 1.0 in Year 0 to 0.5 in Year 20 indicates a 50% decline. Sydeman et al. (1998b) estimated a breeding population on the Farallon Islands of 2,660 in 1992; Nur et al. (1999a) estimated that the total population size in 1992 (including subadults and non-breeders) was a little less than 5,000 individuals.

We estimated the current Farallon Ashy Storm-Petrel population size from the negative binomial regression analysis of mist-netting using year-specific estimates for each of the 3 most recent years, 2010, 2011, and 2012. Results from 3 most recent years are, in our view, more robust than relying on results from a single year We determined the weighted 3-year mean (calculated in natural log values) and then backtransformed it. Weighting was based on the inverse of the standard error of the annual estimate (Kutner et al. 2004). To estimate the current number of breeders on SEFI, we used the estimated proportional change from 1992 to 2010-2012 and multiplied that by 2660, the number of breeders estimated by Sydeman et al. (1998b). All breeder estimates are rounded to the closest even number of individuals.

To obtain a 95% Confidence Interval (CI) around this 3-year estimate of proportional population change, we followed several steps. First, we calculated the mean annual standard error from the standard errors around the annual, year-specific coefficients obtained from the negative binomial regression analysis using output from 2010-2012. Second, we obtained the “3-year mean SE” by dividing the mean annual SE by the square-root of n, where n = number of years used to obtain the mean standard error, i.e., n = 3. Third, we constructed an approximate 95% CI as estimated population change (in ln-units) plus or minus 2 times the “3-year mean SE.” The upper and lower CI bounds were then backtransformed to obtain upper and lower estimates of proportional change.

Population model Leslie matrix: population size and calibration

Population projections were carried out using an age-based Leslie matrix as described above. The elements of the Leslie matrix were held constant over time. Reproductive success was based on recent (10-year) observations in the field (see above for details). Assumptions regarding survival and breeding probability are described above. For each scenario we calculated the adult survival rate that, with the other parameter values set (described above), produced a population whose finite growth rate was either 7.19% decline per year (Scenario A), 3.36% decline per year (Scenario B), or 0.63% increase per year (Scenario C), as described in the Results. Note that adjustment of adult survival also resulted in proportional adjustment of survival rates of first-year, second-year and third-year individuals, as described above. As noted, fourth-year individuals were presumed to display adult survival values.

Population model: modeling impacts of Burrowing Owl predation

The result of the calibration process was that the population dynamic model produced a population that displayed one of three trends over time, corresponding to the three scenarios: Scenario A) steep decline, Scenario B) moderate decline, and Scenario C) near-stable. These correspond to population behavior observed in recent years, under conditions in which Burrowing Owl abundance and predation activity has been high. Thus, we used the "recent population dynamic model" to represent three plausible baseline condition scenarios: the expected population trends in the near future if there were no change in abundance of Burrowing Owl on the island. The "baseline-recent" model, with its three scenarios, is one in which we extrapolate into the future and assume that current conditions continue for the next 20 years - presumably with both mice and owls present.

The next stage of modeling was to estimate the change in the storm-petrel population trend resulting from a change in survival, as a result of an assumed reduction in Burrowing Owl abundance and predation on the island. The change in storm-petrel survival rates was determined from the statistical analysis of mist-net capture-recapture data.

We analyzed the most recent 3 years of data(2009/2010 to 2011/2012) on Burrowing Owl abundance on SEFI to provide the most relevant values regarding current owl levels and how these may be changed in the future as a result of mouse eradication. We considered 2 levels of Burrowing Owl abundance reduction for modeling purposes: reducing abundance by 50% and 71.5% compared to the mean observed for the 3 most recent years. The mean value for the last three years for maximum number of Burrowing Owls observed per month over the 8-month observation period, September to April (see above) was 6.29. The 50% scenario corresponds to a reduction of 3.145 "owls" and the 71.5% scenario corresponds to a reduction of 4.50 "owls," as measured by the mean value of the index, which is the maximum number of Burrowing Owls observed per month.

We suspect that migrating Burrowing Owls may still land on the Farallon Islands in the fall in the future even if all house mice are eradicated. But it is likely that they will move on with their migration within a few days to a few weeks, when no adequate available food source is present. Thus, while it is reasonable to expect that most burrowing owl predation on storm-petrels can be reduced with mouse eradication, it may not result in 100% reduction in Burrowing Owl predation on storm-petrels. For owls arriving in September and October, as many do, there will still be limited opportunities to prey

upon Ashy Storm-Petrels, but the storm-petrels available as prey are present in relatively low numbers during those months, compared to their peak abundances. If 100% reduction of Burrowing Owl predation could be accomplished, the population response of Ashy Storm-Petrels would be even greater than what we have modeled. Furthermore to model the benefit to Ashy Storm-Petrels of a reduction in Burrowing Owl predation, we assumed that first-year and second-year storm-petrel survival did not improve as a result of Burrowing Owl reduction, but only survival of third-year and older individuals improved. For the purposes of modeling, we assumed that second-year birds were absent from the island, but that third-year birds were present and that they are susceptible to predation just as are older individuals. Whereas we have good reason to believe that fourth-year birds are present on the island, we have little information as to whether second- and third-year individuals are present (and therefore subject to Burrowing Owl predation) or absent. Our mist-net data for storm petrels contains very few birds banded as chicks, and so most capture birds are of unknown age. The assumption made in our modeling was intermediate between two more extreme assumptions (complete susceptibility of second- and third-year individuals vs no susceptibility of second and third-year birds).

In summary, we model three levels of reduction in Burrowing Owl abundance: a) No owl reduction, b) 50% owl reduction and c) 71.5% owl reduction. These three levels are each assessed for three different scenarios of population trend: the observed recent steep decline, a moderate decline, and a near stable scenario. For each scenario we consider a 20-year time horizon.

Results

Monthly variation

House mice, Burrowing Owl abundance, and Ashy Storm-Petrel predation by owls each showed a clear and distinctive seasonal pattern (Figure 2). For mice, the population index was lowest in March-May and highest in August-December. For owls, the abundance index was high in October-March and near zero in June-August. The index of owl predation on Ashy Storm-Petrel was highest in February-April, and near zero in June-December. Thus, two temporal trends can be noted: 1) the Ashy Storm-Petrel predation index increases in January and February, just as the house mouse index drops precipitously; 2) at the time that Burrowing Owls arrive on the island (in September and October), house mouse populations are at very high levels . Despite presence of owls in September and October, months that coincide with peak house mouse levels, predation on Ashy

Storm-Petrel is near zero at this time, even though a number of Ashy Storm-Petrels are still breeding in those months (Ainley et al. 1990). This pattern is consistent with mice being the preferred prey of Burrowing Owls.

Most of the monthly variation in the Ashy Storm-Petrel predation index (ln-transformed) was explained by variation in Burrowing Owl abundance and the house mouse abundance index (R^2 = 0.538; Adj R^2 = 0.502; P < 0.0001, Table 1). The effect of Burrowing Owl abundance on owl predation of storm-petrels was highly significant when controlling for the abundance of mice: greater monthly owl abundance was associated with greater predation on Ashy Storm-Petrel (P = 0.001; Table 1). The effect of house mouse abundance was highly significant when controlling for the effect of Burrowing Owl abundance (P < 0.001; Table 1). Greater house mouse monthly abundance was associated with lower Burrowing Owl predation index values for Ashy Storm-Petrel. This finding also suggests that when mice are available, Ashy Storm-Petrels are not the primary prey for Burrowing Owls.

Annual Variation in Population Size and Predation

<u>Annual Trends in Burrowing Owl abundance and Ashy Storm-Petrel predation</u>

Burrowing Owl abundance appeared relatively stable from fall 2000 to 2006 and then began to increase (Figure 3). The overall trend depicted is significant (P = 0.001); the best fit, as determined by AIC was a quadratic transformation, i.e., an accelerating increase over time beginning in 2000, the first year of the time-series (Figure 3). Note that the four years of highest abundance have been the four most recent years (2009-2012).

The results of the analysis show that Burrowing Owl predation on Ashy Storm-Petrels has also increased during the same period (Figure 4). Like the Burrowing Owl abundance index, the trend in the owl predation index on petrels is both significant and accelerating (P = 0.003). The best fit, as determined by AIC is the quadratic transformation of year relative to 2003, the first year of standardized data collection for this variable.

Furthermore, the annual Ashy Storm-Petrel owl predation index is strongly, positively correlated with the annual index of Burrowing Owl abundance. The linear relationship between the two is highly significant (P = 0.003; R^2= 0.740; R^2adj= 0.703). This result strongly suggests that the recent increase in the

Burrowing Owl abundance has led to an increase in predation on Ashy Storm-Petrels.

Variation in Index of Ashy Storm-Petrel Population Size

The Ashy Storm-Petrel population index displayed marked year-to-year variation from 2000 to 2012 (Figure 5). In assessing recent storm-petrel population index trends from 2000 to 2012, we evaluated twelve different models to determine the best parameterization describing the change in population index over time, as determined by AIC. The preferred model was a two part linear spline with a change point between 2006 and 2007 (Table 2, Figure 5).This break, or “knot,” is consistent with the observed increase in Burrowing Owl numbers (Figure 4; see above). Prior to the change point, the storm-petrel population index had increased significantly at 22.1% per year ($p < 0.001$, Table 3). After the change point there was a significant change in trend ($p = 0.002$, Table 3) with a linear decrease in population ($p = 0.095$, Table 3). The trend for the period 2007-2012 was equivalent to a 7.19% decrease per year, which we refer to as the “observed steep decline” scenario. However the standard error around the trend estimate was large, hence the 95% CI included zero. Because the negative trend of 7.19% annual decrease for the period 2007 to 2012 was not statistically significant and its CI was quite large (Table 3), we also considered two other plausible scenarios based on our empirical estimates. It is likely that the 6 year timeframe is too short to produce a significant result with these methods, despite the strong decline. One alternative scenario was a “moderate decline” which was equal to the estimated slope plus 1 standard error, i.e., 3.36% decline per year. The second alternative was equal to the estimated slope plus 2 standard errors, i.e., 0.63% increase per year. We refer to the three scenarios as Scenarios A (“observed steep decline”), B (“moderate decline”) and C (“near-stable”). Population models were calibrated to yield Leslie matrices whose population growth rates corresponded to one of these three scenarios (Table 4). The calibration was achieved by adjusting adult survival (see Methods); demographic parameter values are shown in Table 4.

Ashy Storm-Petrel Population Estimate

Using estimates from the three year period 2010-2012, the estimated change in Farallon Ashy Storm-Petrel was 2.17x as many breeders during this period as in

1992. We estimate 5768 breeders (= 2660 x 2.1681), a 116.8% increase from 1992 to 2010-2012.

The lower bound estimate of population size obtained was a proportional increase of 42.4%; the upper bound estimate was a proportional increase of 230.0%. This translates into lower and upper bounds of the 95% CI of 3790 breeders and 8778 breeders respectively.

Variation in Ashy Storm-Petrel Survival Probability

There was support for year-to-year variation in survival (Likelihood Ratio Statistic = 16.51; df = 10, P = 0.086), comparing a model with year as a factor with a model with constant survival. Of greater relevance was the dependence of annual survival on Burrowing Owl abundance. Specifically, the optimal model (among 128 examined) included two variables affecting survival: Sept-April index of Burrowing Owl abundance and location of mist-netting site (LHH vs. CS). The preferred model also included two variables affecting recapture probability: site and winter SOI. The coefficients and other statistics for the preferred model are depicted in Table 5.

The most relevant result for the modeling is that an increase in the Burrowing Owl index by 1 individual (per month, over the 8-month period) decreased logit survival by 0.1131. The effect is highly significant (P = 0.009, Table 5). Therefore a reduction in the Burrowing Owl index by 50% is expected to increase logit survival by 0.356 for the 3 scenarios examined. A reduction in the Burrowing Owl index by 71.5% is expected to increase logit survival by 0.509.

Note that all three scenarios (A, B, and C) assume the same change in logit survival as a function of a change in the Burrowing Owl index, as enumerated above. However, baseline survival rates differ for the three scenarios and thus the change in survival associated with a change in the Burrowing Owl index differs among the scenarios (Table 6). The estimated magnitude of the effect of reducing (or increasing) Burrowing Owl abundance was large: a decrease of 1 Burrowing Owl in the abundance index (= 8 “owl-months”, based on known numbers of owls) is associated with an absolute increase in survival of 0.8% to 1.4%, depending on the baseline value of survival. Specifically, a 50% reduction in Burrowing Owl abundance during the 8 month period, as calculated for the past 3 years (equivalent to a reduction in the Burrowing Owl abundance index of 3.145 owls, based on known numbers of owls), is expected to

increase adult storm-petrel survival by a relative 2.64 to 4.92% for adults, depending on the scenario; a 71.5% reduction in Burrowing Owl abundance (equal to reduction in the index of 4.5 owls, based on known numbers of owls) is expected to increase adult storm-petrel survival by a relative 3.54 to 6.66% for adults, depending on the scenario (Table 6).

Population Dynamic Model

We developed a population dynamic model for Ashy Storm-Petrels that produced a population that declines at 7.19%, declines at 3.36%, or increases at 0.63% per year, depending on the scenario examined. The demographic parameter values for each scenario are listed and annotated in Table 4. Adult survival varied from 84.3% to 91.4% depending on the scenario. We then modified survival of all individuals beyond second-year individuals (see Methods) under the two “Burrowing Owl reduction levels”, for scenarios A, B, and C. Adult survival values predicted as a result of a decrease in the Burrowing Owl index are depicted in Table 6. The new lambda values under the two Burrowing Owl reduction levels for the three population trend scenarios are also depicted in Table 6. Changes in relative Ashy Storm-Petrel population size over a twenty year time period, for all three levels of Burrowing Owl reduction (0%, 50% and 71.5% reduction) for each population trend scenario are displayed in Figure 6.
The most important results to emerge from this analysis are: A 50% reduction in Burrowing Owl abundance can be expected to change population growth rates by 2.3-3.9% depending on whether we assume Scenarios A or C, with Scenario B values falling in between. This corresponds to changing a population which is declining at 7.2% per year to one that is declining at only 3.3% per year (under Scenario A) or will change a population that is slightly increasing (at 0.6% per year) to one that is increasing at 2.9% per year (under Scenario C). Again, under Scenario B, results are intermediate: the model predicts a change from 3.4% decline to near-stability (0.2% decline per year).

With a 71.5% reduction in the Burrowing Owl abundance index, population growth rates change by 3.1-5.3%, depending on the scenario. The greater reduction in Burrowing Owl abundance (and therefore predation) results in larger population benefits for storm-petrels: the result is a much more modest decline (1.9% per year compared to 7.2% decline with no Burrowing Owl reduction) under Scenario A or a much stronger increase (3.7% per year compared to 0.6% increase per year) under Scenario C. Under Scenario B, we see a modest increase (0.9% per year) instead of a 3.4% decrease per year.

In summary, reduction in Burrowing Owl abundance has strong positive Ashy Storm-Petrel population impacts in all scenarios examined. Under the “Observed Steep Decline” scenario, rates of storm-petrel decline are drastically reduced, under the “Moderate Decline” scenario the storm-petrel population trends change from moderate decline to stable or slight annual increase, and under the “Near Stable” scenario, rates of annual storm-petrel population change from a very weak increase to a strong increase with owl reduction, equivalent to a five-fold increase in the net population growth rate.

Discussion

Our statistical analysis demonstrates that observed variation in Burrowing Owl abundance and predation on Ashy Storm-Petrel do indeed result in ecologically and statistically significant changes in Ashy Storm-Petrel survival. Given these impacts, we can expect, all else being equal, that a decrease in Burrowing Owl abundance will have significant and positive benefits for Ashy Storm-Petrel population trends. Our results show that even a 50% reduction in Burrowing Owl abundance resulting from a proposed invasive rodent removal can be expected to change a steep decline to a moderate decline, change a moderate decline to near-stability, or change a relatively stable population to a growing population. A reduction of recent Burrowing Owl abundance by substantially over 50% has the potential to produce increasing Ashy Storm-Petrel populations on SEFI in two out of the three population trend scenarios assessed. These results provide quantitative evidence supporting the expected benefits to the Ashy Storm-Petrel population from the proposed house mouse eradication on the Farallones, which would provide a significant conservation gain for this species endemic to the California Current. The benefit is especially marked since the South Farallon Islands are home to approximately half of the world’s Ashy-Storm Petrel population.

The monthly data presented here indicate that Ashy Storm-Petrels are a secondary prey item for Burrowing Owls. Burrowing Owls appear to prefer house mice as prey, and depredate Ashy Storm-Petrels when mice are not available. Both the monthly and annual data demonstrate that more Burrowing Owls on SEFI results in greater predation on Ashy Storm-Petrel by owls. Most importantly, the Ashy Storm-Petrel survival analysis indicates that, on an annual basis, more Burrowing Owls present results in lower adult Ashy Storm-Petrel survival. The estimated effect of a reduction in Burrowing Owl abundance was large: A reduction of Burrowing Owl abundance by 16% relative to current levels (equal to 1 Burrowing Owl in the monthly abundance index), is expected to increase Ashy Storm-Petrel survival by approximately 1%. A 50% reduction in owl abundance is expected to increase survival probability by 0.024 to 0.042. This is quite

significant for the population because current adult mortality, from all causes, is in the range of 0.086 to 0.156. For a long-lived seabird, such reductions in mortality and increases in survival rates are of great consequence in improving population viability (Weimerskirch et al. 2002).

Our measure of predator abundance or activity is coarse, but provides an index of year to year variation in attendance of Burrowing Owl on SEFI, an open terrain where owls have persistent, identifiable roost sites. We acknowledge that daily survey effort increased in 2010, so we have used the monthly maximum Burrowing Owl abundance observed on SEFI. The monthly index integrates observations over many days and therefore is less sensitive to the effort in any given day. Moreover, the high correlation (r = 0.860) observed between the annual index of Burrowing Owl abundance and the annual index of Ashy Storm-Petrel predation by owls, an index whose methods have been consistent throughout the time series, provides strong evidence of a causal relationship between Burrowing Owl abundance on SEFI and variation in mortality rates of Ashy Storm-Petrel. In fact, analysis of the Ashy Storm-Petrel predation index in relation to annual survival yields very similar results as those presented here with respect to impact of changes in Burrowing Owl abundance.

In addition, the timing of the recently observed increase in Burrowing Owl abundance, which began in 2007 (Figure 3), aligns with the change point from an increasing population to a declining population in the top model selected to describe recent population trends. That is, during the period 2001 to 2006, Burrowing Owl abundance remained stable and low, during which time the Ashy Storm-Petrel population was growing. Starting in 2007, Burrowing Owl abundance began to increase, and the population trend changed from positive to negative. These are all lines of evidence that support our finding of a statistically significant effect of Burrowing Owl abundance on Ashy Storm-Petrel survival as revealed through the capture-recapture analyses.
The recent increase in Burrowing Owl abundance at SEFI may be due to population increases in Burrowing Owls, or changes in the coastal distribution of this primarily inland species, though there are no published studies to support these hypotheses. As there is no long term time quantitative series on SEFI mouse abundance, it is possible that changes in their numbers have influenced owls, though mice have always been abundant on SEFI in the fall for the last 4 decades (PRBO, unpublished data). The most recent four years have seen the greatest abundance values for Burrowing Owl, and so the current levels of this predator present a grave problem for Ashy Storm-Petrel, if no action is taken.

It is rare in ecological studies to have direct evidence of variation in predation rates that are so tightly coupled with observations on the predator itself (variation in Burrowing Owl abundance) as well as the demographic parameter of interest (variation in survival rates of Ashy Storm-Petrel). Thus, we believe the quantitative relationship between owl abundance and Ashy Storm-Petrel survival rates elucidated here is well-supported. The longer current levels of owl predation continue, the more likely this population is to decline. It should also be noted that these analyses do not include effects of Western Gull predation on Ashy Storm-Petrel, whose overall, population-level impact is similar to that of owl predation. However, per individual, the predation rates of Burrowing Owls on Ashy Storm-Petrels is 775 times that of Western Gulls (Bradley et al. 2011). To reduce the Western Gull predation levels on Ashy Storm-Petrels by a substantial amount, a very large number of Western Gulls would likely need to be removed from the island. Reducing gull predation would have positive impacts for Ashy Storm-Petrel populations, but reduction of Western Gull predation is not required for the population to switch from decline to stability or from stability to growth: a large reduction in Burrowing Owl predation will suffice.

In summary, there is strong evidence for current, significant impacts of Burrowing Owl predation on Ashy Storm-Petrel population dynamics. To what extent mouse eradication results in reduction of Burrowing Owl predation on storm-petrels remains to be seen, but indications from this study and other island eradications indicate that there will likely be a positive and significant population response by Ashy Storm-Petrels and other native species to the removal of the invasive rodent from the Refuge. Eradication of house mice may not prevent migrating Burrowing Owls from visiting the Farallon Islands in the fall. However, it is likely that the owls would leave soon after arriving, as mice would not be present and the few chick rearing storm-petrels that are still present make direct flights to and from their breeding sites, not the extensive flight activity they show during courtship and pre-breeding, where they would be more susceptible to owl predation (PRBO, unpublished). Thus, owls would likely not stay several months on the island, as they currently do, preying on Ashy Storm-Petrels in January through April. In particular, there are few or no Ashy Storm-Petrels on the Farallon Islands in November and December (Ainley et al. 1990, PRBO unpublished). It is not plausible, from an energetic point of view that Burrowing Owls would continue to stay on the island during those months in the absence of both their primary prey (house mice) and their secondary prey (Ashy Storm-Petrel). Predation on other seabirds by Burrowing Owls has rarely been observed (PRBO, unpublished).

Caveats and Limitations

We have used analyses of capture rates of Ashy Storm-Petrels to provide an index of population change. Our analyses have controlled for several variables that may influence capture probability (days of netting, hours of netting, date, the quadratic effect of date, and capture location) but there may indeed be annual differences in capture probability not accounted for by our statistical model. In fact, the survival analysis identified SOI as a factor that may explain annual variation in recapture probability. We emphasize; however, that we have used the population index results to inform us regarding longer-term changes in the abundance of Ashy Storm-Petrels, not year to year changes. We use the change-point analysis of mistnet capture rates in two ways. First, the change-point analysis demonstrated a significant difference between population trend in 2000 to 2006 and the trend from 2007 to 2012. We have no reason to infer that this change in trend was due to a change in capture probability, but this possibility cannot be ruled out. Instead, we argue that the change in trend is consistent with the change in survival rates associated with the marked increase in Burrowing Owl abundance and increase in the predation index that began about 2007. Comparing 2000-2006 with 2007-2012, Burrowing Owl abundance was about four-fold higher in the recent period, and the predation index was more than twice as great. However, we are certainly not arguing that this was the only factor explaining the change in trend. Second, we have used the change-point analysis to characterize the recent population trend, a decrease of 7.2% per year. There is substantial uncertainty around this estimate and therefore in our analyses we have considered three possible current trends, from a very slight increase (less than 1% per year) to a steep decline (over 7% per year). Our results do not depend on assuming any one trend estimate. Though the quantitative results depend on which scenario is assumed, the qualitative results are the same: a 50% reduction in Burrowing Owl abundance is expected to change the annual population growth rate by 2 to 4% per year; a 71.5% reduction in Burrowing Owl abundance is expected to change population growth rate by 3 to 5% per year.

While we produced a recent population estimate for Farallon Ashy-Storm Petrels based on index values from mist-net captures, this analysis focused on changes in trends not absolute numbers. Due to the cryptic nature of this species, it is extremely difficult to estimating breeding population size and the sampled area (and likely resulting estimate) did not include all portions of the islands. The large confidence interval around this population estimate reflects these challenges.

We did not consider direct impacts of house mice or Burrowing Owl on Ashy Storm-Petrel reproductive success (see Wanless et al. 2012). Reproductive success of storm-petrels may increase as a result of house mouse eradication, either directly or indirectly. The direct effect would be a possible reduction in egg and chick mortality due to house mice eradication – though evidence of direct mice effects on breeding Farallon storm petrels is minimal (Ainley et al.1990, PRBO, unpublished). Indirect effects would result from decreases in Ashy Storm-Petrel parental mortality before or during the egg stage (in March and April) due to reduction in Burrowing Owls at this time, resulting in increased breeding attempts and/or increased breeding success.

It is also important to note that our analyses on abundance of owls and their predation on storm-petrels are using index values collected from accessible areas of the island, and over 40% of island area at the South Farallones (particularly West End Island) is not surveyed, therefore absolute values for owl abundance and predation of storm-petrels are higher than index values.

Our projections do not specifically incorporate impacts of environmental variability on future population trends, in contrast to analyses by Nur et al. (2011) and Nur et al. (2012). The goal of our analysis was to determine the impacts to Ashy storm-petrels as a result of a change in predation rates by Burrow Owls. In the variable marine environment of the California Current, reduction of predation impacts will help Ashy Storm-Petrel population's buffer potentially poor oceanic conditions in the future.

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Table 1. Regression Analysis of Ashy Storm-Petrel Predation index (ln-transformed), by month, in relation to House Mouse and Burrowing Owl monthly indices. Number of observations = 29. Test of overall model: F(2,26) = 15.12; P < 0.0001. R^2 = 0.538, $R^2_{adj.}$ = 0.502

Variable	Coefficient	S.E.	t	P value
House Mouse trapping index	-3.463	0.674	-4.96	P < 0.0001
Burrowing Owl abundance index	+0.199	0.056	+3.55	P = 0.001
Intercept	+1.745	0.301	+5.80	P < 0.0001

Table 2. Model results of Farallon Ashy Storm Petrel Population Index (ln-transformed) trends 2000-2012, ranked by AIC values. k = number of model parameters. For linear spline models, the change point is shown; 2006/2007 indicates change point is half-way between 2006 and 2007, etc.

Model	**k**	**AIC**
Two Part linear spline : 2006/2007	3	0.110
Two Part linear spline : 2005/2006	3	0.183
Two Part linear spline : 2007	3	0.193
Two Part linear spline : 2005	3	0.338
Two Part linear spline : 2006	3	0.784
Quadratic	3	0.827
Two Part linear spline : 2007/2008	3	1.256
Cubic	4	2.755
Ln (year)	2	5.873
Inverse year	2	7.543
Linear	2	11.052
Constant	1	17.075

Table 3. Regression Analysis of best fit model Farallon Ashy Storm-Petrel Population Index (ln-transformed) trends 2000-2012: two part linear spline with the change point between 2006 and 2007. Comparing overall trends before and after the change point show significant change in overall trend: F(1,10) =17.06, P = 0.002. Number of observations = 13. Test of overall model: F(2,10) = 20.08; P = 0.0003. R^2 = 0.801, $R^2_{adj.}$ = 0.761

Variable	Coefficient	S.E.	P value	Lower 95% CI	Upper 95% CI
Index prior	+0.200	0.034	P < 0.001	0.125	0.275
Index post	-0.075	0.040	P = 0.095	-0.165	0.016
Intercept	-399.588	67.311	P < 0.001	-549.567	-249.609

Table 4. Ashy Storm-Petrel Demographic Parameter Values Used to Model Current Conditions with no Burrowing Owl Reduction. Three different scenarios are modeled: A) "Observed Steep Decline"; B) "Moderate Decline"; and C) "Near Stable"

Age	Proportional Survival to Mature Adult [1]	Steep Decline Survival [2]	Moderate Decline Survival [2]	Near-Stable Survival [2]	Breeding Probability [3]	Breeding Success [4]
1	0.72	0.607	0.632	0.658	0	0
2	0.86	0.725	0.755	0.786	0	0
3	0.98	0.826	0.860	0.896	0	0
4	1	0.843	0.878	0.914	0.092	0.588
5	1	0.843	0.878	0.914	0.460	0.588
6	1	0.843	0.878	0.914	0.828	0.588
7	1	0.843	0.878	0.914	0.920	0.588
8	1	0.843	0.878	0.914	0.920	0.588
9	1	0.843	0.878	0.914	0.920	0.588
10	1	0.843	0.878	0.914	0.920	0.588
11	1	0.843	0.878	0.914	0.920	0.588
12	1	0.843	0.878	0.914	0.920	0.588
13	1	0.843	0.878	0.914	0.920	0.588
14	1	0.843	0.878	0.914	0.920	0.588
15	1	0.843	0.878	0.914	0.920	0.588
16+	0.98	0.826	0.861	0.896	0.920	0.588

[1] - From Nur et al.1999a

[2] - Adult survival calibrated to produce population lambda for relevant scenario

[3] - Fraction of individuals of that age class that attempt to breed, either for the first time or as an experienced breeder.

5 - Mean value, SEFI, 2002-2011

Table 5. Ashy Storm-Petrel Survival Estimation Results for Top Model, 2000-2011 for Southeast Farallon Island. For the model, Survival (Phi) is a function of site and Sept-April Burrowing Owl abundance; recapture probability (p) is a function of site and Jan-Mar SOI. Model statistics: Number of parameters = 6, -2lnLikelihood = 2635.107, AICc = 2647.124.

Parameter	Estimate	St. Error	Lower 95%CI	Upper 95%CI
Phi: Intercept	1.398	0.281	0.847	1.950
Phi: site (LHH vs CS)	-0.997	0.283	-1.552	-0.443
Phi: Burrowing Owl abundance	-0.1131	0.0413	-0.1941	-0.0321
p: Intercept	-3.740	0.202	-4.136	-3.345
p: site (LHH vs CS)	0.973	0.245	0.494	1.452
p: SOI	0.050	0.030	-0.009	0.110

Likelihood ratio test for effect of Burrowing Owl (compared to corresponding model without Burrowing Owl index): LRS = 6.743, df = 1, P = 0.009.

Table 6. Impact of a Change in Burrowing Owl Abundance on Southeast Farallon Island on Ashy Storm-Petrel Populations. These results are based on Burrowing Owl and Ashy Storm-Petrel data from 2000-2012.Three different scenarios are: A) with the modeled recent decline; B) the recent decline plus one standard error; and C) the recent decline plus two standard errors, the upper boundary of the 95% confidence interval for our modeled results of recent population trends. A decrease of 3.145 in the Burrowing Owl Index corresponds to a reduction of 50% in Burrowing Owl abundance over recent years (2010-2012). . A decrease of 4.5 in the Burrowing Owl Index corresponds to a reduction of 71.5% in Burrowing Owl abundance over recent years (2009-2012), and the value observed in 2011/2012.

A: "Observed Steep Decline" Scenario

Change in Burrowing Owl Index	Adult Survival	Change in Survival	Percent Change in Survival	Lambda	Change in Lambda	Population Growth Rate	Description
0	0.8434	0	0%	0.9281	0	7.19% decline	Recent trend, no change in Burrowing Owl
Decrease by 3.145	0.8849	0.0415	4.92%	0.9673	0.0392	3.27% decline	Recent trend; decrease by 50% of recent mean
Decrease by 4.5	0.8996	0.0562	6.66%	0.9812	0.0531	1.88% decline	Recent trend; decrease by 72% of recent mean

B: "Moderate Decline" Scenario

Change in Burrowing Owl Index	Adult Survival	Change in Survival	Percent Change in Survival	Lambda	Change in Lambda	Population Growth Rate	Description
0	0.878	0	0%	0.9664	0	3.36% decline	Trend +1 SE, no change in Burrowing Owl
Decrease by 3.145	0.9113	0.0333	4.02%	0.9978	0.0314	0.22% decline	Trend +1 SE; decrease by 50% of recent mean
Decrease by 4.5	0.9229	0.0449	5.11%	1.0088	0.0424	0.88% increase	Trend +1 SE; decrease by 72% of recent mean

C: "Near Stable"

Change in Burrowing Owl Index	Adult Survival	Change in Survival	Percent Change in Survival	Lambda	Change in Lambda	Population Growth Rate	Description
0	0.9142	0	0%	1.0063	0	0.63% increase	Trend +2 SE, no change in Burrowing Owl
Decrease by 3.145	0.9383	0.0241	2.64%	1.029	0.0227	2.90% increase	Trend +2 SE; decrease by 50% of recent mean
Decrease by 4.5	0.9466	0.0324	3.54%	1.0369	0.0306	3.69% increase	Trend +2 SE; decrease by 72% of recent mean

Figure 1. Ashy Storm-Petrel netting sites on Southeast Farallon Island, CA. The two mist-netting locations are shown. Inset depicts general location of the Farallon Islands.

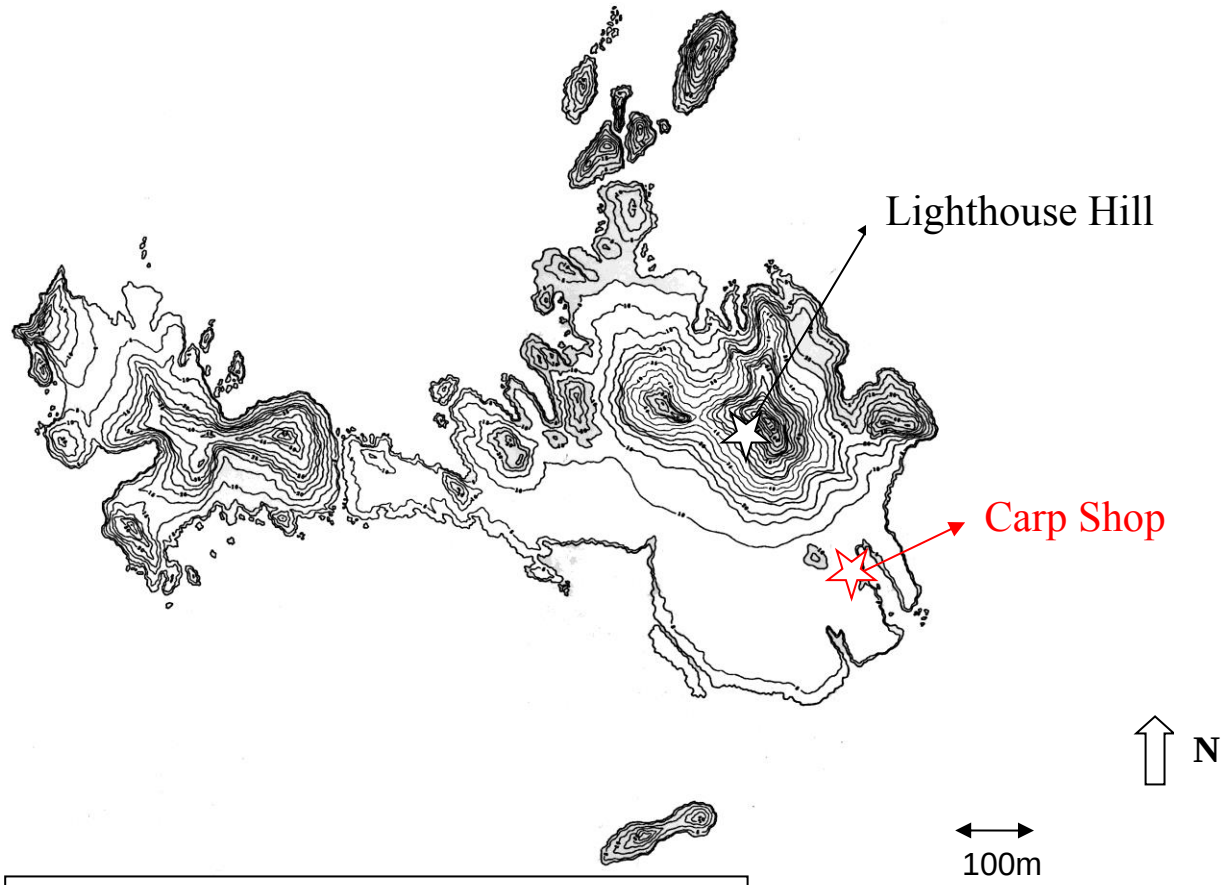


Figure 2. Seasonal Cycle of House Mouse Abundance Index (2001-2004, 2011-2012), Index of Ashy Storm-Petrel predation by Burrowing Owl (2008-2012), and Burrowing Owl abundance Index (2008-2012) at Southeast Farallon Island. Monthly mean values with standard deviation are shown.

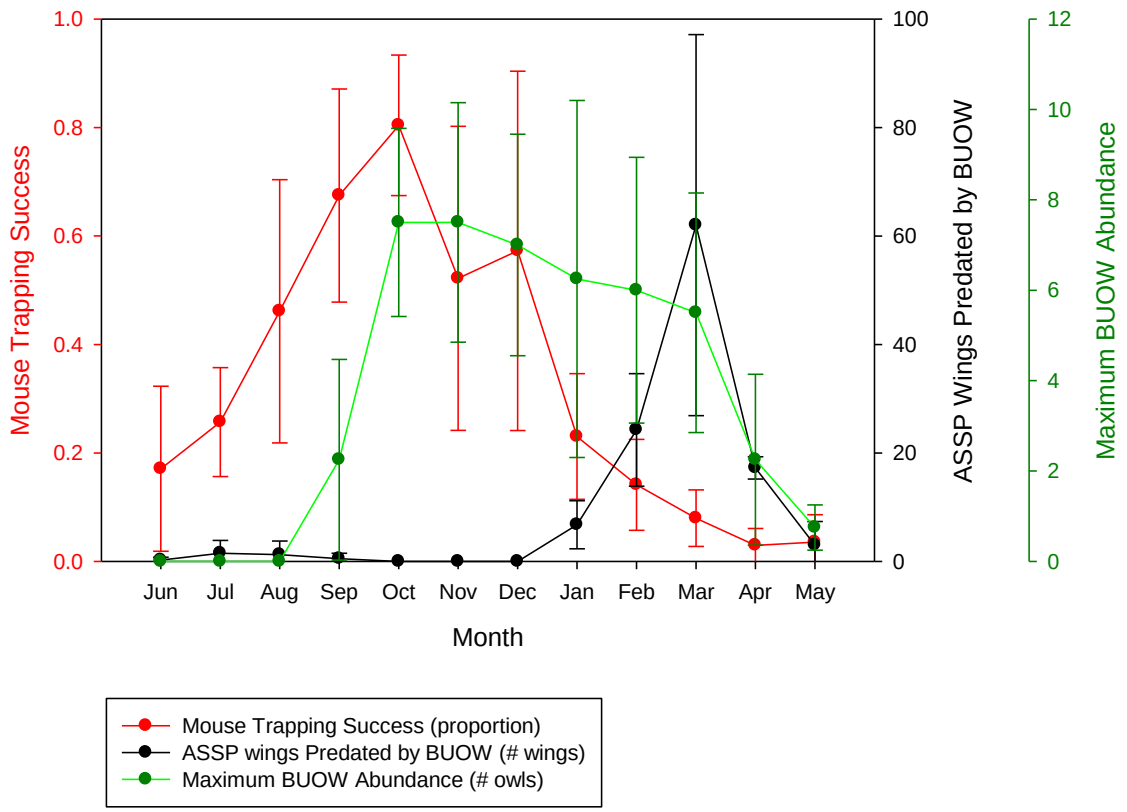

Mouse Trapping Success
ASSP Wings Predated by BUOW
Maximum BUOW Abundance
Month
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Mouse Trapping Success (proportion)
ASSP wings Predated by BUOW (# wings)
Maximum BUOW Abundance (# owls)

Figure 3. Variation in the annual Burrowing Owl abundance index (mean Sept-April abundance) for 2001 to 2012 on Southeast Farallon Island. The curve of best fit, as determined by AIC, is shown: a quadratic, accelerating trend. P = 0.001

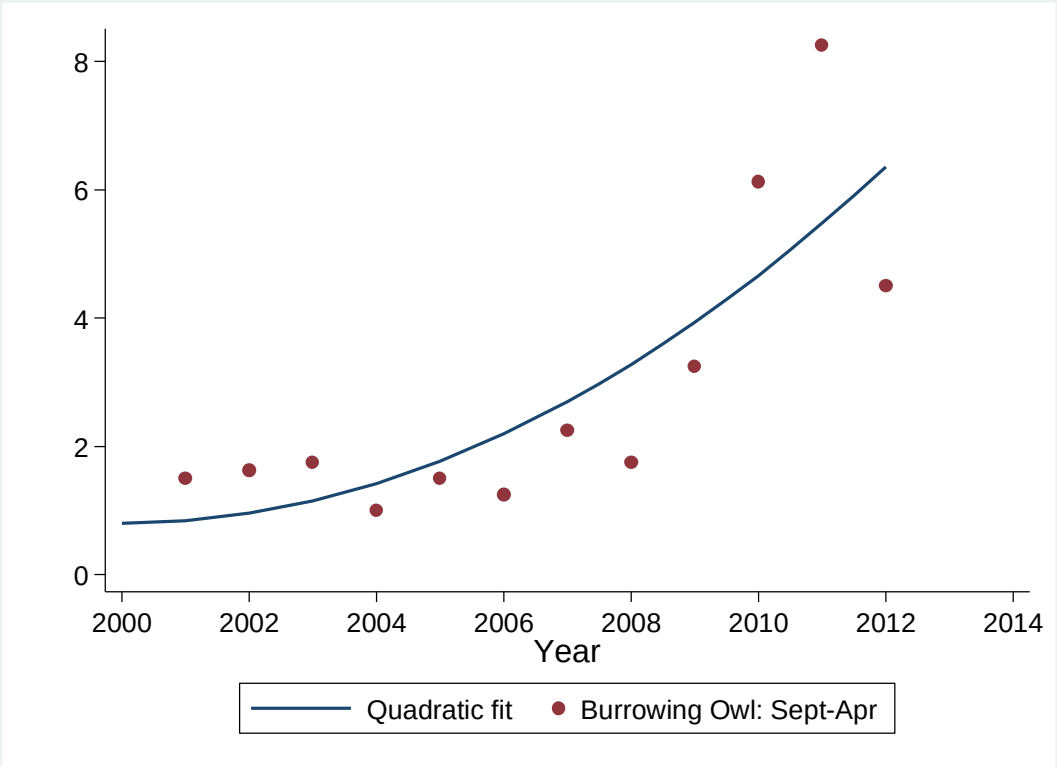


Figure 4. Annual (January-December) index of Burrowing Owl predation on Ashy Storm-Petrels from 2003 through 2011 on Southeast Farallon Island. 2012 data is not included in this figure, as only data through April was available at the time of analysis. The curve of best fit, as determined by AIC, is shown: a quadratic, accelerating trend. P=0.003

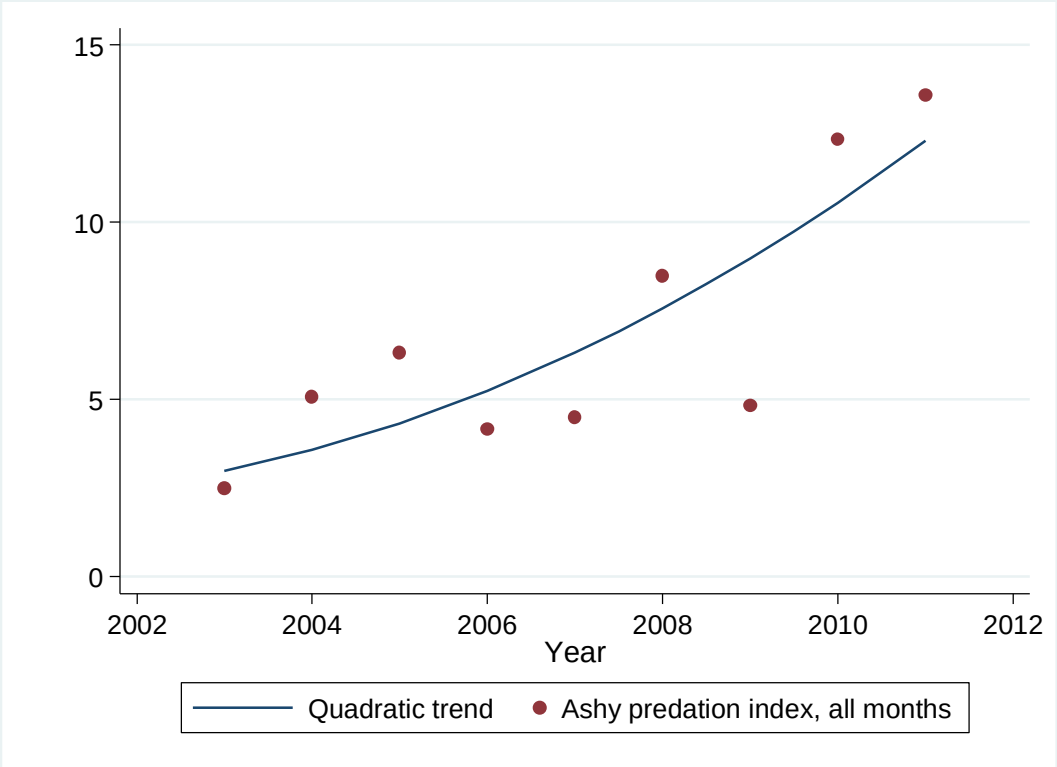


Figure 5. Population Index from Mist-netting Analyses for Ashy Storm-Petrels, 2000 to 2012 from Southeast Farallon Island. Values shown are natural log of the population index, plus one. The index is set at 1 for 2000 for illustrative purposes, though analyses were conducted with 2000 value set to 0 (see Methods). Index values are presumed directly proportional to abundance of Ashy Storm-Petrels. Line is best fit change point analysis showing change in linear trend between 2006 and 2007. Slopes in the two time periods were significantly different (t=4.13, df=10, p=0.002; Table 3)

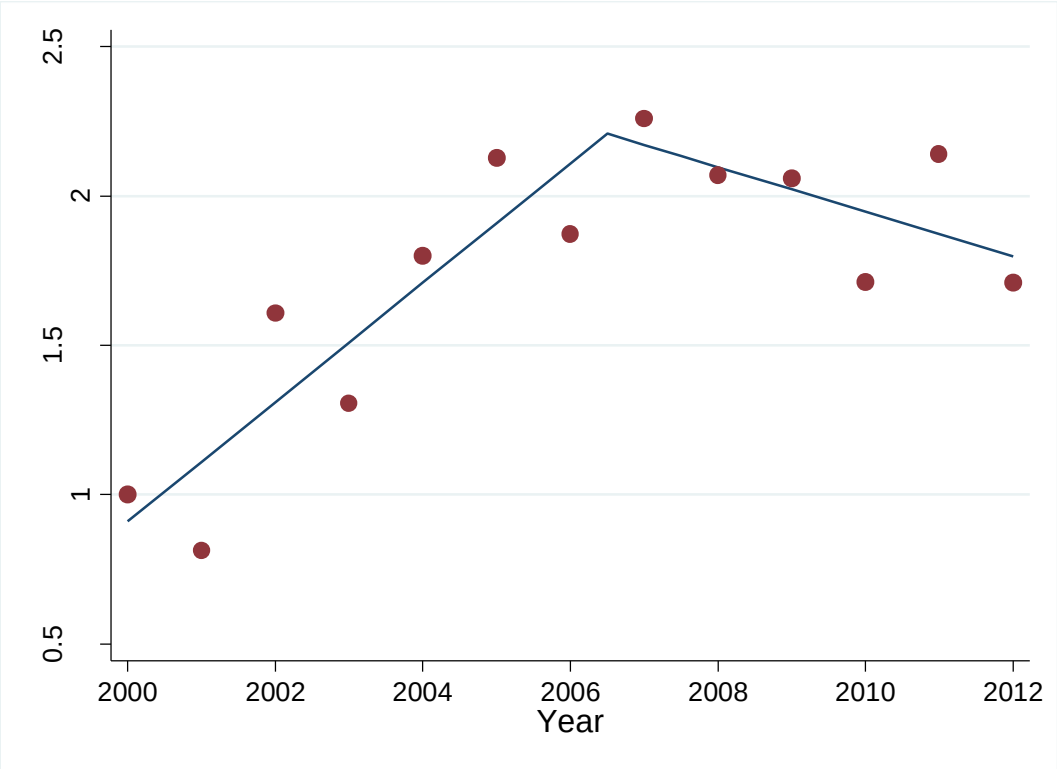
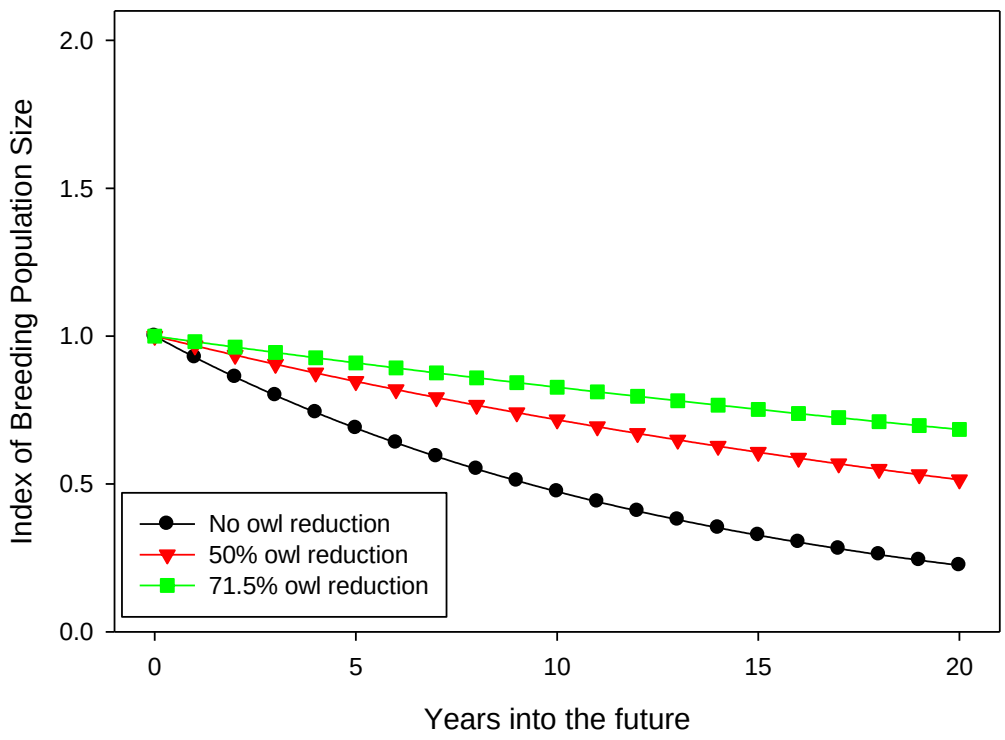
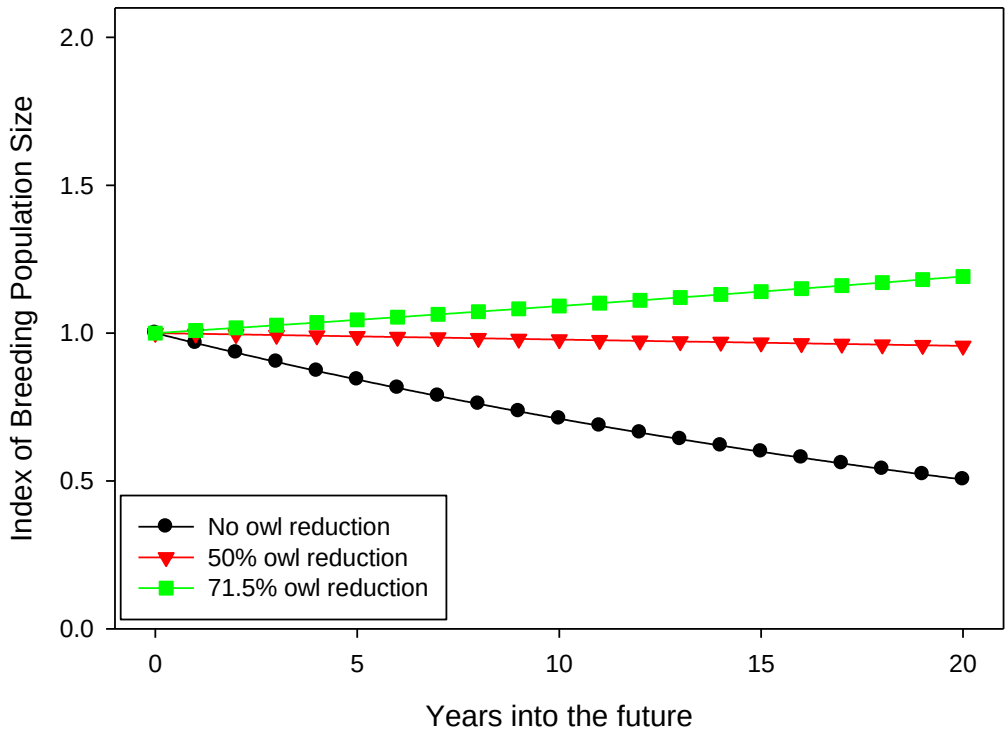


Figure 6. Farallon Ashy Storm-Petrel Population projections under the three levels of reduction in Burrowing Owl Abundance: 0% reduction, 50% reduction, and 71.5% reduction (see Methods). Levels of reduction are modeled for three separate scenarios: A) "Observed Steep Decline"; B) "Moderate Decline" ; and C) "Near Stable" (see Methods).Depicted are relative breeding population sizes for a 20-year period with Year 0 set to 1.0. Year 0 corresponds to most recent conditions and it is during this year that Burrowing Owl reduction is initiated, hence the population is assumed to respond between Year 0 and Year 1.

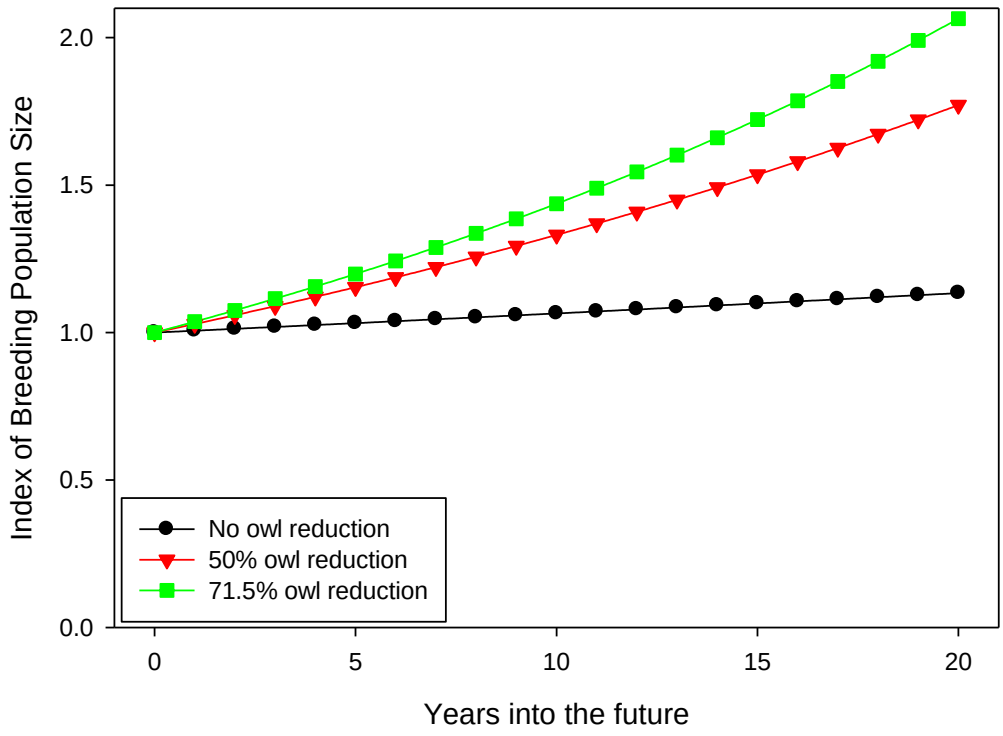
A) "Observed Steep Decline" Scenario



B) "Moderate Decline" Scenario



C) "Near Stable" Scenario



8.13 Appendix N – Gull Population Viability Analysis

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POPULATION VIABILITY ANALYSIS OF WESTERN GULLS ON THE FARALLON ISLANDS IN RELATION TO POTENTIAL MORTALITY DUE TO PROPOSED HOUSE MOUSE ERADICATION

REPORT TO THE U.S. FISH AND WILDLIFE SERVICE
FARALLON NATIONAL WILDLIFE REFUGE

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June 2013

Any reference to or use of this report or any portion thereof shall include the following citation:

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For further information contact the director of the Marine Ecology Division at marinedirector@prbo.org or PRBO Conservation Science, 3820 Cypress Drive #11, Petaluma, CA, 94954.

SUMMARY

Proposed invasive house mouse eradication efforts on the Farallon National Wildlife Refuge have identified Western Gulls (*Larus occidentalis*) as a species at risk of non-target mortality. Analyses of potential population level-impacts to the world's largest colony of this species are important for evaluating the feasibility of this proposed project. Using PRBO's long term datasets, we conducted a population viability analysis to model future trends for this population, assessing scenarios with and without eradication mortality, under varying environmental conditions. Scenarios were classified as: "Optimistic" assuming moderately high gull productivity (based on historic data, but with no recurrence of near-failure in reproduction); "Realistic", assuming long-term average productivity with historic frequency of near breeding failure; and "Pessimistic", assuming higher incidence of near-failure in reproduction at the recent frequency.

- Our analysis to assess the population viability of Farallon Western Gulls has been conducted using the best available demographic data for this species, in the population of interest, accounting for strong stochastic variability in parameters over a multi-decadal time scale.
- Future population trends for Farallon Western Gulls, in the absence of any mouse eradication-related mortality, will depend on likelihood of reoccurrence of years with especially low reproductive success, as was observed from 2009 to 2011, which were likely driven by environmental conditions.
- Under "Optimistic" environmental conditions, the model predicts that this Western Gull population would grow by 10.6% after 20 years (median result; quartile range +41% [first quartile] to -14% [third quartile]).
- Under "Realistic" environmental conditions, the model predicts that the population would decline by 8.7% after 20 years (median result; quartile range +18% to -29%).
- Under "Pessimistic" conditions, the model predicts that the population would decline by 27% after 20 years (median result; quartile range -4% to – 45%).
- We determined what level of project-related gull mortality would be ecologically indistinguishable from population trends in the absence of the eradication project (≥

95% overlap in expected outcomes after 20 years). The threshold was 1700 gulls for the “Realistic” scenario. Under assumptions of our modeling, mortality less than this value would be ecologically indistinguishable after 20 years.

- Under “Realistic” conditions, additional mortality of 1700 gulls would cause the population to demonstrate a cumulative decline of 12.7% after 20 years relative to initial conditions (median result, quartile range +4% to -47%).
- Given assumptions of the model and the demonstrated high variability of parameters, additional mortality less than 1700 gulls would not result in outcomes that, after 20 years, are effectively distinguishable when comparing project mortality and no-project mortality scenarios.
- We conclude that a mortality event of less than 1700 Western Gulls, given an overall population of 32,200 birds, would be unlikely to cause long term irreversible population impacts for this population. However, we acknowledge uncertainty associated with this modeling exercise and that this analysis is independent of assessments of actual gull mortality associated with this proposed project.

1. INTRODUCTION

The South Farallon Islands, California harbor the world's largest known colony of Western Gulls (*Larus occidentalis*) (Ainley and Boekelheide 1990). Proposed invasive house mouse eradication planning on the Farallon National Wildlife Refuge has identified Western Gulls as a species potentially at risk of non-target mortality, due to direct or indirect consumption of toxic rodenticide. While several mitigation measures are being considered to minimize any mortality, analysis of potential population level impacts on Farallon Western Gulls is needed for evaluating the potential impacts to this species from this proposed project. Our goals were to assess the future trajectory of this population, under varying environmental conditions, and to evaluate the long-term impacts of any potential increased mortality on a twenty-year time scale.

Scope of Study

To meet our goals, we conducted a population viability analysis (PVA) of the Western Gull population on the Farallon Islands to contrast scenarios with additional mortality and scenarios without additional mortality (Nur & Sydeman 1999). This study builds on data collection, compilation, previous demographic modeling, and analysis of demographic parameters of recent data for Farallon Western Gulls presented by Spear & Nur (1994), Nur et al. (1994), Pyle et al. (1997), and Lee (2011). The demographic modeling presented here relies on detailed observations and statistical analysis of the Farallon breeding population, covering the period 1986 to 2011, though the set of parameter values used focused on the latter half of the time series, because that time period is most relevant for this assessment.

An important strength of Population Viability Analysis is that it incorporates stochasticity, the unpredictable variation in demographic parameters that reflects underlying environmental variability (Burgman et al. 1993, Beissinger 2002). This allows for a probabilistic assessment of future populations and evaluation of actions that may reduce or increase risk (Nur & Sydeman 1999, Akçakaya et al. 2004).

Using information on the Western Gull population and how it may be impacted by additional mortality resulting from proposed eradication efforts, we develop projections

for the future using a time-frame of 20 years. We evaluate three scenarios that make different assumptions about future Western Gull productivity, likely a proxy for environmental conditions, and their impacts on the population dynamics of the Farallon population. For each scenario we contrast the "no additional mortality" scenario with a scenario of a specified level of mortality, the number of Western Gulls that may die, which we call *C*). One goal of the study is to determine the value of *C* such that mortality below this level cannot effectively be distinguished from no mortality 20 years into the future, given assumptions regarding unpredictable variability in environmental and demographic parameters.

The population model presented here assumes that immigration equals emigration. We do not assume a closed population, but rather that there is no "net immigration" (Nur & Sydeman 1999). The three different scenarios that we model all incorporate information on variation in demographic parameters observed during the recent time period (from 1999 to 2008 or 2009, depending on the parameter), and differ with respect to levels of reproductive success. Reproductive success in 2009, 2010, and 2011 was extremely low, less than 0.15 chicks fledged per pair in each of the three years. In the 23 years preceding, reproductive success had never been less than 0.30 chicks fledged per pair and was usually much higher. The cause of this near-failure in 2009-2011 has not been identified, but is likely linked to reduced food availability for this species, as a result of both marine and human influences, during the breeding season, as well as increased intra-specific predation on chicks, itself likely due to reduced food availability. Thus, the three scenarios evaluated are:

(1) Optimistic -"Near-failure" does not reoccur in the future. Reproductive success is variable but reflects observations made prior to 2009.

(2) Realistic - "Near-failure" occurs at the historic frequency of 3 times per 26 years in the period analyzed 1986-2011.

(3) Pessimistic - "Near-failure" occurs at the "recently observed frequency" of 3 times per 12 years.

It is possible that near-failure may occur at a frequency even higher than that recently observed, but we have not evaluated that possibility in this report. Our

"Pessimistic" scenario accounts for unprecedented rates of near breeding failure in our long term Western Gull time series.

For this exercise, we focus on modeling the Farallon population as observed during the recent time period, 1999 to 2011. We use population trend data for this period to derive a Leslie matrix population dynamic model that incorporates stochasticity (Nur & Sydeman 1999). We consider the recent time period to be most relevant for this exercise, as demographic data from the 1980's and early 1990's reflects a different population than exists at present – with the earlier part of the time series showing higher population numbers, lower recapture probability and survival, and higher reproductive success (Figures 1, 2, and 3). Therefore, we maintain that only the more recent demographic data are appropriate as a baseline for predicting future change, as the goal of this study is to assess impacts of a one-time mortality event on the current population in the near future.

Specific objectives addressed by this study are to:

(1) Evaluate future population dynamics based on demographic parameter values and observed population trend, assuming no additional mortality, but considering different scenarios for future environmental conditions. This component of the study quantified the median (expected) behavior of the population as well as the risk of more extreme results (upper quartile and lower quartile of population results) under three different productivity scenarios.

(2) Evaluate future population dynamics as in (1) but include impact of mortality of *C* gulls at the outset of the simulation. Part of this objective entailed determining the level of mortality (*C*) such that any mortality below this level, given the variability in parameters, cannot be effectively distinguished from the "no additional mortality" scenarios in this modeling exercise. For the purpose of this exercise, we considered the mortality scenarios to be effectively indistinguishable from each other if the overlap in terms of expected simulation results between one probability distribution and the other (i.e., with and without mortality) was at least 95%.

METHODS

Rationale of Our Approach

The basis of the PVA is a Leslie matrix whose values (i.e. elements) are allowed to fluctuate in relation to variation in the future environment (Nur & Sydeman 1999, Caswell 2001). Here we first briefly describe the demographic parameters being modeled: survival, reproductive success, and probability of breeding. Variation in demographic parameters with respect to age and environmental variability were simultaneously estimated.

vii) **Survival of adults.** Annual survival was determined through capture/recapture analysis of banded gulls from 1986-2011, with respect to age and year-specific variation.

viii) **Survival of juveniles and subadults.** This refers to annual survival of first-year, second-year, and third-year individuals. By the fourth year of life, evidence indicates that Western Gulls have reached adult levels of survival (Spear & Nur 1994, Pyle et al. 1997). Farallon Western Gulls generally disperse widely during the first one to three years of life (Spear & Nur 1994). Therefore it was not possible to derive accurate estimates of survival from capture/recapture using island-based observational data. Instead, we relied on empirical and statistical studies of age-specific survival of this population (Spear & Nur 1994, Pyle et al. 1997).

ix) **Reproductive Success** is the number of young reared to fledging per breeding pair per breeding season. We used data from 1986 to 2011from three plots on Southeast Farallon Island, called C,H, and K plots, used to monitor gull reproductive success. This estimate is conditional on an individual attempting to breed.

x) **Probability of Breeding** is a demographic component that reflects the likelihood that an individual that has survived to the beginning of the breeding season, attempts to breed in that season. This parameter potentially varies with the age of the individual. Almost all adults were resighted only when attempting to breed; for that reason, recapture probability is used as an estimate of breeding probability. Note that, in terms of the demographic model, we partitioned probability of breeding into two components: 1) the probability an individual is breeding for the first time and 2) probability that an individual that has previously bred, is currently attempting to breed (see Nur & Sydeman 1999). We used demographic parameter estimates for both probabilities based on the capture/recapture analyses of individuals previously banded as well as observations of age of first-time breeders (see also Pyle et al. 1997).

2.

We incorporate information on annual variation in these four demographic parameters based on observations made during the period 1986 to 2011, as described below, focusing on the most recent period, 1999 to 2011. An important feature of our study is that we calibrated the demographic parameter values used so that the model reproduced the observed population trend data during the recent time period, 1999 to 2011. We assume that all age classes are considered equally at risk to any mortality associated with the proposed project, due to extensive observations of Western Gulls utilizing supplementary food resources during recent field studies (PRBO unpublished data).

Population Trend Data

We used whole colony counts of Western Gulls on the South Farallon Islands at the time of peak incubation for the period 1999 to 2011 and estimated the annual constant rate of change by conducting linear regression on ln-transformed counts (Nur et al. 1999). Results were very similar whether we considered the periods 1999 to 2011, 2000 to 2011, or 2001 to 2011. The observed trend over 1999 to 2011 was a modest growth of 0.74% per year (Figure 1). Therefore, our population model was calibrated to reproduce this growth rate.

Estimation of Demographic Parameters in Relation to Annual Variation in Survival, Recapture Probability, and Reproductive Success:

Annual survival (symbolized phi) and recapture probability (symbolized p) were estimated over the period 1986 to 2009, for both males and females (Figure 2). It was not possible to estimate year-specific survival beyond 2009 while simultaneously estimating year-specific recapture probability due to limitations of capture-recapture analysis (Cooch et al. 1996). For the initial parameter values in the population model we used mean survival estimates, averaged across the two sexes, based on the most recent 10 years, 1998/1999 to 2008/2009. We also assessed variation in survival and reproductive success across the entire time series (1986 to 2009), but found that the magnitude of annual variation differed between the two time series. The between year standard deviation (SD) was much greater for the 1986-2009 time series, specifically 15% greater for survival and 31 % greater for reproductive success. The between-year SD includes not only variation in underlying demographic parameters among years, but also variation due to sampling error (Gould & Nichols 1998). Recognizing that, we chose to use the smaller of the two between-year estimates of variance (1998/1999 – 2008/2009 time period) for modeling survival and reproductive success. By using the smaller estimate from the recent 10-year period rather than the 24-year period, we were reducing the effect of over-estimation of process variance due to inclusion of sampling error.

The between year SD in adult survival was determined from the year-specific analyses (above). For juvenile and subadult survival, we scaled the between year SD relative to that of adults, given that survival is a binomially distributed random variable and its variance = phi (1-phi) (Mood et al. 1974). That is, the closer survival is to 0.50, the greater is its variance. See Table 1 for SD values used.

Reproductive success (RS; the number of fledged young per breeding pair) was determined each year for our 3 study plots and then averaged across plots and years to determine a mean RS for the period from 1999 to 2008 (Figure 3). The poor reproductive success observed in 2009 to 2011 was modeled separately (see below).

We also quantified the mean annual capture probability (p), which we use as a measure of breeding probability for individuals that have bred before, and the between

year variation observed for this parameter. Here, capture probability, refers to the probability that an individual that has bred before breeds in a given year. This assumes that resight probability, probability an individual is resighted and identified given that it is breeding in a given year, is effectively equal to 1. This assumption is justified because breeding birds are highly site tenacious, and once having bred, nearly all surviving individuals return each year to attempt reproduction (Pyle et al. 1991, 1997, Spear et al. 1987), Quantitative estimates of resight probability for breeding birds using program MARK =0.953 (see below). However, we must also consider the probability that an individual that has never bred before, breeds in a given year (Nur & Sydeman 1999). While we were not able to explicitly estimate this latter parameter on a year by year basis over the 24 year time series, we were able to estimate how this probability varies with age, and used that in the modeling.

The demographic model also required estimation of variance in “net fecundity” where net fecundity is defined as the product of RS * p *0.5. We calculated variance in net fecundity based on the product of these individual parameters (Mood et al. 1974), assuming no covariance between RS and p. Thus, our estimate of variance in net fecundity is conservative because inclusion of positive covariance (likely the case: in “good” years both RS and p tend to be high and in “bad” years both tend to be low) would have increased the variance of net fecundity beyond what we were able to calculate. In general, we have attempted to be conservative with respect to variance estimation in order to avoid over-estimating annual variance. Over-estimating annual variance would have resulted in over-estimating the mortality level *C* that the Western Gull population could tolerate with no detectable long-term effects.

Poor Reproductive Success in Recent Years

An important feature of the Farallon Western Gull population for the purposes of this modeling is that there was unusually low reproductive success observed in the last three years of the data set (2009 to 2011). From 1986 to 2008, annual reproductive success ranged from 0.30 to 1.55 fledged young per pair (Figure 3). However in the most recent three years, an average of only 0.06 to 0.13 fledged young were produced per pair. Comparing 2009-2011 to the 10 years previous to that (1999 to 2008), indicated a reduction of 86.2% in mean reproductive success (Figure 3). We believe

that this recent "near-failure" could significantly impact population modeling results if it were to continue over the coming years or repeat at some time in the future. Therefore, to model reproductive success we used the mean value over the recent period (1999 to 2008), with between-year variability for the same period (1999 to 2008, excluding 2009-2011). To this we then added the probability of near-failure in reproduction occurring at three different probability levels, one for each scenario.

Age-specific Estimation of Parameters for the Population Matrix

Survival and Fecundity

Survival by age was estimated using the program MARK (Cooch and White 2012) for individuals banded as chicks and subsequently captured or identified at the South Farallon Islands. Age-specific estimates were then incorporated into the model as appropriate. For adults, age 4 and older, annual survival showed no clear pattern with respect to age, for either males or females (Lee 2011). Therefore the model assumed that all adults had the same survival value (see Table 1). Survival prior to age 4 could not be estimated from these capture-recapture analyses since a very small number of marked subadult gulls have been identified at the colony before breeding. Therefore, to estimate juvenile and subadult survival, we relied on prior analyses based on intensive field observations and statistical analysis by Spear & Nur (1994) and Pyle et al. (1997). We used mean values for males and females, for all ages, prior to calibration for the initial survival values in the model (Table 1).

The first component of fecundity, age-specific reproductive success (RS), was directly estimated from females of known-age (Lee 2011). We assumed that patterns for males were similar to that of females (Pyle et al. 1997). RS appeared to differ with respect to age. RS increases with age up to age 7, then is fairly level through age 16, and then declines subsequently. On the basis of age by age estimates, we developed a simplified table, categorizing adults into four groups: Young adults (ages 4-5 yrs), transitional adults (age 6), prime-age adults (ages 7 to 16 yrs), and old adults (ages 17 and older) (Table 1).

Capture or resighting probability (p) was used to estimate breeding probability. Age-specific estimates were obtained as part of the survival modeling described above (see Lee 2011). Results indicated that p differed little with age for either sex and remained high throughout life (mean = 0.953 averaging across the two sexes; Lee 2011). Therefore we assumed that once an individual bred it did so with probability of 0.953 (see Table 1).

Age-specific breeding probability includes a second component, the probability an individual breeds for the first time. Capture-recapture analyses provided estimates of the transition from pre-breeder (never having bred before) to breeder (Lee 2011). The model assumed the earliest age of breeding is 4 years, with probability of breeding at age 4 being 19% (mean value for males and females). For 5 year olds, 52% attempt to breed, composed of individuals that bred the year before (as 4 year olds; 19%, see above) and an additional 33% that are breeding for the first time as 5-year olds. Similar calculations apply to age 6, at which age 81% are attempting to breed. By age 7, we assume that individuals reach the full-adult value of 95.3% breeding probability. Age-specific breeding probability is summarized in Table 1.

Post-breeding Census and Density Dependence

The Leslie matrix population model can be implemented with respect to either a pre-breeding or post-breeding census (Caswell 2001, Akçakaya 2005). We chose the latter, primarily because it splits first-year survival into its own row, which can easily be manipulated. As a result, the youngest age class in the simulations refers to individuals who have just fledged (juveniles). There is no evidence that survival or reproductive rates vary in relation to population size or density for this population (Nur and Sydeman 2003, unpublished). Therefore we assumed population parameters to be independent of density (Nur & Sydeman 1999) .

Calibration

Estimates of survival, whether of sub-adults or adults, will underestimate true survival due to permanent emigration of individuals from the study area (Clobert and Lebreton 1991). Such emigration could be from one part of the island to another, or off

of the island altogether. The dispersal can be of pre-breeders or of individuals that have already bred. We acknowledge the occurrence of permanent emigration from the study area, but assume (in the absence of other information) that emigration equals immigration. In other words, individuals that leave the study area never to return are replaced by individuals moving into the study area. Given immigration/emigration, it is important to attempt to obtain an unbiased estimate of survival. Failure to do so would result in under-estimating true survival rates.

To allow us to correct for this under-estimation, we calibrated the performance of the population model such that the set of demographic parameter values used produced a population whose median trajectory corresponded to the observed population behavior. From 1999 to 2011, the breeding population demonstrated an average (time-constant) increase of 0.74% per year (Figure 1). To replicate these conditions, we were required to increase survival by a small amount. For first-year survival, we increased the value from 0.582 to 0.610, but note that female survival was estimated by Spear & Nur (1994) at 0.61, so this simply means using the higher of the two sex-specific values, an adjustment needed to allow for some emigration at a relatively low rate. For second-year survival, we increased the value from 0.794 to 0.810, but note that female survival was estimated by Spear & Nur (1994) at 0.81, so this, too, means simply using the higher of the two sex-specific values to allow for some emigration. For third-year survival, we increased the value from 0.854 to 0.875, but note that female survival was estimated by Spear & Nur (1994) at 0.89, so this reflects a value that is in between the male and female estimates but slightly closer to the female value. For survival in the fourth-year of life, we assumed the same value as adults (Pyle et al. 1997). For all individuals four years old and older, we adjusted calculated survival from 0.885, the mean value for males and females, to 0.890, a very slight adjustment to allow for some emigration. Note that extensive evidence for gulls in general and for this population specifically indicates that adult dispersal is less than that of juveniles and subadults, consistent with a smaller adjustment (Nur & Sydeman 1999). To reiterate, the population model allows for some emigration but assumes that emigration equals immigration. We could not verify this assumption directly, but given the general absence of quantitative estimates of emigration rates for seabirds, this was the approach we took. We did not adjust fecundity values. All the simulations used the

survival values adjusted through this calibration process. Survival and fecundity values used in the simulations, once the model was calibrated, are listed in Table 1.

Details of the Stochastic Modeling

The stochastic population modeling was carried out with RAMAS GIS version 5 (Akçakaya 2005). The primary outcome variable of the modeling was the number of individuals in each age class of the population in each year of the simulation, as a function of environmental variability and starting population size. The simulations depict results in which the demographic parameter values for survival and fecundity in a given year in a given simulation are randomly chosen from a distribution whose mean and variance were determined as described above.

In these analyses, we present results for a hypothetical 20-year simulation using the best data appropriate to the present state of the Farallon Western Gull population. Projections beyond 20 years would be excessively uncertain. In the output, years since the beginning of the simulation are shown as year 0, 1, 2, etc., up to 20.

Starting Population Size, Mortality Scenarios, and Simulations

The starting total population size for the simulations is 32,200 individuals of all age classes, in the absence of any additional mortality. This corresponds to a breeding population size of 17,400 individuals, the best recent estimate, from 2011 (Warzybok and Bradley 2011), assuming a stable age structure as determined by the Leslie matrix (Caswell 2001), and assuming average breeding probability. In other words, our results indicate that given the calibrated demographic parameter values used and a breeding population size of 17,400 individuals, there are on average an additional 14,800 sub-adults and non-breeding adults. Note that the 3-year average for 2009-2011 is 17,100 breeding individuals, within 1.6% of the 2011-only value. Therefore, our results are robust to whether we use the most recent year (2011) or the 3-year average.

In scenarios with mortality, the starting population size in year 0 was 32,200 – *C* gulls, where *C* was determined to be 1700 gulls (see Results and Figure 7). For these scenarios, we assumed that *C* gulls were removed in proportion to the age distribution of the total population, as there are no data to suggest otherwise. In other words, 5.3% (=1700/32200) of all age classes were removed at the start of the simulation.

3. This value of *C* was determined from an assessment of whether the set of outcomes under a "no-additional-mortality" scenario, henceforth "no mortality", is different from the set of outcomes under an "additional mortality" scenario – under the "realistic" scenario productivity values, as described above. We did this by assessing overlap of the modeled distributions for 20 years in the future. We defined two probability distributions to be different if the overlap of one with the other was less than 95%. In other words, if the no-mortality distribution overlapped the additional mortality distribution by 95% or more, we considered the two distributions to be effectively indistinguishable even though statistically they may be distinguishable (e.g., their medians may be statistically different).

4. To operationalize this definition we first identified the median of the no mortality distribution, call this m_{no}. For example, this value might be 29,400. By definition, 50% of all outcomes were below this value, m_{no} = 29,400. We then analyzed the distribution of outcomes under the same conditions except that *C* gulls were removed at the outset. We then identified the value of *C* such that, with *C* gulls removed, the distribution of outcomes had been shifted by 5%, i.e., 55% of outcomes were now below the original median. A displacement in the distribution of 5%, from 50% below m_{no} to 55% of outcomes below m_{no}, is equivalent to an overlap of 95% between two distributions, *assuming the two distributions differ only in their location and they have the same shape and spread*. Note that a displacement of 0% means an overlap of 100%, whereas a displacement of 50% entails an overlap of 50%. In the latter case, 100% of the new distribution lies below m_{no} which in turn corresponds to the value below which 50% of the original distribution lies, i.e., the overlap is 50%: 50% of the original distribution lies above the maximum value observed for the new distribution.

5. To be clear, the value of *C* used in these modeling exercises was determined as the maximum level of mortality that produced ecologically indistinguishable differences in scenarios, defined here as 95% overlap, in the probability distributions of Western Gull population size 20 years in the future. This included scenarios with and without mortality, under "Realistic" productivity conditions, given our estimates of the total Farallon population. This level of mortality is completely independent of any assessment of acceptable level of mortality by any partners of the proposed mouse eradication project, or predicted mortality based on gull attendance

during any proposed eradication action, exposure to toxic rodenticide, or toxicity of rodenticide.

All scenarios depict results based on 10,000 simulations, the maximum for the RAMAS program. For the calculations of overlap of distributions we used 30,000 simulations, combining results of three different runs of 10,000 simulations each. The simulations consider the 3 scenarios of Western Gull productivity: “Optimistic”, “Realistic”, and “Pessimistic” and 2 levels of mortality (i.e., no mortality or removal of *C* gulls).

RESULTS

Results of the population viability analyses are summarized in Figures 4, 5, and 6, corresponding to “Optimistic”, “Realistic”, and “Pessimistic” scenarios. For each scenario we depict results with either no additional mortality (starting population size is 32,200 individuals) or with removal of *C* gulls at the outset. By simulating results with different mortality levels, we determined that removal of 1700 gulls results in a shifting of the distribution by 5% and thus represents 95% overlap between the no mortality and removal of *C* gulls options on a 20 year time horizon. This is the case assuming “Realistic” environmental conditions where “near-failure” occurs at historic frequency (p = 0.1153 per year). The overlap in the two distributions under the “Realistic” scenario, with and without additional mortality, is depicted graphically in Figure 7.

Figure 4 depicts results under the “Optimistic,” no near-failure scenario. In the absence of additional mortality, the population is expected to grow by 10.6% after 20 years, to 35,600 individuals, using the median result of the modeling. However, there is a 25% probability of a decline of 14% or more after 20 years, and a 25% probability that the total increase will be 40% or more after 20 years. If the population incurs mortality in year 0, after 20 years it is expected to be at median value of 33,500, an increase of 4.0% compared to the pre-mortality population size of 32,200. Under the same set of assumptions, there is a 25% probability that there will be 26,100 individuals or fewer, which represents a population decline of 18.9% or greater compared to the pre-mortality population size. Thus, under this scenario, but not the other two, the population will

have likely increased after 20 years, even with additional mortality. However, as in the other scenarios, there is also a substantial probability that the population will be at lower levels than it was prior to the mortality event in year 0.

Figure 5 depicts results under the scenario under “Realistic” conditions, of near-failure occurring at the historic frequency of 3 times per 26 years. In the absence of additional mortality, the population is expected to decline by 8.7% after 20 years, to a median outcome of 29,400 individuals. However there is a 25% probability of a decline of 29% or more after 20 years, and a 25% probability that the total increase will be 32% or more after 20 years. If the population incurs mortality in year 0, after 20 years it is expected (median value) to be at 28,100, a decline of 12.7% compared to the pre-mortality population size of 32,200. Under the same set of assumptions, there is a 25% probability that there will be 21,500 individuals or fewer, which represents a population decline of 33.2% or greater compared to the pre-mortality population size. That said, there is also a 25% probability that after 20 years, under this scenario, the population will have grown to 36,500 or more individuals, a 13.4% or greater increase compared to the pre-mortality size of 32,200, even though the population sustains a loss of 1700 gulls.

If near-failure occurs at the recent frequency of 3 times per 12 years, under the “Pessimistic” scenario, then we can expect population declines, at least by year 20 (Figure 6). In the absence of additional mortality, the population is expected to decline by 27% after 20 years, to a median outcome of 23,500 individuals. In addition, there is a 25% probability of a decline of 45% or more after 20 years, and a 25% probability that the decrease after 20 years will be 3.7% or less. In fact, under this scenario, and with no additional mortality, the probability of a net population increase of any magnitude after 20 years is 22%. If the population incurs additional mortality in year 0, after 20 years it is expected to be at a median value of 22,200, a decline of 31.1% compared to the pre-mortality population size of 32,200. Under the same set of assumptions, there is a 25% probability that there will be 17,900 individuals or fewer, which represents a population decline of 44.4% or greater compared to the pre-mortality population size. That said, there is also a 25% probability that after 20 years, under this scenario, the population will have not declined or declined to 29,300 or more individuals; that is, the net decrease compared to the pre-mortality size of 32,200 is a decline of 9.0% or even

less of a decline. Under this scenario, a loss of 1700 gulls would likely leave the population at a lower level than at the outset, prior to incurring additional mortality, with only the magnitude of the decline to be established.

CONCLUSIONS

Our modeling effort indicates that, under “no-additional-mortality” scenarios, the Farallon Western Gull population will increase over the next twenty years with “Optimistic” productivity estimates, but will decline with assumption of “Realistic” productivity, and likely decline 3 times faster if incidence of recent near breeding failures were to occur with probability of 25% per year.

In assessing mortality scenarios, we determined the level of mortality that produced 95% overlap in the probability distributions of Western Gull population size 20 years in the future, for scenarios with and without mortality, under “Realistic” productivity conditions, given our estimates of the total Farallon population. This value was 1,700 gulls, assuming a total starting Farallon population of 32,200 birds. These results are independent of any assessment of actual risk to this Western Gull population from rodenticide exposure. We fully support all efforts to mitigate and minimize any mortality associated with any proposed actions.

If the Western Gull population incurs a one-time loss of 1,700 individuals, this could have a detectable effect on the population dynamics compared to no such additional mortality. For example, an expected 8.7% decline after 20 years could become, instead, after the one-time mortality event, a 12.7% net decline under the “Realistic” productivity scenario (Figure 5). Nevertheless, our results indicate that environmental variability due to “normal” variation in demographic parameters as well as the incidence of “near-failures” of reproductive success will have much greater impact than the effects of a mortality event such as loss of 1,700 gulls. Furthermore, the ability of the population to recover from the loss of 1,700 individuals will very much depend on the incidence of reproductive failures in the future, unrelated to the mouse eradication project; such reproductive failures are difficult to forecast.

Our analysis to assess the population viability of Farallon Western Gulls has been conducted using the best available demographic data for this species, in the population of interest, accounting for strong stochastic variability in parameters over a multi decadal time scale. This information should be strongly considered in assessments of population level impacts to this species for any future management actions.

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Table 1. Summary of compiled demographic parameters for Western Gull in relation to Age. Calibrated Survival and Net Fecundity values (and Standard Deviation) were used in the Population Dynamic Model Matrix. Excluding "Near-Failure" Years of 2009-2011. Data compiled from: Lee (2011), Spear & Nur (1995), Nur et al. (1994) and Pyle et al. (1997)

Age	Repro Success	Breeding Probability	Adult Survival	Calibrated Survival	SD	Net Fecundity	SD
1	0	0	0.582	0.610	0.060	0	0
2	0	0	0.794	0.810	0.049	0	0
3	0	0	0.854	0.875	0.041	0	0
4	0.436	0.191	0.885	0.890	0.039	0.0367	0.014
5	0.436	0.524	0.885	0.890	0.039	0.101	0.039
6	0.649	0.810	0.885	0.890	0.039	0.233	0.089
7	0.882	0.953	0.885	0.890	0.039	0.372	0.143
8	0.882	0.953	0.885	0.890	0.039	0.372	0.143
9	0.882	0.953	0.885	0.890	0.039	0.372	0.143
10	0.882	0.953	0.885	0.890	0.039	0.372	0.143
11	0.882	0.953	0.885	0.890	0.039	0.372	0.143
12	0.882	0.953	0.885	0.890	0.039	0.372	0.143
13	0.882	0.953	0.885	0.890	0.039	0.372	0.143
14	0.882	0.953	0.885	0.890	0.039	0.372	0.143
15	0.882	0.953	0.885	0.890	0.039	0.372	0.143
16	0.882	0.953	0.885	0.890	0.039	0.372	0.143
17	0.718	0.953	0.885	0.890	0.039	0.303	0.116
18	0.718	0.953	0.885	0.890	0.039	0.303	0.116
19	0.718	0.953	0.885	0.890	0.039	0.303	0.116
20	0.718	0.953	0.885	0.890	0.039	0.303	0.116
21	0.535	0.953	0.885	0.890	0.039	0.226	0.087

Figure 1. Western Gull breeding population trends for the South Farallon Islands, 1986-2011.

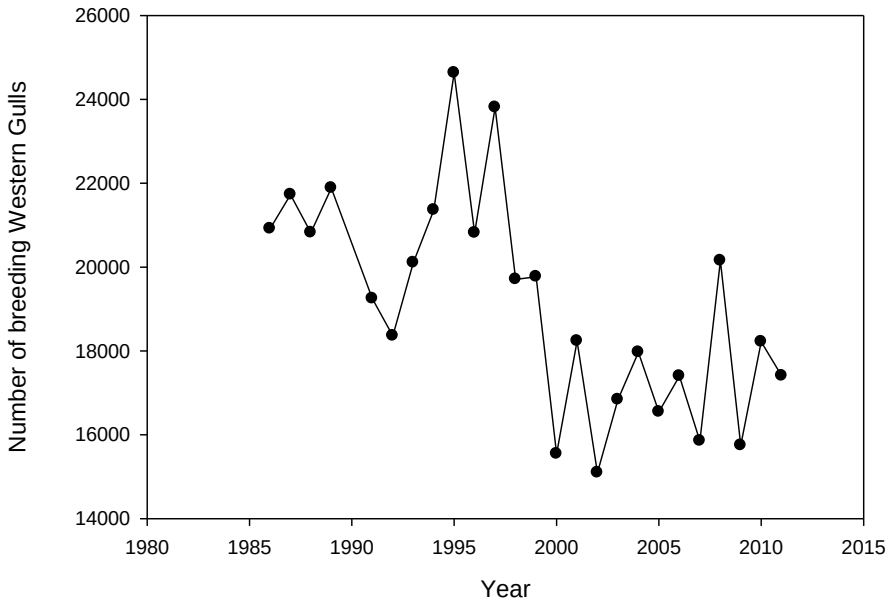


Figure 2. Annual variation in recapture probability and survival (± SE) for Farallon Western Gulls from long term study plots, 1986 to 2009 for both females and males. Missing vales for female recapture probability could not be estimated in program Mark.

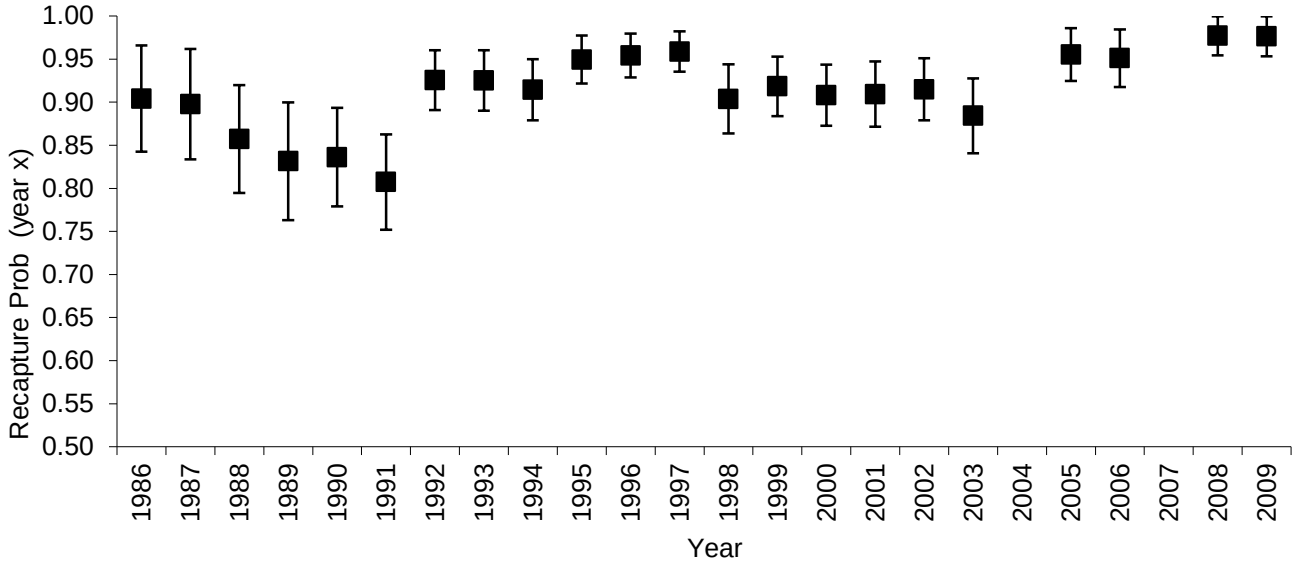


Figure 2a. Female recapture probability

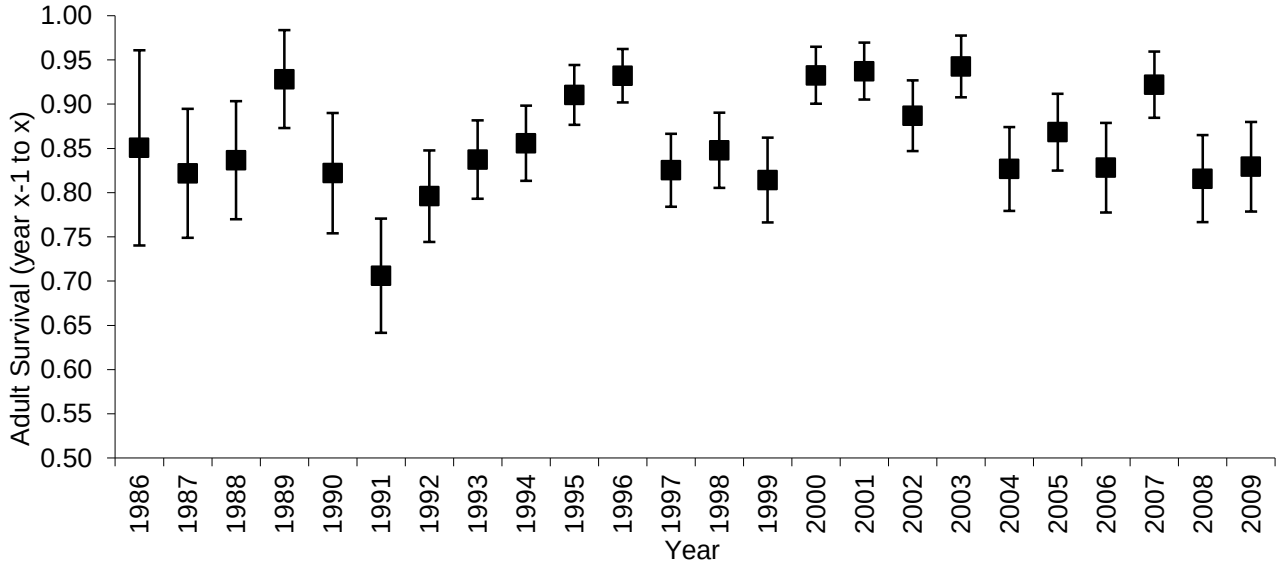


Figure 2b. Female Survival

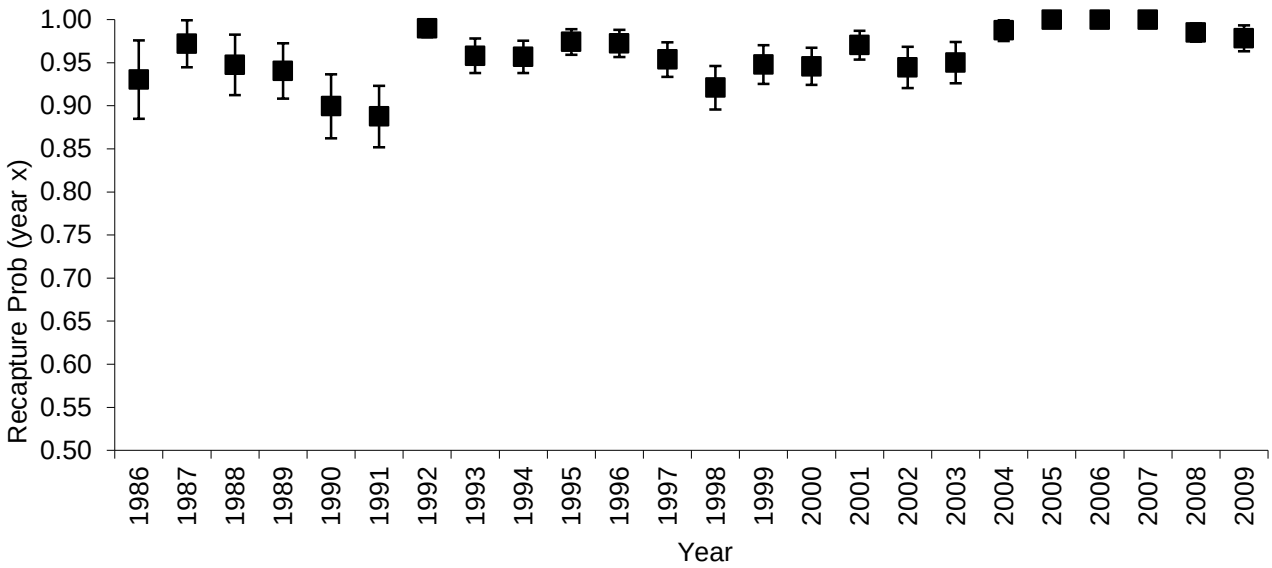


Figure 2c. Male recapture probability

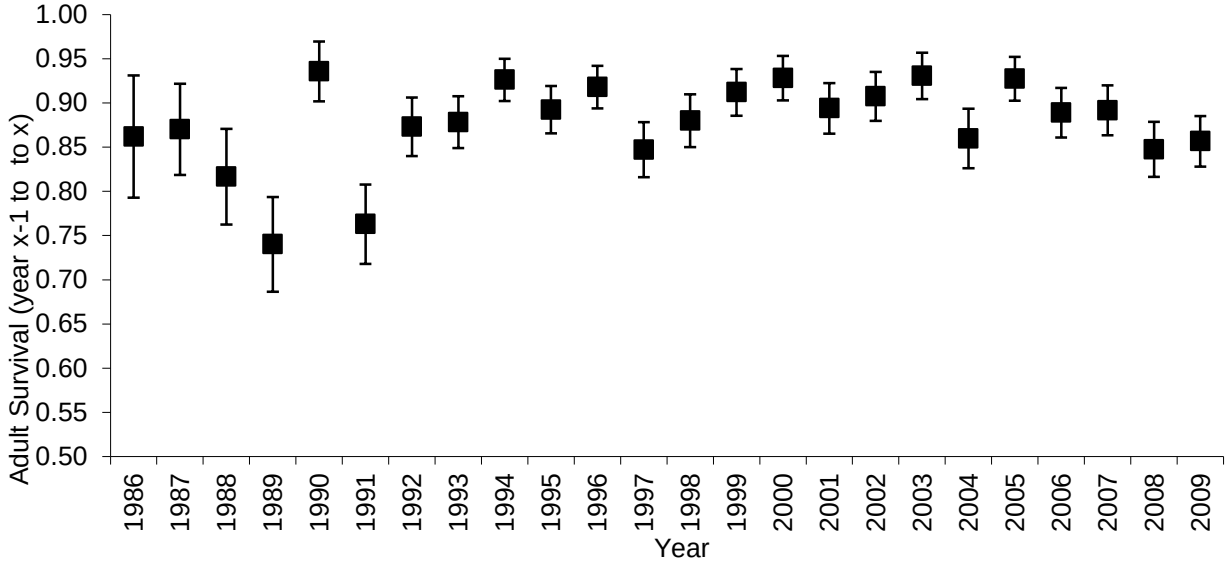


Figure 2d. Male survival

Figure 3. Annual estimates (± SE) for mean number of chicks fledged per female Western Gull breeding in C, H, and K plots combined on Southeast Farallon Island, California 1983-2011.

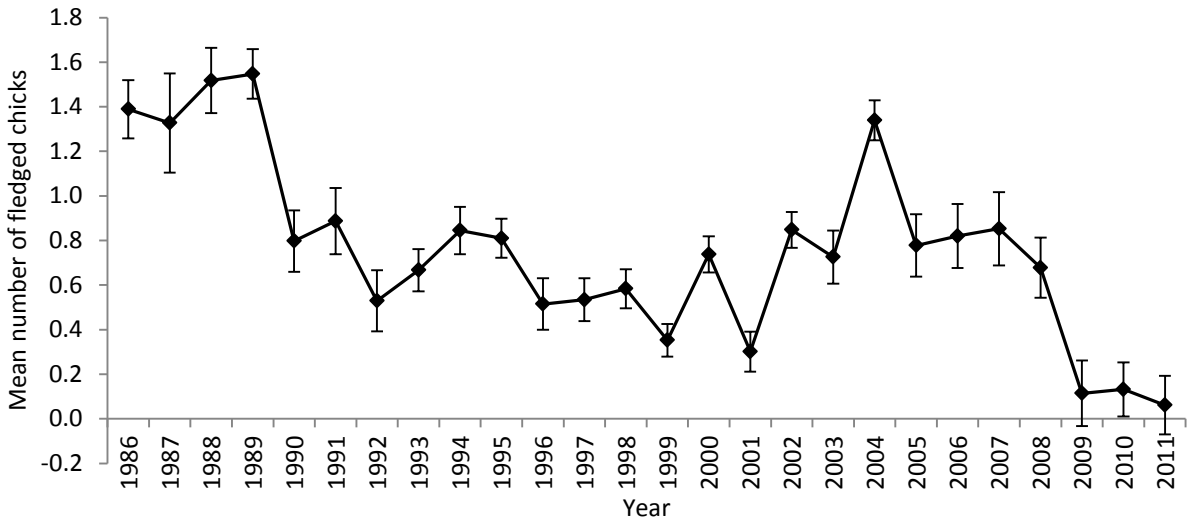


Figure 4. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Optimistic" conditions (no re-occurrence of near-failure years), with (red) and without (black) eradication-associated mortality. Shown are the 25th percentile, 50th percentile (solid regression line and circles), and 75th percentile outcomes. Mortality scenario removes 1700 birds in year 0. Assumes a starting population of 32,200 birds.

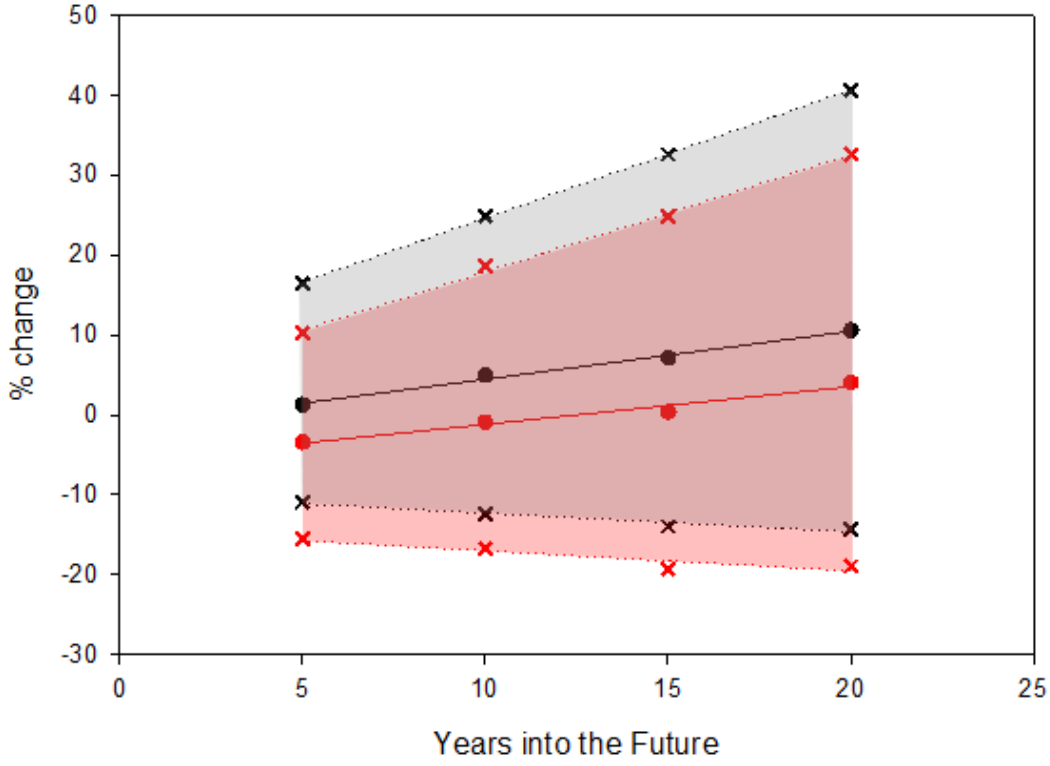


Figure 5. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Realistic" conditions (re-occurrence of near-failure years at historic frequency of, on average, 3 times per 26 years), with (red) and without eradication-associated mortality (black). Shown are the 25th percentile, 50th percentile (solid regression line and circles), and 75th percentile outcomes. Mortality scenario removes 1700 birds in year 0. Assumes a starting population of 32,200 birds.

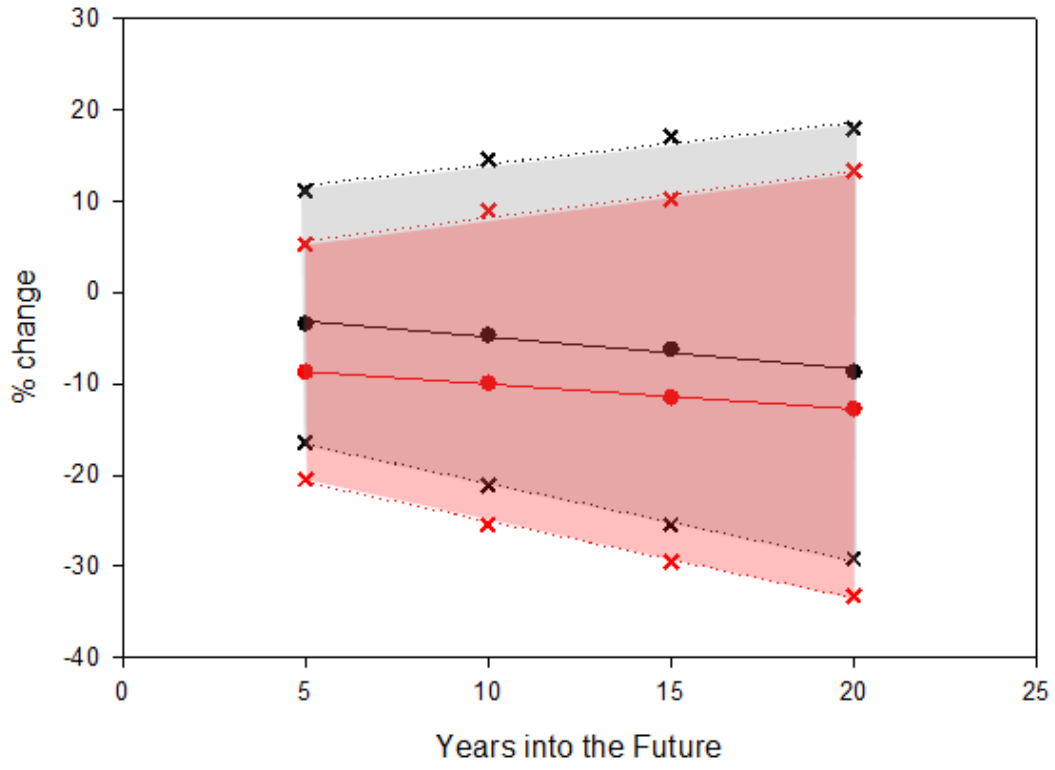


Figure 6. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Pessimistic" conditions: re-occurrence of near-failure years at recent frequency (on average, 3 times per 12 years), with (red) and without (black) eradication-associated mortality. Shown are the 25th percentile, 50th percentile (solid regression line and circles), and 75th percentile outcomes. Mortality scenario removes 1700 birds in year 0. Assumes a starting population of 32,200 birds.

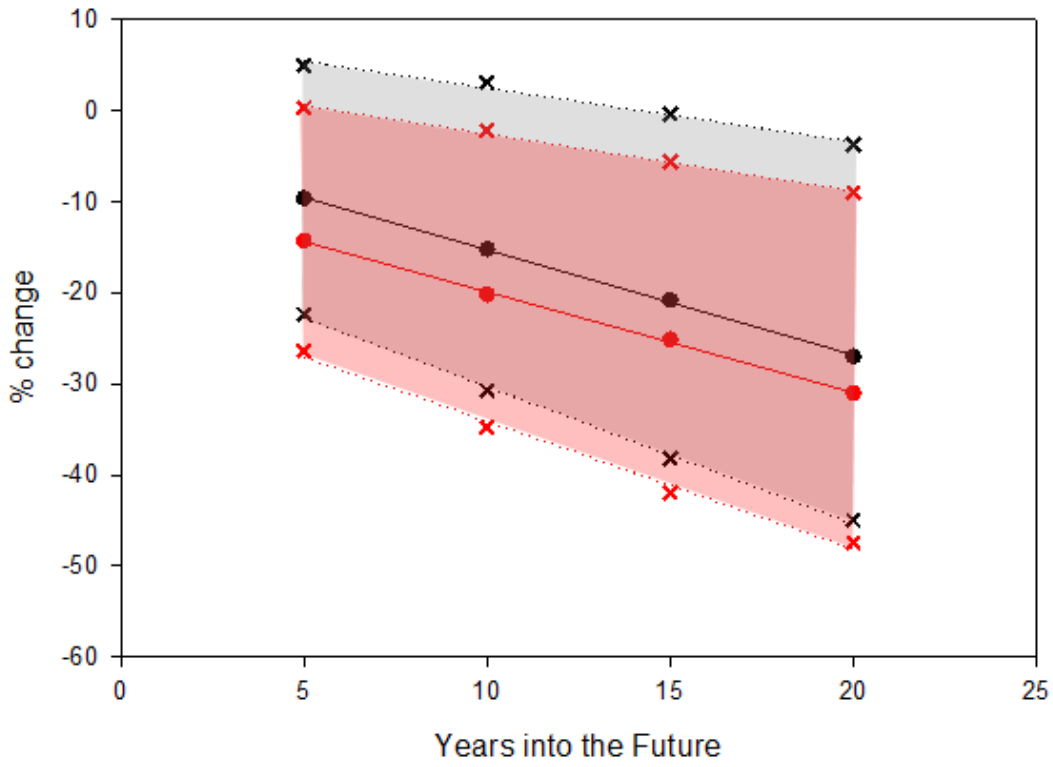
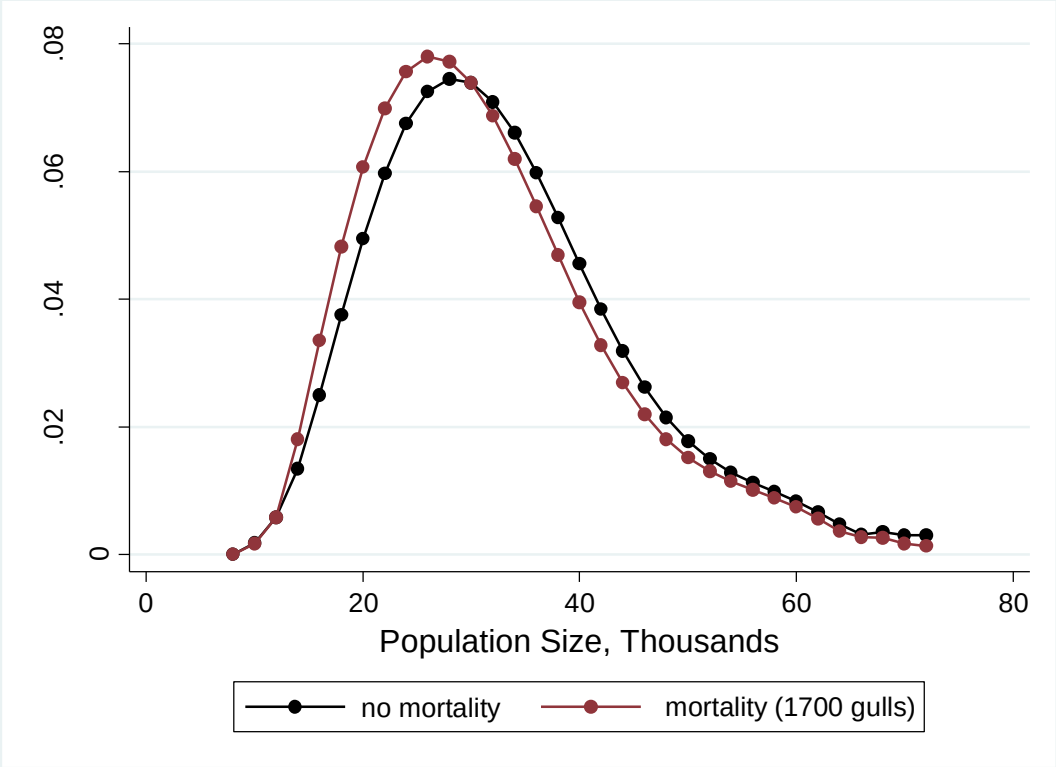


Figure 7. Probability distribution for "no mortality" and "mortality of 1700 gulls" scenarios, after 20 years, under "Realistic" Conditions: "historic" frequency of near-failure (results of 10,000 simulations for no mortality and 30,000 simulations for mortality of 1700 gulls). Note initial population size, with no mortality, is 32,200 individuals. Results binned into bins of 2,000 and then a polynomial (fourth-order) smoothing function was applied, except that the extreme tails are actual values. The two probability density functions overlap by approximately 95%.



8.14 Appendix O – 2011 Scoping Comments

House Mouse Eradication from the South Farallon Islands Project

U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex
Public scoping period: April 26th – June 10th, 2011
Public scoping meeting held May 12th, 2011; Attendees 20

Overall characterization:
We received 56 comments, and 2,709 signed WildCare petitions (497 included comments) against the project, 41 signed other petitions against the project.

Comments were received from the following groups and individuals:
U.S. EPA, California Dept. of Fish and Game, USDA – Wildlife Services, California State Water Resources Control Board, Poison Free Action Coalition, Keep Barn Owls In Berkeley, Golden Gate Audubon Society, American Bird Conservancy, Center for Biological Diversity, Institute for Bird Populations, Marin Humane Society, Marin Audubon Society, Project Coyote, Hungry Owl Project, WildCare, Stockton Buck, Joelle Buffa, Stephanie Strait, Patricia Blau, Randy Frank, Jonathan Van Bourg, Donna, Roseanne Manina, Emily M. Renzel, Grier Cooper, Michelle Rutledge, Billiejean Snyder, Jean Arnold, Ellen Nadeau, Irene Lopez, Patricia Herve, Mary-Ellen Burton, Diane Lynch, Randall Frank, Eleanor Lyman, Margaret Deedy, Laurel Bertoncini, Joanne Miller, Britt Clemm, Richard Poché, Richard Pavek, James Muller, Suzanna Anderson, David Senesac, Earle W. Cummings, Linda, Pat Cline, Leonard Blumin, Dan Silver, Jesse Irwin, Dudley Miller, Roger D. Harris, Mark Rauzon, William Sydeman, David Ainley, Brian Dempsey, Malcolm Coulter, Michael Ellis, Dotty E. LeMieux, Hans Peeters, Lisa Owens Viani, Ann L. Riley, Joe Eaton, Christopher Kroll.

1. 13 (23% or 2.4% including petitions) in full support of the listed alternatives
    - 3 organization(s)
    - 10 individuals
2. 9 (16% or 1.7% including petitions) in support of the listed alternatives w/ exceptions
    - 3 government agencies
    - 1 organization(s)
    - 4 individuals
3. 30 (54% or 5.6% including petitions) against the list of alternatives: rodenticide use
    - 2 organization(s)
    - 22 individuals
4. 4 (7% or 0.7% including petitions) against the list of alternatives: mouse eradication
    - 1 organization(s)
    - 3 individuals
5. 2,751 (92% including petitions only) against the list of alternatives: Brodifacoum-25 use
    - 1 organization(s)
    - 2,750 individuals

Common themes compiled from comments/petition	Frequency occurred
Reducing non-target impacts	9
Analyze more than one rodenticide	4
Justification for purpose and need	3
Analyze success/failures of previous island rodent eradications	7
Minimize rodenticide dispersion into marine environment	3
Translocation of burrowing owls	7
Does not support use of rodenticide	28
Supports the use of mechanical methods to control/eradicate mice	43
Does not support the use of "Brodifacoum-25 Conservation"	2,709

Substantive Comment Summaries

Note: Numbers correspond with stance on listed alternatives (listed above). Letters correspond with substantive comment categories: A- Purpose and Need, B- Alternatives, and C- Non-target Impacts; (ie.) 2 B,C is a comment that supports the alternatives with exception and commented on the alternatives and non-target impacts.

No.	Comment	Freq.	Category

1	EPA:
	• EPA would like to be a cooperating agency to provide early input on pre-project planning, impact assessment, and alternatives development
	• If IC will continue to work with FWS then FWS must prepare a disclosure statement stating that IC has no financial interest in the outcome of the project.
	• If IC or other contractors write the EIS, FWS must review and approve of the document.
	  o Purpose and Need:
	  ▪ Write a clear Purpose and Need statement
	  ▪ Provide a framework for a complete project description and alternatives
	  ▪ Write a detailed Biosecurity plan since prevention of reentry is a part of the stated Purpose and Need
	  ▪ Describe how mice got to the Farallones
	  o Alternatives:
	  ▪ Evaluate a reasonable range of alternatives
	  ▪ Include different rodenticides, different application rates, and combined methods. Also consider non-pesticide alternatives
	  ▪ Make the alternatives selection process transparent
	  ▪ Analyze the No Action Alternative – show how mice impact the islands
	  o Application Methods:
	  ▪ Consider topography, costs, and nontarget species
	  ▪ Consider bait stations independently or
		1	2 A,B,C

No.	Comment	Freq.	Category
	supplementally (determine home ranges of mice to determine spacing) ▪ Consider hand broadcast and bait station alternative ▪ Consider an aerial application for SEFI and hand bait other islands ▪ Considerations for rodenticides – palatability, appropriateness of toxicant for target population, potential for resistance, potential efficacy, and non-target impacts ▪ Don't limit pre-project studies to brodifacoum ▪ Weigh the risk of failure vs. risks to non-targets ▪ Don't consider rodenticides that include insecticides to avoid impact to camel crickets o Operational Planning and Monitoring: ▪ Include logistical planning in EIS including who will implement and organizational structure ▪ Write pre and post application monitoring and include an index of target and non-target species for abundance before and after ▪ Take genetic samples to determine if post eradication to determine if attempt failed or island was reinvaded. o Excess Bait and Carcass Disposal: ▪ Explain how excess bait will be disposed of later ▪ Develop a monitoring, collection, and disposal plan for dead animals ▪ Evaluate the impacts that could occur from carcass disposal ie) if buried o Cost: ▪ Include cost and funding of the project for factors that are relevant to decision making ▪ Conduct a cost-benefit analysis since eradication have failed due to funding and manpower o Impact Assessment: ▪ Identify all nontarget and target species impacts that will be on or near the island during eradication ▪ Acknowledge uncertain information that cannot be obtained due to cost • Provide a statement of incomplete information, a statement of relevance, and summary of existing credible scientific data ▪ Evaluate impacts of rodenticides on ASSP and the ability for the population to recover from such impacts ▪ Address owl hyperpredation better – provide <u>sufficient</u> documentation to support assumptions ▪ Analyze impacts from the No Action Alternative		

No.	Comment	Freq.	Category
	▪ Analyze impacts of a failed eradication attempt ▪ Objective 1.1 in the CCP is intended to reduce gulls on SEFI • How will this project help reach that goal ▪ Analyze impacts to marine mammals by using placebo baits o Threatened and Endangered Species: ▪ Discuss how FWS will meet ESA Section 7 obligations for stellar sea lions (brown pelican mentioned – delisted in 2009) ▪ Discuss any candidate species o Water Resources: ▪ Predict impacts to ground, surface, and coastal waters ▪ ID drinking water sources, potential impacts, and safety measures o Climate Change: ▪ Describe the effects of climate change on island and species, as well as cumulatively with other project impacts o Mitigation Measures: ▪ Identify and discuss any proposed mitigation measures ▪ State mitigation measures in terms of measurable performance standards or expected results to establish performance expectations ie) remove mouse and gull carcasses and unconsumed bait to reduce secondary poisoning o Cultural Impacts: ▪ Identify impacts to cultural resources o Recreational Impacts: ▪ Identify impacts to recreationalists (whale watching and fishing) ▪ Document any environmental justice issues		
2	<u>California DFG – Bay Delta Region:</u> • The DFG supports FWS's goal to eradicate house mice from the islands • The Draft should describe the background, purpose and need, and a range of alternatives with mitigation measures • Recommendations: o Discuss historic use by species and population trends of breeding seabirds that may be adversely impacted o Address impacts to mouse predators (birds of prey) to secondary effects o Purpose and Need – thorough description of mouse/owl/ASSP relationship ▪ Describe direct and indirect impacts to island species o Describe lessons learned from previous rodent eradication	1	2 A,B,C

No.	Comment	Freq.	Category
	projects ▪ Describe how this project will apply lessons learned and decrease impacts to non-targets ie) use of smaller pellets, dyed pellets, use of a deflector o Impacts analysis should describe the mechanism and mobilization of brodifacoum in soil, water, biota, and whether these attributes differ from previous projects (show the lessons learned) o Consider a reasonable range of alternatives ▪ 2 alternatives using one rodenticide and aerial application is not acceptable ▪ Consider a large group of alternatives and clearly describe why an alternative was dismissed from further consideration ▪ To the extent possible – consider non-pesticide alternatives		
3	<u>USDA – Wildlife Services:</u> • We believe that the eradication of invasive rodents on island has the potential for enormous conservation benefits, that the proposed use of brodifacoum may be warranted, and that it is a vital conservation tool for protecting native island habitats. • Eradication projects must be carefully planned to avoid unacceptable short or long-term negative impacts as these could put the use of this tool for future invasive management activities at risk. • We urge FWS to proceed cautiously and to engage fully in the NEPA planning, partnering, and document development processes to ensure that a full range of alternatives are considered and environmental impacts are identified. o Scoping: ▪ Utilize the expertise of a broad range of experts ▪ A proposal with only the most toxic remedies in its range of alternatives is unacceptable o Need for Action: ▪ Provide a detailed discussion of the need for the project and the need to implement at this time to help identify the environmental issues that should be evaluated. ▪ The use of the toxicant should be a last resort o Environmental Issues: ▪ How does the proposed action and alternatives meet the objective of eradicating mice with long term benefits to native species? ▪ Likely negative and positive non-target effects, water, and humans o Alternatives: ▪ Explore other action alternatives that minimize harmful environmental effects	1	2 A,B,C

No.	Comment	Freq.	Category
	▪ Bait stations in combination to increase precision of product delivery and reduce spillage ▪ The use of diphacinone may require evaluating a new formulation for mice would be warranted due to the high likelihood for significant adverse effects to BUOW and other raptors and gulls. ▪ Include detailed mitigation o Monitoring: ▪ Strong monitoring effort for eradication efficacy, ecosystem response, and ecological impacts should be integral of the eradication planning ▪ Monitoring must be adequately funded o Biosecurity: ▪ Provide a detailed biosecurity plan • If FWS is interested in having WS provide technical review, analysis, meeting time with staff, and travel expenses to help develop alternatives, analyze impacts, and provide detailed document review, we would ask for a written agreement specifying the expectations of the Service.		
4	<u>CA State Water Resources Control Board:</u> • FWS has their work cut out for them since this is a very controversial and challenging project • Use the Anacapa model for land/soil, intertidal, and water quality sampling. • We would like to see post-treatment intertidal water quality sampling at 3 different locations • We would like to see pre and post-treatment mussel sampling if Brodifacoum is used for the eradication at our mussel sampling site. • I came across an eradication method called 'death by constipation'. Could this be considered a safe alternative to rodenticide use? • The article by Howald et al on the Eradication of black rats from Anacapa is one of the best articles I have read on the topic.	1	2 B,C
5	Use lessons learned from other similar island rodent eradication projects. Consider timing of the project, type and quantity of poison, captive holding of sensitive species, and minimizing spread of poison into marine environment to minimize harm to non-target species.	1	1 B,C
6	Defer to USFWS and PRBO scientists expertise. Concerned with potential impacts to Burrowing Owls and other raptors. Suggest USFWS improve communications with the public.	1	1 B,C
7	Alternative B and C are unacceptable due to the potential significant impacts to non-targets, which have been reported for previous rat eradications (Rat and Anacapa Island). EIS needs to consider possibility of eradication failure, alternatives other than aerial bait broadcast, mouse control by use of snap traps, and owl relocation.	1	3 A,B,C
8	Does not support use of rodenticides and suggests leaving island uninhabited for a minimum of 30 years to restore ecological balance.	1	3 A,C

No.	Comment	Freq.	Category
9	Does not support use of rodenticide	3	3 A
10	Translocate burrowing owls to a faraway location, such as east of the Sierras, and trap mice to eradicate population.	1	2 B,C
11	Weigh long-term impacts more heavily than short-term, and similarly population level effects more than individuals. Consider using parallel overhead wires to exclude gulls from certain areas during rodenticide application.	1	1 B
12	Non-native mice alter the ecosystem by providing food for owls during fall, yet the vast majority die off in winter from starvation, causing the owls to often starve by early spring.	1	1
13	In addition to brodifacoum, other potential rodenticides need to be compared and analyzed for palatability, primary, and secondary toxicity. Concern about aerial broadcast of brodifacoum, the potential environmental contamination, and non-target risks, including the thousands of gulls inhabiting the island.	1	2 B,C
14	Non-toxic and environmentally sustainable alternatives are needed.	1	3 B,C
15	Die baits to colors that birds find objectionable. Conduct a pilot study to determine how many mice die above or below ground when consume bait.	1	2 C
16	Utilize raptors to hunt the mice instead of using rodenticide.	1	3 B
17	Educate the public on the success of previous eradication operations, potential non-target poisoning, and the adverse effects of mouse presence to the natural ecology of the island.	1	1
18	The islands will experience an explosion of vegetation once mice are removed, and this may negatively impact nesting habitat for storm-petrels. Mouse eradication should not occur unless a strong vegetative component is included.	1	2 B
19	Urge against rodenticide use because it is extremely inhuman and will have adverse impacts going up food chain	6	3
20	Great potential harm to raptor is too great. If alternatives require more money (from labor and traps), it is worthwhile.	1	3
21	Let evolution play its course and leave the island alone.	1	4 A
22	A rodenticide so toxic and harmful will not restore the ecosystem.	1	3
23	The potential harm to non-targets is great and the possibility of fully eradicating mice is low and the process would continue.	1	3
24	A better solution than poison must exist; there are not enough predators. Native vs. non-native is illogical thinking because habitats change. A perfect balance will not exist.	1	3 B
25	The public scoping meeting seemed pre-decisional. The logic of removing the mice from the ecosystem seems illogical. Will poisoning continue after mice are removed if plants become unbalanced?	1	3
26	The planned poisoning is unthinkable and should be unlawful. Is it possible to cut back the food source of the mice?	1	3
27	The secondary toxicity of brodifacoum is greater than other anti-coagulants, including a half-life of 180 days. The USFWS should follow the example of the USEPA, which is moving away from brodifacoum.	1	3 B

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28	Broadcasting brodifacoum will also poison raptors such as red-tailed hawks and also the Farallon arboreal salamander. Instead, remove burrowing owls and replace them with Northern harriers to control the mice problem in the spring and summer, and then remove them from the island in the fall. Great blue herons can also be introduced to consume mice.	1	3 B,C
29	The pesticide can have negative affects to trophic interactions associated with its use as well as its ability to enter the surrounding aquatic ecosystem. The implications of using this toxin are unclear.	1	3 C
20	The serious side-effects of this chemical need to be considered. The possibility of having more deaths to Ashy storm-petrels may be greater with the rodenticide approach than by the current rate of predation from burrowing owls. Trapping may be an alternative solution to reduce the mouse population and then if necessary, apply a less toxic chemical to eradicate them.	1	3 C
31	Trying to control the mouse population is like two wrongs do not make a right. Controlling one species may not simply solve the problem, it may create other problems.	1	4 A
32	Non-native species have been very destructive in the Galapagos and eradication programs have been successful without much detriment to other species. The Farallones has very important seabird colonies which are vital to the entire Eastern Pacific ecosystem. The mice are a direct threat to Ashy storm-petrels and they deserve our protection.	1	1 C
33	Every bio-control has a downside; the good achieved must be weighed with the potential harm. We have a chance to restore the island community and we must accept the short-term negative consequences in order to achieve the greatest long-term good.	1	1
34	I support removal of non-native mice from the South Farallon Islands.	4	1
35	Eradicating the introduced mice will be a big step in restoring the natural processes of the island ecosystem. The mice are contributing to the decline of the ashy storm-petrels and are likely factors in the native and non-native vegetation community, preferring some species over others.	1	1
36	I support the eradication program; the collateral mortality to gulls and other species is acceptable. There is no evidence of the impacts from brodifacoum to the pelagic ecosystem. There are no other methods to successfully eradicate house mice without extensive damage to fragile habitats.	1	1 B,C
37	A better solution is to put pellets into small cages only mice could fit into. Crabs may also fit but their numbers are inexhaustible.	1	3 B
38	Other less toxic rodenticides should be investigated besides brodifacoum	1	2 B,C
39	Use mechanical means to eradicate the mice (traps, predators, birth control) instead of toxins	29	3 B,C
40	I am alarmed by the proposal to saturate the Farallones with brodifacoum to eliminate house mice and thereby discourage burrowing owls from lingering. Rodenticide-poisoned rodents do not usually die	1	5 B,C

No.	Comment	Freq.	Category
	quickly making them easy targets for predators. I believe a much better solution would be to trap and relocate burrowing owls. Eliminating owls in a benign way would be preferable. The downstream consequences of applying brodifacoum ad lib are not to be underestimated.		
41	We urge FWS to reject the proposed aerial dumping of "Brodifacoum-25 Conservation" rodenticide on the Farallon Islands as a rodent mitigation measure (petitions)	2,750 (signatures)	5 B

<u>Summary of the Comments from the May 17,2011 Scoping Meeting</u>

Attendee Comments:

1. <u>Need For Action- Notes and Questions:</u>

- Mouse sterilization as an alternative to rodenticide. Any option over rodenticide.
- Partner with pesticide manufacturer's to create better/ safer products for eradications.
- Do the studies available confirm the need for this project?
- Make Scoping comments/ any activity from 2006 available to the public.
- Consider other toxicants in pre-project planning studies- can't just evaluate brodifacoum.

2. <u>Environmental Concerns- Notes and Questions:</u>

- Aerial application: What are the impacts to water/ocean impacts of rodenticide to fish, food web, and marine life?
- How long does rodenticide stay in target animal (persistence in animal/ environment)
- Believes there will be "collateral damage" and secondary uptake
- What if you do nothing?
- What about a less toxic poison?
- What are the safest measures to protect non-target species?
- What studies are you basing your decision on? Make available to the public online.
- Are you aware of failed BUOW translocation attempts? Why not just translocate the owls?
- What are the impacts of the mice on the islands plants
- What is the efficacy of traps?
- What are you doing to control invasive plants?
- What is the amount of rodenticide planned?
- Don't think you can get 100% eradication. Can we provide studies that show success?
- Any studies on rodenticide impacts on amphibians & inverts (provide studies)
- Analyze impacts to passerines
- Incorporate lessons learned from the Rat Island project
- What if we reduce the food source for the mice? Can we discourage the owls?
- What other factors are affecting ASSP (other than mice)? How can we reduce/ respond to these impacts?
- How to reduce impacts to gulls and raptors from secondary uptake?
- Where else do ASSP's breed?
- Include description, life history and threats to the ASSP's
- What are the impacts to the ASSP from WEGU's

3. <u>Removal Methods- Notes and Questions:</u>

- What would the duration of exposure to rodenticide be?
- Efforts to remove mice after exposure should be considered to avoid secondary exposure
- Considering hazing of scavengers/ predators to discourage consumption of mice that have been expose to the Rodenticide
- What is the Half Life of Brodifacoum? How long will it be present in the environment?
- Could something be built that would cause the mice to gather making them easier to collect? (i.e. Strychnine causes rodents to seek out water)
- Concerns about bioaccumulation of rodenticide and stability in environment. (Would like to see more documentation of the risk level of different compounds)
- What level of success can be guaranteed? (100 % eradication? And what % is considered acceptable?)
- Concerns about what the project will cost
- When would the rodenticide be applied? At peak of the population or at the seasonal low?
- Public safety issues to address: i.e. whale watching boats during the eradication