U.S. Fish & Wildlife Service

Farallon Islands National Wildlife Refuge

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

Photos Courtesy of Island Conservation

Final Environmental Impact Statement - Appendices

South Farallon Islands Invasive House Mouse Eradication Project

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

Prepared by:

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Project Feasibility and Non-Target Risk Trial Report

ISLAND CONSERVATION

Preventing Extinctions

Farallon Islands Restoration Project

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

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ISLAND CONSERVATION
Preventing Extinctions

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 or in any of the owl 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 (2011). 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 (a California Species of Special Concern), 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 1994, Ruscoe 2001).

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 along with a number of bird species as potential non-target species at risk from a mouse eradication (Howald et al. 2003). 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 these birds 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 1994, Baber et al. 2007). 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 an invertebrate and not considered to be at risk because invertebrates are not generally susceptible to anticoagulants (Brooke et al. 2011) because of their different physiology, 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 applying 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 2006), 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).

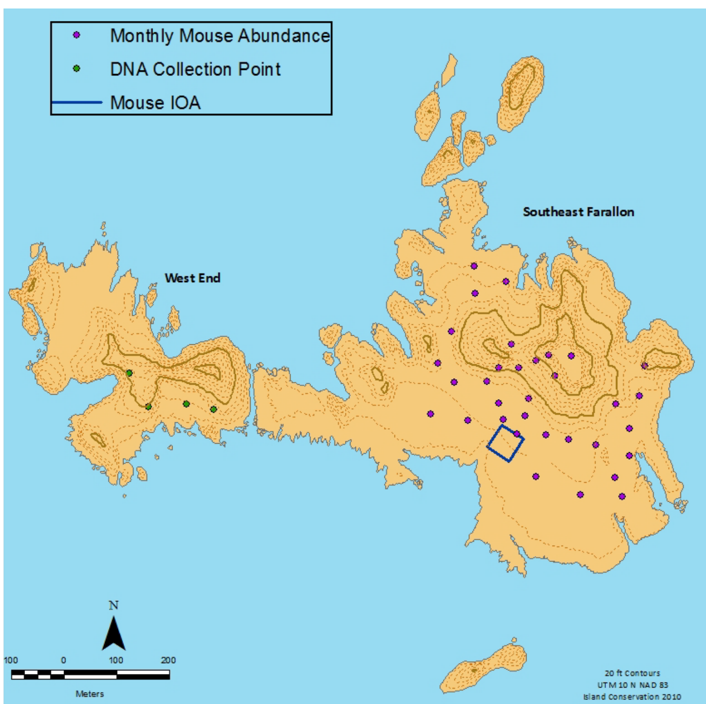

Fig. 1. Location of the Index of Abundance trapping grid and monthly mouse trapping locations.

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 2005). 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 (2003). 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 in autumn 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.

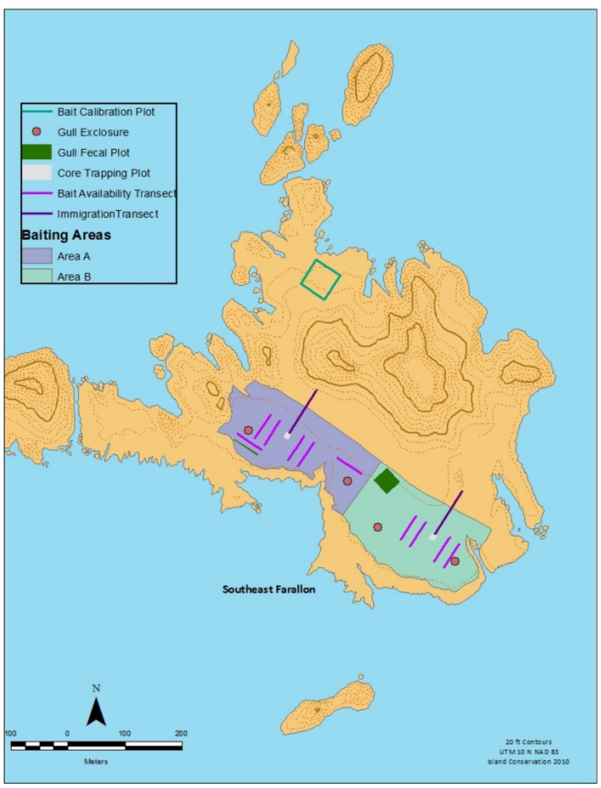

Fig. 2. A map of baited areas, availability transects, immigration transects, core trapping grids, gull fecal plots, and gull exclusion cages

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.

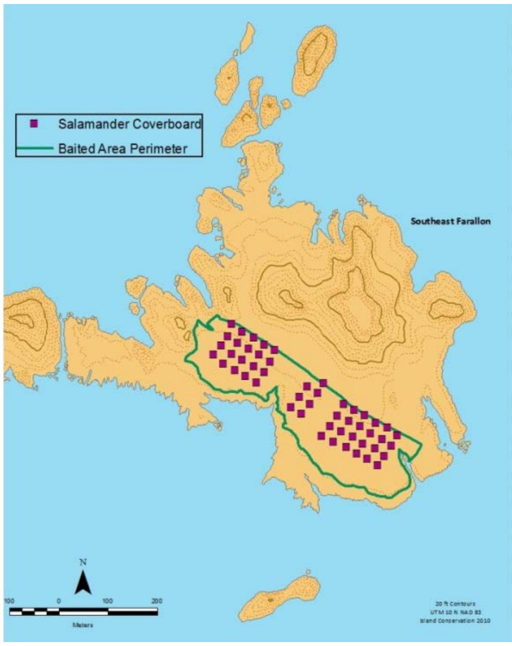

Fig. 3. Salamander cover board locations in relation to baited areas

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)

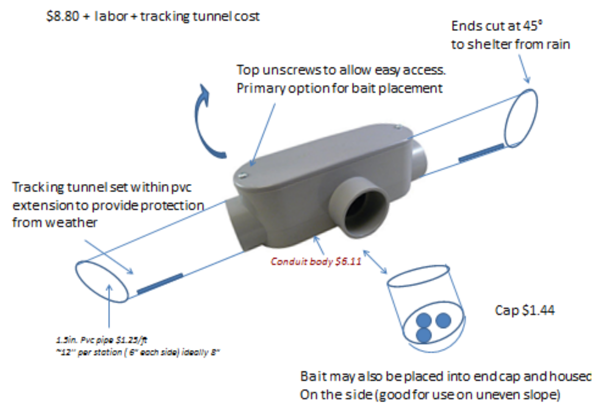

Fig. 5. Novel bait station (developed by Island Conservation)

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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 1984).

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 (0.4mg/kg (Dubock and Kaukeinen 1978)) 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 (Pott et al. 2015). 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 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.

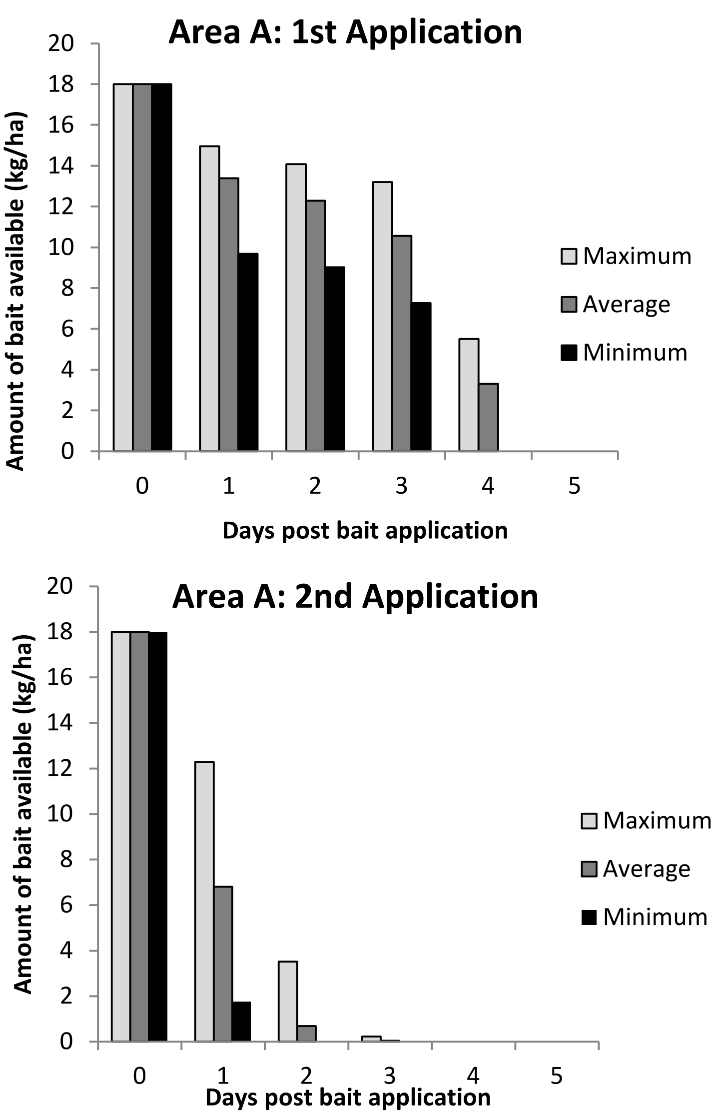

Fig. 6. Bait availability over time in Area A on SEFI following two applications of rodent bait (1g pellets) at 18kg/ha across a 3 ha trial area.

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.

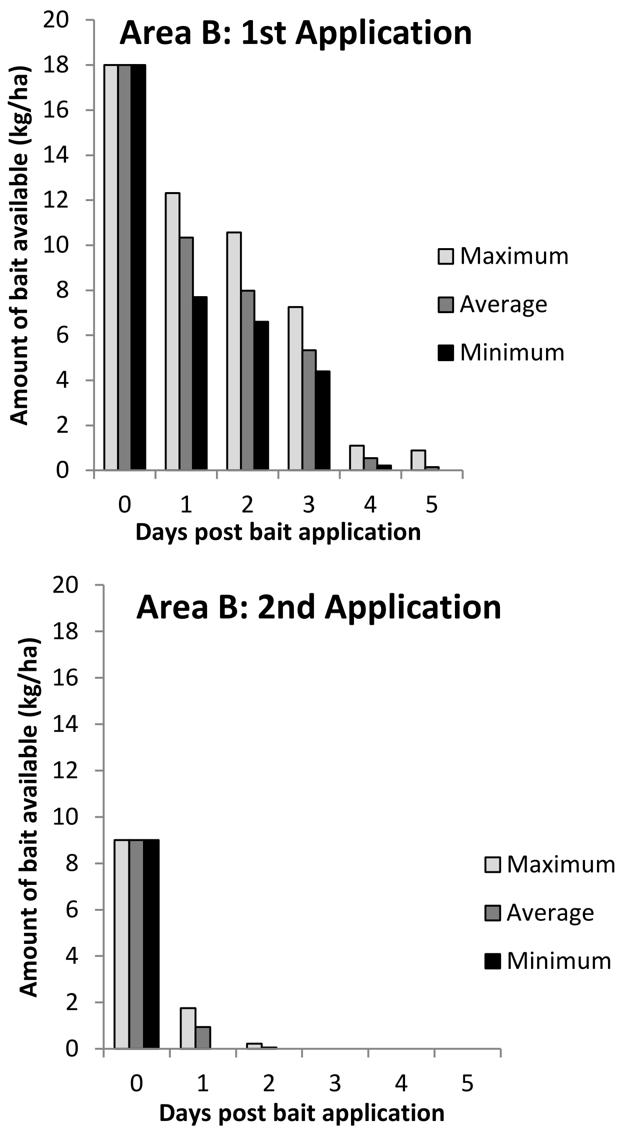

Fig. 7. Bait availability in Area B over time on SEFI following two applications of rodent bait (1g pellets) at 18kg/ha and 9kg/ha across a 3.2ha trial area.

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 starting two days after bait application. 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 between two and four days 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
November 10 - First Bait Application						
Core Grid A Nov. 12	200	2	2	100	0	0
Core Grid A Nov. 13	200	2	2	100	0	0
November 15 - Second Bait Application						
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
November 10 - First Bait Application						
Core Grid B Nov. 12	200	16	16	100	0	0
Core Grid B Nov. 13	200	9	9	100	0	0
November 15 - Second Bait Application						
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 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. It is considered unlikely that the mice that tested negative for the biomarker chose not to eat the bait especially as the population was likely food limited during the trial (per sobs.). 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 eradicating 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. 2012).

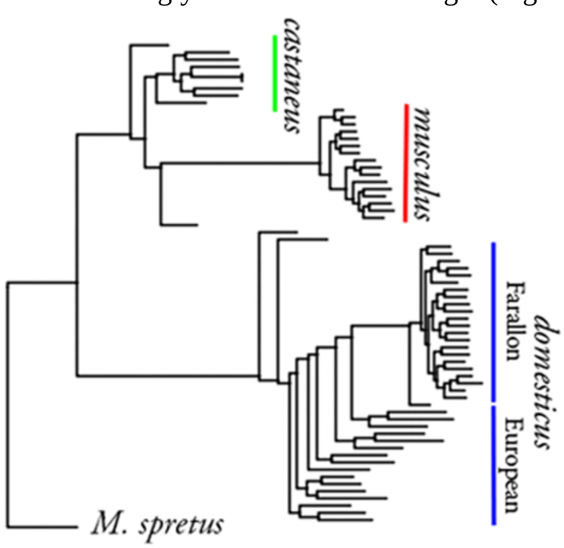

Fig. 8. Origins of introduced house mice found on Southeast Farallon Island

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. 2012).

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. 2012).

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. This figure agrees with the relative proportion of gulls seen foraging on bait, but it must be noted that a baseline to determine naturally occurring fluorescence was not established. Consequently, it is possible that this method could have 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.

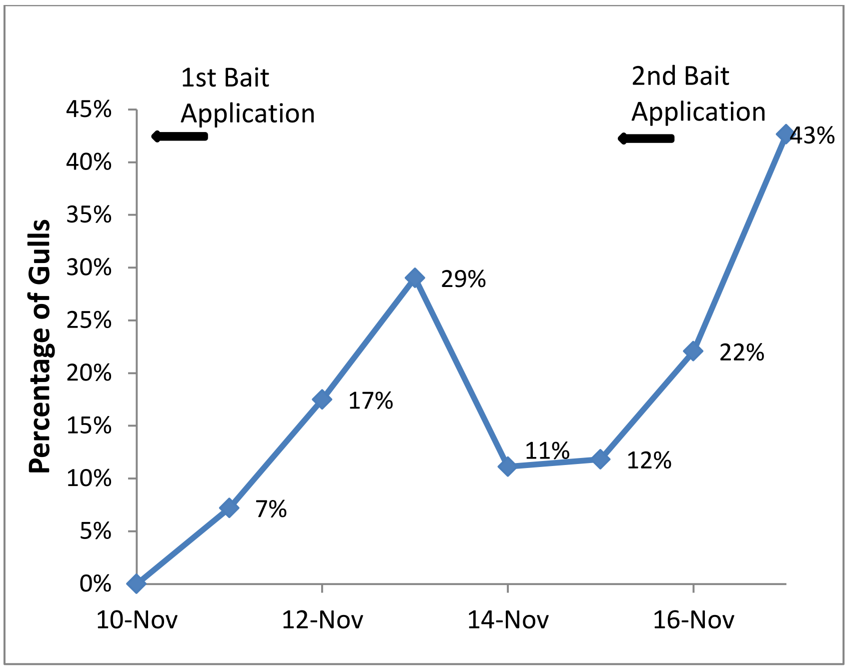

Fig. 9. Percentage of gulls in study area observed feeding on bait

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 within 100m of sites A and B 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, these results are not considered conclusive and 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 during the trial. However, raptors and corvids present during a mouse eradication should still be considered to be at risk through either primary or secondary poisoning.

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*).

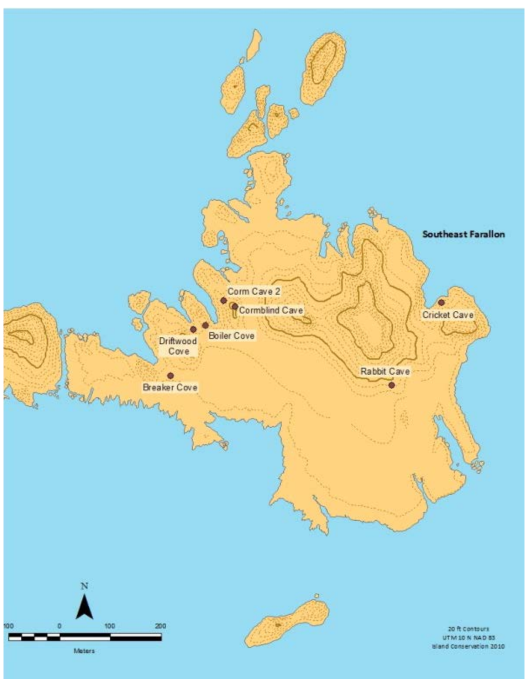

Fig. 10. Caves and coves inspected during the November 2010 trial and recorded on GPS units

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. 1997). Experiments exposing other Orthopterans such as locusts (*Locusta migratoria*) (Craddock 2003) and tree weta (*Hemideina crassidens*) (Morgan and Wright 1996) 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 hand 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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Appendix B:

Biosecurity Plan

FARALLON ISLANDS NATIONAL WILDLIFE REFUGE RODENT BIOSECURITY PLAN: PREVENTION, DETECTION AND RESPONSE

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

In order to mitigate and prevent the risk of a rodent reinvasion of the Farallon Islands National Wildlife Refuge following a mouse eradication effort, a biosecurity plan to prevent and detect rodent incursions must be implemented. This plan is a working document that will require periodic reviews and updates as deemed necessary given operational conditions. Southeast Farallon Island hosts a biological research station that is operated year-round by U.S. Fish and Wildlife Service (Service), Point Blue Conservation Science (Point Blue), and other personnel that require a steady influx of supplies in order to maintain operations. The primary pathways by which a rodent incursion might occur include marine vessels (including shipwrecks), helicopters, and their associated cargo. Biosecurity measures will focus on the packaging and inspection of all cargo transported to the island, on-island surveillance, and response 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 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 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, 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 this working document 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 the Service and Point Blue, and will include appropriate staff training.

PURPOSE

The Service has developed a Final Environmental Impact Statement (FEIS) for a proposed house mouse (*Mus musculus*) eradication effort on the Farallon Islands 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 prevention measures must be implemented if any eradication effort is to be considered successful in the long term. This biosecurity plan supplements the FEIS and provides a plan to prevent, detect and respond to potential future rodent incursions on the Farallon Islands National Wildlife. It is recognized that this plan is a working document and will need periodic review and updating as needed. This plan was developed following review of other available island rodent biosecurity plans, of which a selected bibliography is provided.

Access

The Refuge is administered by the Service and Southeast Farallon Island (SEFI) hosts a biological research station that is operated year-round by Point Blue Conservation Science and Service personnel. Personnel and supplies are regularly transported to the islands by way of ocean-going vessels (>25/year) and less frequently by helicopters (<15/year). 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 in conjunction with an eradication effort and continued indefinitely.

Access to SEFI is restricted due to the sensitive nature of the wildlife and habitat. Only Refuge personnel, partners, contractors, permittees and United States Coast Guard (USCG) are allowed to visit the islands. A limited number of Special Use Permits (SUP) may be issued for purposes necessary for management of the island's resources (Table 1).

Table 1. Agencies and organizations that regularly access Southeast Farallon Island.

Parties and Organizations	Reason	Pathway
Fish and Wildlife Service or entity with SUP or contract	Operational, maintenance, restoration monitoring, research, law enforcement	Volunteer, other agency or contracted boat; other agency or contracted helicopter
Point Blue Conservation Science	Monitoring, research, stewardship	Volunteer or contracted boat
U.S. Coast Guard	Maintenance of aids-to-navigation	Agency boat or helicopter

The four basic elements of biosecurity that is included with this plan are prevention, inspection/packaging, surveillance and incursion response. Currently, implementation, oversight and funding responsibility for biosecurity measures for the Refuge are the responsibility of the Service and Point Blue. Point Blue will be the primary lead for managing biosecurity measures on all Point Blue-managed transports, including the Farallon Patrol, other personnel and supply transports, and Point Blue contractor and cooperator transports. The Service will be the lead for the implementation of measures on Service-managed transports, including all Service personnel and supply transports, and Service contractor and cooperator transports.

Elements of Biosecurity Plan

1. Prevention
2. Inspection/Packaging
3. Surveillance
4. Incursion Response

Element 1: Prevention
Awareness and Education

- An informational brochure shall be created outlining the importance of biosecurity and some key actions that can occur. These should be displayed in plain sight of Service and Point Blue employees and distributed to other agencies and personnel who visit the island.
- A similar brochure should be distributed to tour operators that regularly use the waters near the South Farallon Islands. This brochure should encourage reporting any incidents such signs of rodents on vessels.
- Basic biosecurity measures shall be incorporated in to the standard operating procedures (SOP) for the Farallon Islands National Wildlife Refuge information document that is distributed to all island visitors.
- All communication materials should include specific instructions on how to report any sightings or suspicions of rodents on the islands, on transport vessels, or in cargo bound for the islands.

Biosecurity Management Standard Operating Procedures

Prevention measures during planned visits are largely the same regardless of the mode of transportation to the islands. The Biosecurity Management SOP (Appendix 1) will be followed during each visit to ensure that prevention measures are in place. The checklist in this SOP will be completed and returned to the Refuge Manager or Biosecurity Officer on completion of the trip for record keeping.

Key actions:

- Ensure all visitors know the risks of biosecurity, the most likely pathways and how to inspect;
- Inspect all clothing, boots, equipment and cargo;
- Inspect all vessels;
- Report any suspected pest sightings; and
- Return completed biosecurity checklist to the Refuge Manager or Biosecurity Officer

Prevention measures on mainland

- The Service and Point Blue will maintain a rodent proof room or structure to store all biosecurity related supplies. As funding permits, this may or may not be a separate quarantine facility;
- The Service and Point Blue will manage for pests where equipment and cargo is stored in mainland facilities. This will help reduce the chance of rodents and other pests nesting in cargo bound for the island; and
- The Service will purchase and use rodent proof containers. Rodent proof containers will be made of metal or hard plastic and have tightly sealing lids. The use of these containers will be a requirement for all other parties accessing the islands;

Prevention measures for permitted island users

- All parties that access the islands legally will be required to obtain a Special Use Permit (SUP); and
- The SUP will specify protocols that must be followed by the entity including but not limited to: requirement to certify the vessel utilized as rodent free; certifying compliance with Biosecurity Management SOP; use of rodent proof containers; cleaning of containers, boots and equipment prior to transport.

Prevention measures for chartered or volunteer vessels

Chartered vessels are typically 35' to 65' motorized marine vessels used for fishing or sightseeing trips. Chartered vessels are owned and/or operated by individuals that maintain USCG safety certifications. Volunteer vessels (Point Blue Farallon Patrol) are typically small to moderately sized sail boats that are owned by private citizens not involved with commercial activities. All of these vessels have home ports at different locations around the San Francisco Bay Area.

- The Service will develop biosecurity protocols similar to those utilized for SUPs for vessels that are chartered or volunteer for the government, partners, contractors or other permittees to transport personnel and cargo to the islands

Prevention measures for tour operators and fishing vessels used as alternative transportation

- The Service will develop biosecurity protocols similar to those utilized for SUPs for vessels that operate in waters adjacent to Farallon Islands NWR (e.g., whale watching, fishing, and dive operators).

Element 2: Inspection and Packaging

Inspection and packaging of all cargo

All items will be inspected during the packaging process. All cargo including small construction materials, tools, food, drink, clothing, personal items and other supplies, shall be securely packaged and sealed in clean, watertight, hard-sided rodent proof containers (i.e., plastic containers, sealed buckets, coolers, etc.) prior to loading onto the transport vessel or aircraft. Food may only be stored in containers that are totally sealed (i.e. hard-sided container with a tight fitting top and no holes). No loose material or with sharp edges are permitted. All cargo will be inspected for signs of rodents (such as chew marks or droppings) and cleaned of any living organisms or prior to packaging. No plant seeds, rodents or other living organisms shall be present. Personal gear (such as overnight kit, sleeping bag, pillow, towel, linens, & extra cloths) shall be securely packaged in clean, rodent-proof, sealed garment bags or containers (dry bags, plastic totes or similar are recommended). Cargo packed in paper products such as cardboard boxes must be in the manufacturers original packaging, be inspected. undamaged, cleaned, sealed and immediately stored in rodent proof containers or packaging (i.e. plastic wrap) for storage and transport. All plastic bags, must be placed inside a sealed rodent proof containers for storage and transport. No corrugated cardboard boxes may be used to transport food. No previously used corrugated cardboard boxes may be used for any reason. Any cargo items not packaged to specifications will be rejected from entering the Farallon Islands NWR. Any cargo packaged and stored overnight must be stored in a rodent proof containers. All island visitors will need to supply their own packaging which will inspected for approval by The Service or Point Blue staff.

Monitoring Island Visitation

The 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. The multiple stage process of transferring cargo between vessels and from vessel to land allows for an added measure that can prevent rodent incursions from occurring directly from the “long-haul” vessels to the islands.

There are currently no restrictions in place that require the long-haul vessels to maintain rodent free certifications, which would better prevent rodent infestation of cargo during transport and potentially prevent some rodents from swimming from the vessel to the island. 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 Service staff or trained individuals designated by the Service. However, future revisions and plans will research the feasibility and cost associated with maintaining rodent-free certifications from third-party inspections.

Equipment and Construction Materials

Large and bulky equipment and construction materials, especially hollow items (such as pipes, conduits reels, etc.), and lumber will require special and more intensive inspections for signs of rodents or other living organisms. These items must have all openings closed off in order to prevent rodents and other small animals from entering. The Biosecurity Officer will be responsible for enforcing the requirements for the inspection and packaging of these materials. More detailed procedures for packaging, inspection, storage, and transportation of these materials prior to transport will be developed and applied to all contracting and SUP documents.

Inspection of chartered and volunteer transport vessels (Point Blue Farallon Patrol)
All volunteer and charter boats will be provided self-inspection checklists and rodent detection kits. Boat owners will provide written statement asserting that vessel is rodent free based on completion of inspection checklist and routine monitoring. A plan will be developed to determine the feasibility and cost associated with maintaining rodent-free certifications from third-party inspections.

Inspections of aircraft
Government Helicopters (such U.S. Coast Guard and Air National Guard)
All agency helicopters must be thoroughly inspected for signs of rodents. The USCG maintains a clean facility at Air Station San Francisco and thus risk of rodent infiltration is quite low. However, USCG helicopters at times land at other airports prior to landing on SEFI, and so there is a low risk of rodent infiltration at these other locations. Future agreements with the USCG may require that they depart only from Air Station San Francisco. Any use of other government helicopters will require inspections of the aircraft prior to conducting operations on the Refuge. The Biosecurity Officer will be responsible for confirming rodent free inspections of other government aircraft.

Contractor Private Helicopters
Contracted helicopters will require inspections prior to conducting operations on the Refuge. The Biosecurity Officer will be responsible for confirming the rodent free inspections of any private helicopter.

Element 3: Surveillance
Surveillance will commence immediately following the implementation of the mouse eradication effort. Routine assessments at landing sites and annual island wide comprehensive surveys for rodents should be able to detect small populations before they spread. Prior to such confirmation, monitoring will be conducted more frequently in accordance with the post-eradication operational and monitoring plan.

Routine Assessments
The use of rodent detection devices such as live traps, sticky traps, snap traps, track pads, chew blocks, and cameras will be maintained at key locations around the South Farallon Islands. Locations might include but not be limited to the landings, houses, Powerhouse, and Carpenter Shop. Devices will be checked at a regular interval.

Periodic Assessments
A South Farallon Islands wide effort utilizing rodent detection devices may be conducted on a weekly, monthly, annual, or some other periodic interval.

Element 4: Incursion Response
An incursion is when a rodent makes it to an island. An incursion may consist of one or multiple individuals. The response to an incursion initially should be focused around the area of introduction and/or detection, but larger or island-wide monitoring may be necessary to confirm the response was sufficient.

Incursion response must occur before the species has had an opportunity to establish a population. Once population has been established the removal action would no longer be an incursion response but would be considered a full eradication.

Following an eradication effort, a quantity of registered pesticide bait product(s), live traps, sticky traps, snap traps, track pads, chew blocks and/or cameras would be stored at the SEFI field station. The Service and Point Blue 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 and Pesticide Use Permits.

If a rodent sign were encountered or a rodent sighting occurred, rodent detection devices 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 response period, and until the point at which rodents have not been detected for a pre-determined period of time. The response to any detection would be adaptively managed to minimize risk to non-target species while maximizing the probability of removing all target individuals.

Response Decision Making

For the purposes of response decision making and response, a Biosecurity Officer will be designated by the Refuge Manager. The planning of any response to an incursion of any invasive species on the South Farallon Islands will be led by the Biosecurity Officer.

Action	**Responsible party**
Service or Point Blue or other island personnel reports possible detection of invasive species	Service and Point Blue personnel
Confirm the detection by conducting additional surveys and assessments.	Service and Point Blue personnel
Assess the level of risk posed by the incursion (number of individuals, species, what impact might be caused by the incursion, likelihood of population establishing, etc.)	Refuge Manager, Biologist, Biosecurity Officer
Decide what actions should be taken, and when.	Refuge Manager, Biosecurity Officer
Implement response actions.	Refuge Manager, Biosecurity Officer
Review outcome of response actions. Review should include an analysis of likely incursion route, and identify any changes that can be made to the biosecurity plan to prevent another incident.	Refuge Manager, Biosecurity Officer

The operational response will depend on the exact details of a particular incursion. As there are many different factors that affect a scenario it has been decided that a detailed operational response plan cannot be pre-planned for every likely scenario. Appendix 3 outlines recommended strategies for responding to high risk events and confirmed incursion response.

Response Readiness
In order to be ready to respond to a high risk event or confirmed incursion, the following key actions need to be taken:

- Maintain a rapid response team that will be activated by the Refuge Manager or Biosecurity Officer.
- Maintain biosecurity supplies in a secure and accessible location on island and mainland facilities.
- Maintain compliance that provides the flexibility to quickly carry out any possible response actions. Application of rodenticide bait, if needed, must be done in accordance with the Federal Insecticide Fungicide Rodenticide Act of 1972 (FIFRA) and U.S. Environmental Protection Agency (EPA)-approved bait label issued to the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA/APHIS), which define the legally allowable use and restrictions of the specific pesticide under FIFRA, as well as a Service-approved Pesticide Use Proposal (PUP).

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Appendix 1. Biosecurity Management Standard Operating Procedures for Staff & Visitors to Farallon Islands National Wildlife Refuge

Island biosecurity refers to the policies and protocols designed to protect island ecosystems from the threat of invasive species. Historically, the South Farallon Islands have been impacted by human-introduced, invasive species including house mice, various plants, and European hares, and house cats. Eradication and control of invasive species is an expensive, labor-intensive process. In order to protect the fragile island ecosystem and to permit continued human access to the islands, it is critical to prevent further human-caused introductions of wildlife and plants. A single lapse in biosecurity has the potential to cause significant ecological harm and years of protection and restoration efforts. The following is a summary of biosecurity procedures to be followed by anyone visiting the Farallon Islands National Wildlife Refuge (NWR or, Refuge).

General Protocols

- The role of Biosecurity Officer will be assigned to one Service staff member as part of their regular duties. The Biosecurity Officer's duties are to implement the Farallon Islands NWR Biosecurity Plan. When the Biosecurity Officer cannot be present, a Biosecurity Officer designee(s) will be assigned to carry out the duties of the position.
- The Biosecurity Officer/Designee will brief all visitors to the Refuge on biosecurity protocols and procedures.
- The Biosecurity Officer/Designee will be responsible for maintaining any biosecurity monitoring in place on the Refuge, and for maintaining monitoring supplies and equipment on the island.
- The Biosecurity Officer will ensure that any vehicles (boats, helicopters) transporting personnel or cargo to the Farallon Islands NWR are inspected for animals and seeds prior to loading and before departure.
- When contracting or chartering boats, agreements should include the right to inspect the vehicle and/or require that necessary biosecurity measures are in place.
- The Biosecurity Officer/Designee will ensure that all cargo is inspected immediately before loading onto the boat/helicopter. Particular attention will be placed on high-risk cargo such as food, construction materials, fabric, and other items that may attract or hide living organisms, plant seeds or invertebrate eggs. All food and small cargo will be packed in rodent-proof containers or luggage.
- All containers, luggage, etc. will be sealed tightly to prevent rodents, other organisms, or plant seeds from gaining access. All cargo, daypacks, clothing, boots, etc. must be clean and free of plant seeds, insects, other invertebrates, dirt, and other debris. Even items that "look clean" can harbor seeds and small invertebrates. Items including clothes, backpacks, sleeping bags, etc. should be freshly cleaned and not worn or used elsewhere prior to travelling to the island.
- Any observations or signs of rodents, other small mammals, or any other newly discovered species on the Farallon Islands NWR will be immediately reported to the Biosecurity

Officer/Designee or the Refuge Manager. Record as much detailed information about the observation/sign as possible. Take photos and collect any sign (e.g. scat) for analysis.

Protocols for Packing Equipment and Supplies

- Clean and inspect all clothing, shoes, and fabrics.
- Physically remove all traces of dirt and seeds.
- For soft items, if difficult to clean entirely, place in a freezer or fumigate for 48 hours prior to departure.
- Use heavy duty plastic containers, coolers or luggage that can be sealed tightly.
- Ensure that containers are completely clean. Check that seeds and invertebrates are not hidden in grooves of the lid and handles.
- Do not use corrugated cardboard, paper bags, or plastic bags. Corrugated cardboard should only be used if it is the original packaging, is undamaged, heavily sealed, and never used to store food.
- Pack all items at one time. Securely close each container. Do not leave unattended cargo containers open as this may allow rodents, invertebrates, and seeds to enter.
- Once packed, place a strip of duct tape across the lid or top of a container and label it clearly as to indicate that it is has been checked and is ready for transport.
- Avoid re-opening any container to prevent living organisms or seeds from entering.
- Report all signs of rodents in any packing facility or container to the Biosecurity Officer.

Protocols while on-island

- Use secured rooms designated for the unpacking of cargo, where any organisms or seeds that previously escaped biosecurity measures can be quarantined and captured.
- Any living organisms or seeds found will be captured, documented, and disposed of or saved following the Early Detection Rapid Response protocol. Notify the Biosecurity Officer. A can of insectecticide should be available to deal with any insects or spiders found while unpacking that cannot be easily killed otherwise. Any rodents or other small mammals discovered must immediately be captured to be frozen for later inspection and genetic analysis.
- Rodent Early Detection and Rapid Response supplies/equipment and kits will be maintained on the island and deployed in and around the landings, houses, Powerhouse, Carpenter Shop.

General Procedures

Pre-departure Procedures

1. All personnel coming ashore must eliminate off-the-shelf packaging and re-pack in thoroughly cleaned rodent-proof containers following the SOPs.

- 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 inspected and sealed to prevent rodent entry.
- 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.

2. Visually inspect all cargo for signs of rodents or potential rodent entry points, especially containers of foodstuffs and large equipment while loading on to vessels or aircraft.
    - All items loaded onto vessels or aircraft must be inspected for holes, cracks or other signs of potential rodent entryways.
    - If any deficiency is found, cargo must be inspected and re-packaged prior to arrival or it will not be permitted on the island.
    - Any items not packaged to specifications will be assessed for rodent intrusion, inspected and re-packed prior to placement on vessel or it will be rejected and not permitted on island.

Post-arrival Procedures

3. Visually assess all cargo for signs of rodents or potential rodent entry points, especially containers of foodstuffs and large equipment before being loaded on to landing vessels.
    - The Biosecurity Officer will have designated staff that will visually assess all cargo to ascertain if it is packaged in required containers.

a) 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.

b) As soon as practicable, unpack and visually assess all cargo inside secured building areas.
- All cargo will be first unpacked in secure room indoors to reduce the risk of a rodent escaping to the outside environment.
- All island visitors will be instructed on unpacking procedures of all cargo to include self-inspection for the presence of rodents or rodent sign.
- Food will be unpacked in secured kitchen area.
- If rodent is detected, immediate quarantine of room and/or building will be implemented to ensure the rodent does not escape to outside environment.
- If rodent escapes, immediate response measures will be undertaken that follow a specified contingency response plan (to be written).

Biosecurity Management Checklist

Use this checklist to confirm that you have carried out the required protocols.

Items/Actions	Required action	Check when completed	Comments
Biosecurity Officer/Designee	Name of Biosecurity Officer or Designee for the trip		
Packs, duffle bags, and containers	Empty all packs, bags and containers for inspection prior to packing other items inside.		
	Inspect all containers for holes, cracks or other signs of potential rodent entryways.		
Clothing and footwear	Ensure clothes and boots are completely clean of plant seeds, living organisms, mud, and debris, including the soles, seams, laces, zippers, and pockets.		
Food	Ensure food has been inspected and packed in a sealed, rodent proof container.		
Other Supplies/Equipment	Thorough cleaning and inspection of all cargo and equipment to ensure it is free of rodents, plant seeds, other living organisms, mud, and debris .		
	Non-bulky items are packed in sealed, rodent proof containers.		
Freezing/Fumigation	Freeze or fumigate all appropriate soft gear for 48 hours or prior to transport. This is especially critical for gear that has been used in other Locations.		
Vehicles	Ensure rodent detection and removal measures were completed for at least 7 days immediately prior to departure.		
	Ensure transportation vessel (e.g. boat, aircraft) has been cleaned and inspected for the presence of rodents, other living organisms, and plant seeds, checked.		
Other	Assess the need for any other special biosecurity risks or concerns and address as needed.		

Appendix 2. Early Detection Methods for Routine Surveillance of Rodents on the Farallon Islands National Wildlife Refuge

To secure the longevity of native wildlife on the South Farallon Islands and ensure that the islands are maintained as rodent-free, periodic assessments for non-native species are necessary. These assessments provide confidence that the biosecurity protocols are being successfully implemented and allow the Service to make informed decisions and Rapid Response actions should any rodent(s) or other non-native vertebrate species be detected.

Personnel

The Early Detection protocol will be implemented by the Biosecurity Officer. When the Biosecurity Officer is not present on the island, a trained Biosecurity Officer Designee will be assigned.

Locations

Early Detection surveillance will be focused at the boat and helicopter landings, houses, Powerhouse, and Carpenter Shop. These are where any rodents or other animal stowaways would likely arrive on the islands. Rodents also are attracted to human habitations and food sources. Periodically, other areas of the islands also should be monitored for incursions. Surveillance tools should be employed on West End Island on an annual basis. Installation should be done at the start of the seal monitoring season, then inspected and removed on the next trip.

Documentation and Communication

If any rodent sign is detected or suspected, there must be immediate notification of the Biosecurity Officer or Refuge Manager. The Rapid Response Protocol must be implemented immediately in order to prevent any individual animals from reproducing into a self-sustaining population. Records must be kept of the circumstances surrounding any initial detection. This includes: who detected the animal, location, date, time, method of detection, number of animals, and who the detection was reported to. Record as many details as possible.

Detection Methods

Tracking Tunnels

Tracking tunnels is a common method for monitoring small mammal presence on islands. The technique uses a ‘run through’ tunnel containing two pieces of paper (track pads) on either side of a sponge soaked with a tracking medium (ink or food coloring). As an animal passes through the tunnel it picks up the tracking medium on its feet, then as it departs from the tunnel it leaves a set of footprints on the track pads. The tunnel prevents native wildlife (mostly birds) from disturbing the pads. Tracking tunnels may be more sensitive than snap traps for detecting the presence of rodents at low abundance. The method is also less labor intensive than trapping because the tunnels can remain permanently in place between monitoring sessions.

- Tracking tunnels will be placed around landings, as well as inside and around the

exterior of houses, Powerhouse, and Carpenter Shop;
- Tracking tunnels should be inspected weekly at minimum;
- Any track pads showing evidence of rodents or other small animals should be photographed, and stored in a safe place. Track pads should be analyzed as soon as possible by trained personnel.

Chew Blocks

Chew blocks are an excellent tool for detecting rodents. The blocks can be easily made by cutting sturdy corrugated plastic sheets into one inch squares and then injecting peanut butter into one edge to act as an attractant. Chew blocks can be made in advance and taken along on any trips to the island. For routine deployment, plain peanut butter can be used.

- Chew blocks will be placed around landings, houses, Powerhouse, and Carpenter Shop;
- Chew blocks should be inspected weekly at minimum;
- Any chew block(s) showing evidence of chewing should be removed, photographed, and stored in a safe place. Chew marks should be analyzed as soon as possible by trained personnel.

Traps

Traps are an efficient means of detecting and capturing rodents as specimens. A variety of traps and bait types should be used to maximize the chances of capturing rodents.
- Traps will be placed around landings as well as inside and around the exterior of houses, Powerhouse, and Carpenter Shop.
- Bait traps with known attractants that will not degrade rapidly. Peanut butter is typically used as rodent bait. Check all traps at a minimum weekly.
- Any rodent captured must be collected and analyzed.
- DNA should be collected from any animals removed. DNA analysis may help determine source population.

Sign Search
- All island staff should be familiar with typical rodent tracks and scat. A protocol and key cards will be provided with images of tracks and scat of the most likely rodents or other small mammals to be introduced to Farallon Islands.
- Constant vigilance for rodent and other introduced vertebrate sign must be done within the course of all activities and all areas visited on the South Farallon Islands.

Cameras

Surveillance cameras (e.g, camera traps) may be placed in and around landings and buildings to help detect and identify rodents or other non-native vertebrates.

Appendix 3. Recommended Rapid Response Actions for Rodent and Other Introduced Vertebrates on the Farallon Islands National Wildlife Refuge

Roles and Responsibilities

Refuge Manager

- Designate a Biosecurity Officer and maintain a Rapid Response Team:
  - Biosecurity Officer or other designees should be personnel that are familiar with the Refuge and pertinent logistics
  - Rapid Response Team can consist of Service and partner (e.g. Point Blue Conservation Science) staff, be created through a contract with an outside firm, or some combination of both
  - Ensure funding is in place to support response actions
- Maintain regulatory compliance:
  - Any application of rodenticide would be undertaken in accordance with the Federal Insecticide Fungicide Rodenticide Act of 1972 (FIFRA) and EPA-approved supplemental bait label issued to the USDA/APHIS, which define the legally allowable use and restrictions of the specific pesticide under FIFRA. All bait application activities would be conducted under the supervision of a certified pesticide applicator holding a Qualified Applicator Certificate from the State of California. If necessary to satisfy special operational needs not covered under a current bait EPA-approved label, the Service will consult with the USDA/APHIS and EPA. If deemed necessary, the Service would then work with the USDA/APHIS to apply for a supplemental label.
  - Service policy requires an approved Pesticide Use Proposal (PUP) before conducting any federal action involving the application of pesticides. The Refuge Manager should request a PUP annually in case it is necessary to apply a rodenticide to respond to an introduced mammal incursion.
- Direct rapid response team response actions

Biosecurity Officer

- Maintain good communication with Refuge Manager and other island personnel, partners, and local agencies
- Create and maintain rapid response kits
  - All needed items should be acquired in advance and stored together in an easily accessible location on the island.
  - Perishable items (i.e., bait such as peanut butter and oats) must be replaced as needed.
- Coordinate training for members of the Rapid Response Team

Rapid Response Team

- Be aware of pre-established locations of monitoring and removal tools
- Be prepared to respond quickly to all events

Confirming the Incursion

- Any sightings or evidence of an incursion will be reviewed by the Biosecurity Officer or designees to determine if and what type of response actions are necessary.
- If the evidence is unclear the Biosecurity Officer will coordinate additional investigations with expert consultation.
- If necessary, the Biosecurity Officer will coordinate and implement actions of the Rapid Response Team.
- Any information gathered during this stage, such as locations, or species identification, should be used when determining response.

Response Actions

Confirmed Incursion

The following are recommended response actions following a confirmed rodent or other small mammal incursion on the South Farallon Islands. If any other newly introduced vertebrates are discovered, literature and/or expert consultation should be conducted immediately to determine appropriate response actions:

- Utilize a variety of removal methods including bait stations, snap traps, cage traps, and/or hand broadcast of bait.
- Trapping and bait station grid should cover all habitat types across the island. Traps and bait stations should be placed at a higher density around key habitat and detection sites.
- All trap and bait station locations should be numbered, visibly marked, and mapped. Any member of the response team should be able to easily locate every location.
- Place traps in locations with plenty of natural cover, and where animals are likely to be active. Place additional traps near any footprints or scat.
- Traps should be covered and/or placed in locations (e.g. attached to tree limbs) that reduce the chance of interference by non-targets.
- Bait traps with known attractants. Check all traps daily and bait stations daily or every other day. Peanut butter mixed with rolled oats makes good rodent bait.
- Keep detailed records. Any sign should be recorded and analyzed.
- DNA should be collected from any animals removed to help determine the source population.
- Staff should continually search for sign and new trap locations.
- Additional investigations and research should be on going to determine the best tools available removing rodents.

Recommended Equipment

The table below provides guidance on what items may be necessary for responding to an incursion. The response kit is an example of what items may be necessary to implement a long-term monitoring program on the island. Note that not all items will be needed for each incursion; the nature of the incursion will dictate what exactly will be utilized.

These supplies should be acquired in advance and stored on the island. If a larger scale response is needed, additional supplies can be obtained:

Item	Quantity
Laminated map of Southeast Farallon Island with monitoring sites noted	1
Photocopies of map for writing on	5
Copy of Southeast Farallon Island Biosecurity Plan	1
Contact information for experts in various species	1
Copy of locations of long term monitoring tools	5
Copy of user's manuals of any applicable monitoring tools	1 for each item
Key to identifying likely invaders	5
Waterproof notebooks	5
Zip lock bags	50
Pens/pencils	10
Permanent marker	10
Disposable gloves	50
GPS unit	2
Digital Camera	2
Colored flagging	5 rolls
Spare batteries	Enough to meet needs
Tape measure	1
Sharp knife	1
Various tools (pliers, wire cutters, hammers, spades, etc.)	
Radios for communication on island	Enough for crew
Personal protective equipment needed for work (e.g. leather gloves, eye protection)	Enough to meet needs
Insectecticide spray	1-2
Rodent proof containers	Enough to meet needs

Appendix C:

Alternatives Selection Report

Alternatives Selection Process Report

For the Farallon House Mouse Eradication DEIS

U.S. Department of the Interior
Fish and Wildlife Service

Prepared by:
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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.

Table of Contents

1 Introduction

1.1 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.

1.2 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.

2.1 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

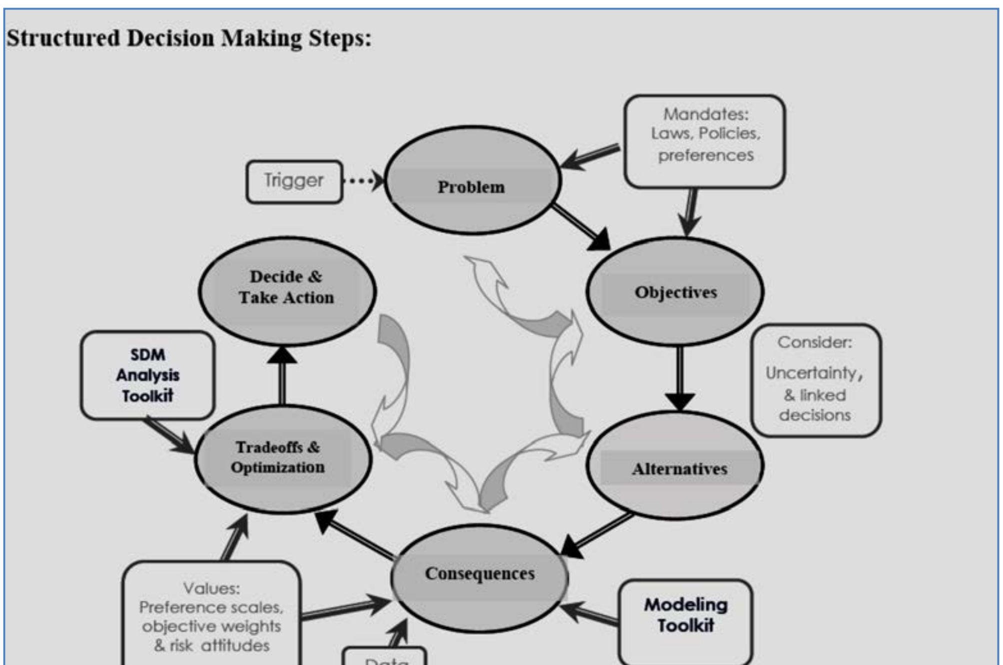

Figure 1: FWS 2008 Fact Sheet

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 between multiple 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

2.2 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.

2.2.1 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.

2.2.2 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.

2.2.3 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:*

<u>Aerial Broadcast:</u> 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.

<u>Hand Broadcast:</u> 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.

2.3 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.

2.4 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.

2.4.1 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)

2.4.2 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

3 Results

3.1 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

3.2 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.

3.3 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.

3.4 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	48	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).

4 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.

4.1 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 ills 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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6 Appendices

6.1 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

<u>Scoring Resources</u>

- 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

1. Carcass removal
2. Gull hazing – intended to reduce gull take to a minimal level
3. Raptor capture/hold/relocation
4. Captive holding of salamanders
5. Captive holding of camel crickets
6. Tarp drinking water catchment pad
7. 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	Many methods are used for controlling rodent numbers on the mainland with variable rates of

	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.	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.

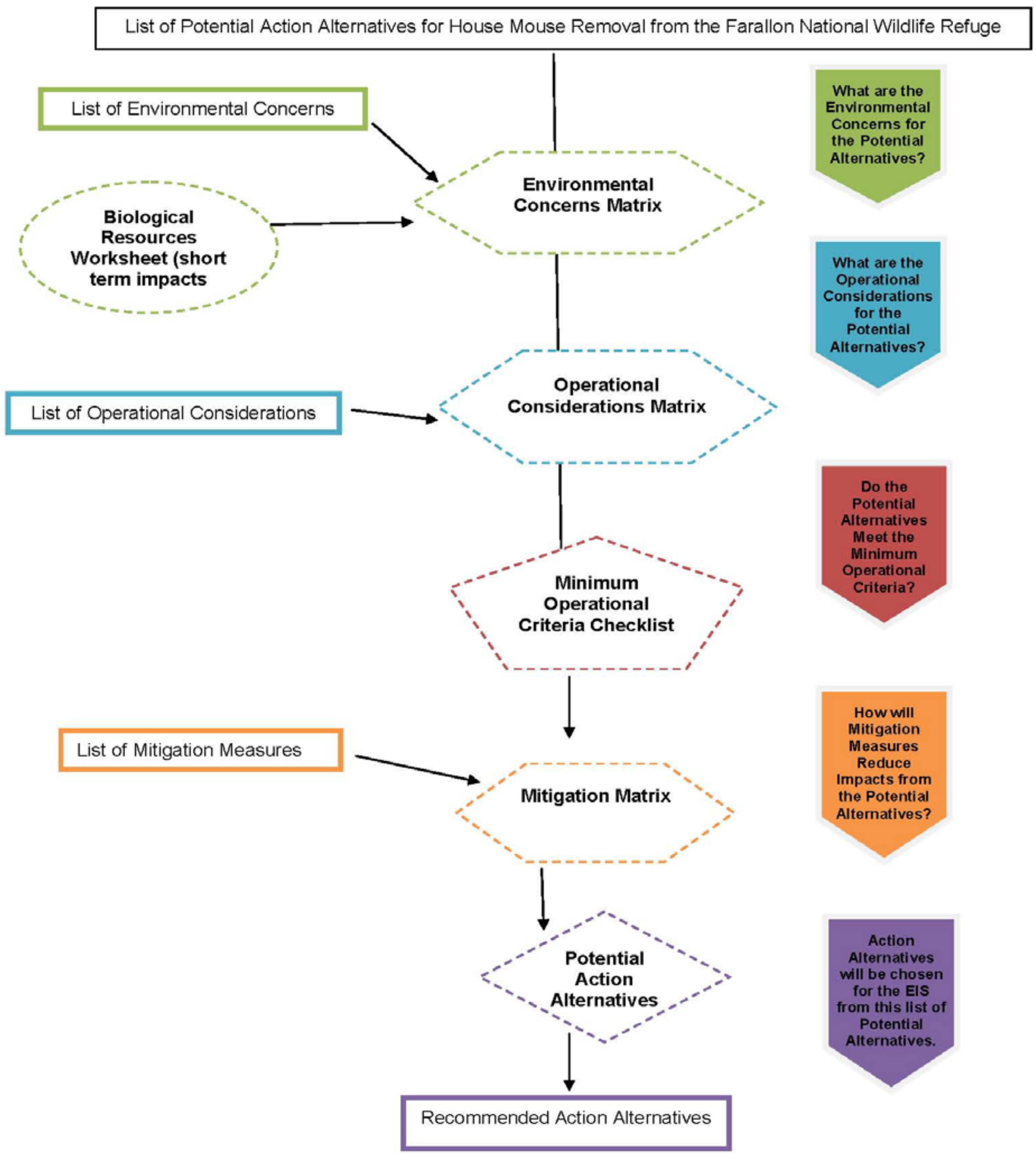
When mice are the only target species on the island, the eradication success rate is now over 90%. Table 5.1 summarizes the results of the attempted mouse eradications and corresponding success rates.

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**



6.2 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.

Appendix D:

Bait Degradation Trial Report

Farallon Islands Restoration Project

Evaluating the duration of potential risk exposure to susceptible non-target species following the application of rodent bait.

Prepared by:

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100 Shaffer Road, Santa Cruz, California 95060

May 2015

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.

Autumn 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 palatable or available 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 in degradation rate observed between bait types 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 15 weeks or longer.

ISLAND CONSERVATION
Preventing Extinctions

Contents

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. Non-toxic bait consists of the same inactive ingredients (which comprise 99.9975% of the bait) as the toxic bait product so is considered representative of the actual bait product with respect to degradation rate. 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.

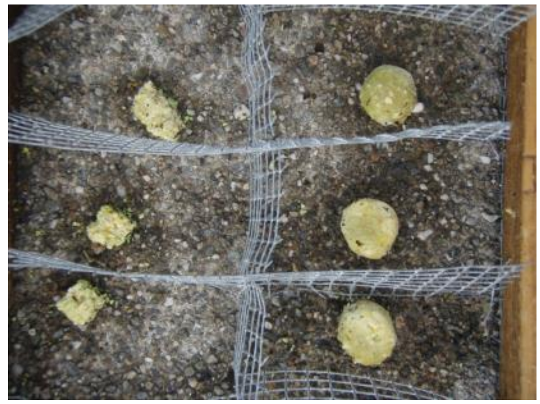

Fig. 2. Close up of the two bait types during the trial (Brodifacoum-25D Conservation on left and Diphacinone-50 Conservation on right)

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 (2003)	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 to bait 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).

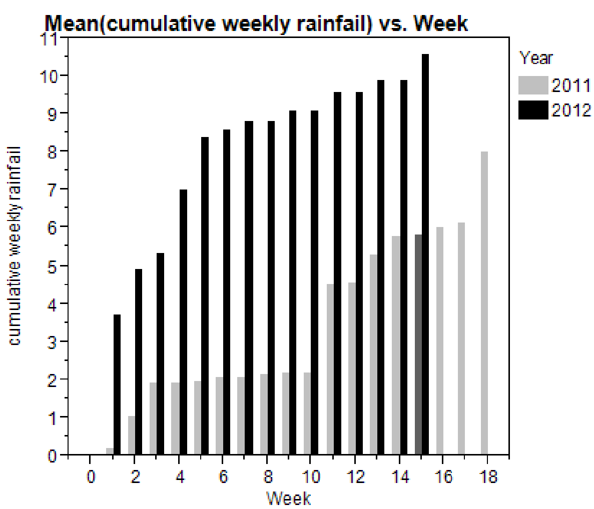

Fig. 3 Cumulative rainfall on SEFI during the two trials

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 after 15 weeks and 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 1987, Howald et al. 2001).

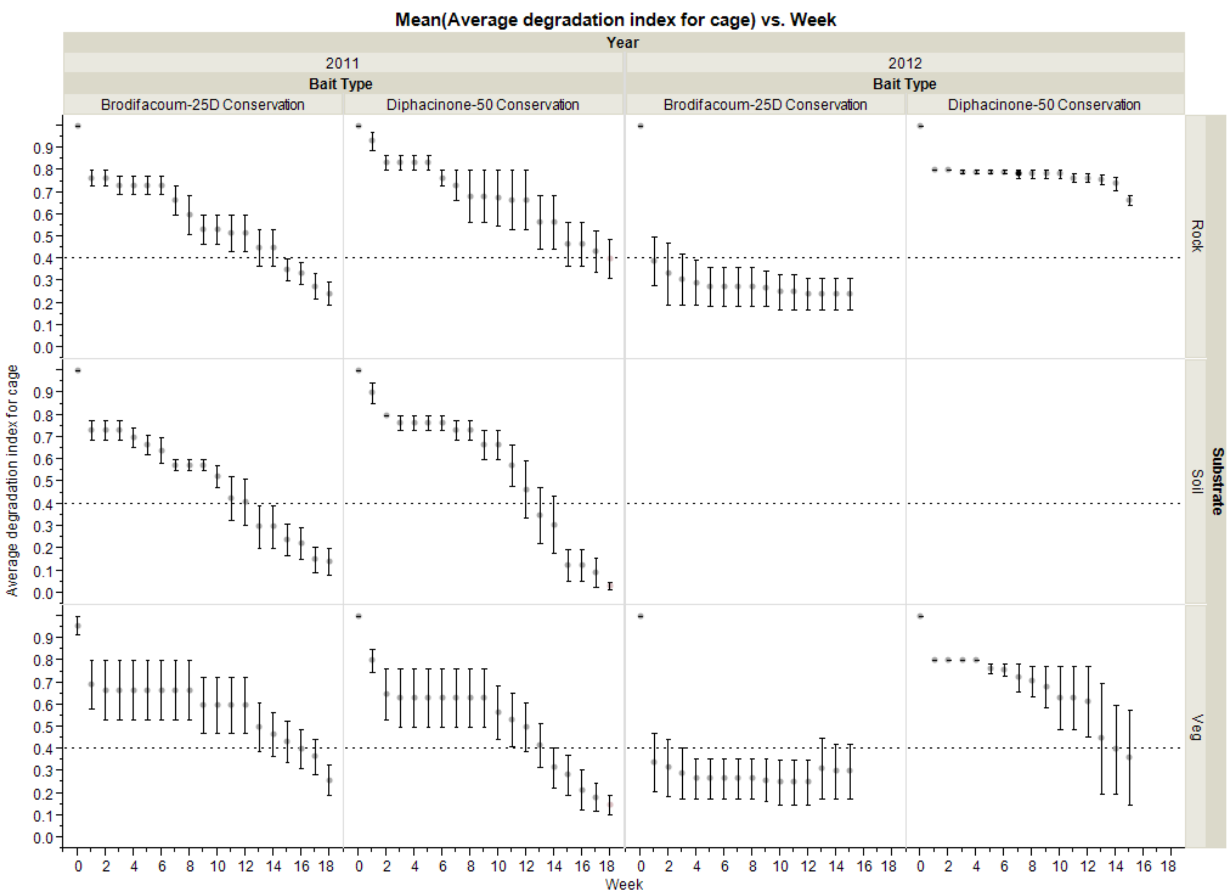

Fig. 4. Relative availability and palatability of non-toxic Brodifacoum-25D Conservation and Diphacinone-50 Conservation rodent bait protected from consumption by vertebrate consumers observed over time on rock, vegetation and soil substrates during two trials undertaken beginning in the fall of 2011 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	$F_{1,36.4}=0.38$, $p=0.537$	$F_{1,38.0}=0.26$, $p=0.613$
bait	$F_{1,32.5}=0.46$, $p=0.504$	$F_{1,32.4}=2.09$, $p=0.157$
substrate	$F_{2,32.5}=8.98$, $p<0.001$*	$F_{2,32.5}=11.38$, $p<0.001$*
bait x substrate	$F_{2,32.5}=3.84$, $p=0.032$*	$F_{2,32.4}=6.64$, $p=0.004$*
year x bait	$F_{2,32.5}=16.74$, $p<0.001$*	$F_{2,32.4}=8.11$, $p=0.008$*

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 1987, 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. In the first trial 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, and likelihood that bait degradation was also affected by invertebrate consumption on the tropical 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
Palmyra	5	3[1]	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

[1] From Howald *et al*. (2004)
[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*. (2008)
[5] Estimated based on average monthly rainfall data for Wake provided by the Western Regional Climate Center.

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.

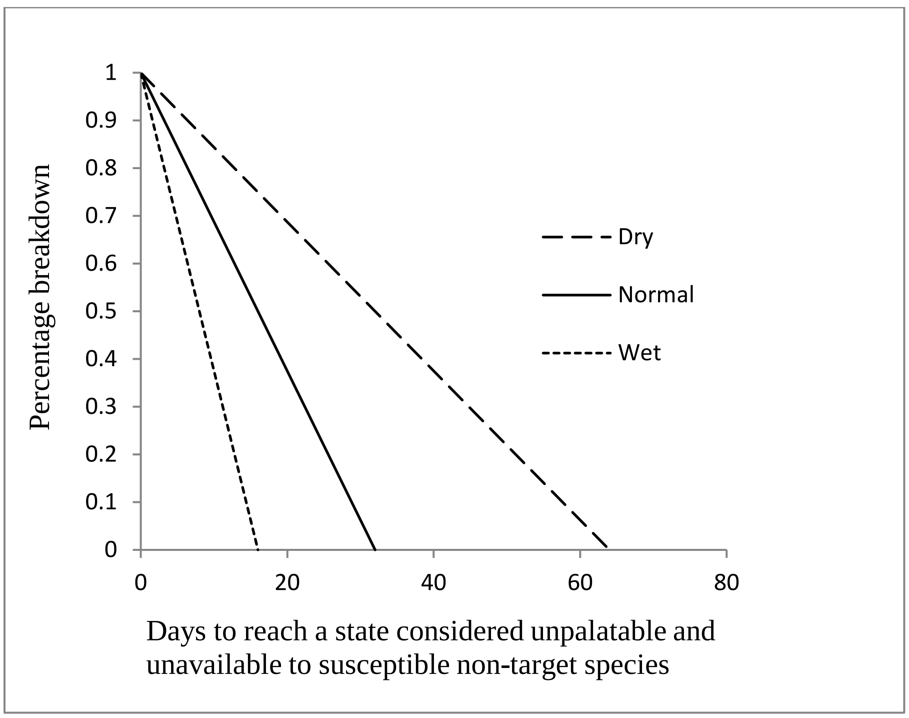

Fig. 5. Fig 5. Hypothetical bait degradation rates for Brodifacoum 25D under three projected rain scenarios for the Farallones. Slopes were calculated by multiplying rainfall by the rate of bait breakdown calculated for Brodifacoum 25D and shown in Table 4. Rainfall for a wet year was estimated as twice the amount seen in a normal year and half the normal rainfall was used for a dry year. Both extremes have been documented on the Farallones.

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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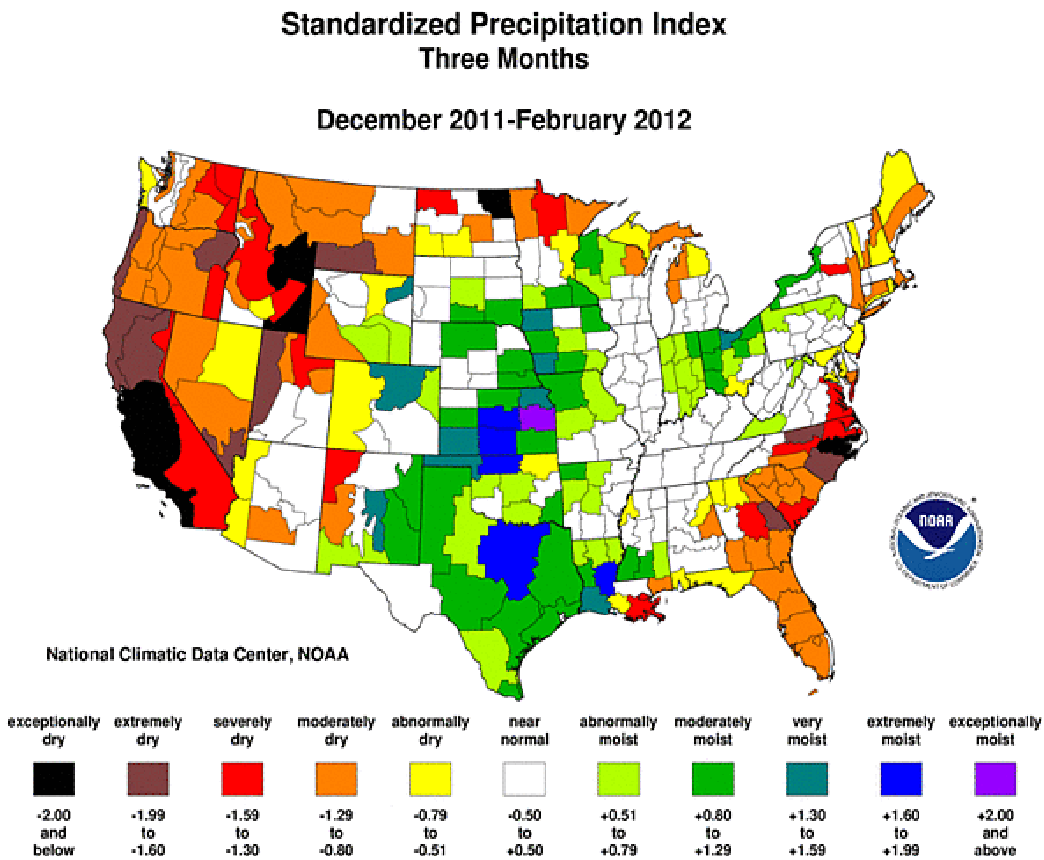
Appendix 1. Bait degradation scale used (Craddock 2004).

	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.



Appendix E:

2012 Gull Hazing Trial Report

Point Blue
Conservation science for a healthy planet.

ISLAND CONSERVATION
Preventing Extinctions

Evaluating the use of non-lethal hazing techniques to minimize potential exposure of Western Gulls to rodenticide from a proposed rodent eradication on the South Farallon Islands

Report to the Oiled Wildlife Care Network

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December 2013

LAY ABSTRACT

Introduced House mice pose a threat to the Ashy Storm-petrel and other native species of the South Farallon Islands. The United States Fish and Wildlife Service, which manages the Farallon National Wildlife Refuge, has proposed that mice be removed from the islands to restore the island's unique ecosystems and wildlife. Methods being considered for removing mice include the application of rodent bait by helicopter. However, the bait, that contains a rodenticide, poses a risk to some non-target wildlife such as Western Gulls. To confirm if the risk to Western gulls could be effectively mitigated through the use of wildlife hazing techniques, a trial was completed in the fall of 2012. The trial that tested a range of hazing tools such as biosonics, pyrotechnics, lasers, reflective objects and effigies (dead gulls tied to a pole) successfully demonstrated that gulls could be kept off the islands for an extended period of time. The trial also demonstrated that most hazing techniques had no significant negative impact on other wildlife present such as seals and sea lions. The trial provided confidence that the risk to gulls can be reduced to low levels if a mouse eradication took place. Results from the trial will be used by the USFWS in planning for the proposed mouse eradication but will also be useful to other agencies engaged in hazing wildlife such as the Oiled Wildlife Care Network.

SCIENTIFIC ABSTRACT

Introduced House mice (*Mus musculus*) pose a threat to the Ashy Storm-petrel and other native and endemic species of the South Farallon Islands. The United States Fish and Wildlife Service, which manages the Farallon National Widlife Refuge, has proposed their eradication as part of continuing efforts to restore the islands' ecosystem and conserve the populations of native species. Methods being considered for removing mice include the aerial application of rodent bait containing a rodenticide which will pose a risk of exposure to some non-target wildlife such as Western Gulls (*Larus occidentalis*). In a 16 day hazing trial conducted in November and December 2012, we evaluated the effectiveness of a combination of non-lethal wildlife hazing techniques including biosonics, pyrotechnics, lasers, reflective objects and effigies, for temporarily reducing gull numbers at the South Farallon Islands. We examined the relative effectiveness of these tools for dissuading gulls as well as the impact of these treatments on pinnipeds and other non-target bird species present on the islands. The hazing trial successfully demonstrated the feasibility of keeping gulls off the islands for an extended period of time (in this case a 12 day interval) while having relatively minor impacts on other species. There were significant differences between individual hazing techniques both in terms of their effectiveness and their disturbance to non-target species. Lasers, effigies and techniques that combined auditory and visual stimulus had the highest hazing efficiency. These results provide valuable guidance for USFWS in planning for the proposed mouse eradication as well as other resource

managers, such as oil spill responders when choosing appropriate techniques for their individual applications. Although the suite of tools tested appears sufficient to minimize the risk to gulls during the proposed mouse eradication, provision should be made for the use of additional hazing methods to ensure the risk to gulls is minimized.

INTRODUCTION

Non-lethal hazing of wildlife is an important tool used by resource managers to reduce wildlife damage, decrease harmful interactions with humans and protect wildlife from harm (Gilsdorf *et al.* 2003; Gorenzal *et al.* 2004). Examples of its application include deterring gulls from landfills (Cook *et al.* 2008; Baxter and Allan 2006; Curtis *et al.* 1995), reservoirs (Duffiney 2006; Golightly 2005) and airports (Belant and Martin 2011; Washburn *et al.* 2006), reducing the impact of Canada geese in urban and rural environments (Smith *et al.* 1999), reducing crop damage by foraging birds (Nemtzov and Galili 2006) and reducing the impact of oil spills on waterbirds (Gorenzal *et al.* 2006; Ronconi *et al.* 2004).

Non-lethal hazing techniques include a suite of physical, visual and auditory methods that may be used to disperse or dissuade wildlife from an area (Belant 1997; Gorenzal *et al.* 2008). Previous studies have demonstrated the utility of several non-lethal hazing methods including biosonic devices that broadcast alarm, distress or predator calls (Whitford 2008); pyrotechnics which frighten wildlife through a combination of noise, light and movement (Gorenzal and Salmon 2008); lasers (Gorenzal *et al.* 2010; Werner and Clark 2006; Blakwell *et al.* 2002); visual deterrents such as kites, ballons and mylar tape (Seamans *et al.* 2002, Gorenzal and Salmon 2008); effigies (Seamans *et al.* 2007); and helicopters (Marsh *et al.* 1991). In this study, we evaluated a variety of hazing methods in order to test their efficacy in minimizing the risk of rodenticide exposure to Western Gulls during proposed mouse eradication on the South Farallon Islands, California. We also assessed impact from hazing activity to non-target species[1] including pinnipeds and roosting shorebirds and evaluate their potential efficacy for use in hazing birds away from oil spill areas.

The South Farallon Islands lie approximately 30 miles west of San Francisco, California and are part of the Farallon National Wildlife Refuge (Fig. 1). The islands are home to 13 breeding species of marine birds, five species of pinnipeds and countless migratory birds each year. With more than 300,000 breeding birds, they are the largest seabird breeding colony in the contiguous United States (Ainley and Boekelheide 1990) and include globally important populations for Ashy Storm-petrels (*Oceanodroma homochroa*), Brandt's cormorants (*Phalacrocorax penicillatus*) and Western gulls (*Larus occidentalis*). During the 1800's, human activity on the islands resulted in the introduction of invasive House mice (*Mus musculus*) that have had both direct and indirect negative impacts on the native wildlife, most notably on Ashy Storm-petrels (*Oceanodroma homochroa*) (a California species of special conservation concern and IUCN listed endangered species) and other native and endemic species of the Farallon Island ecosystem.

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[1] For the purposes of this report a non-target species was defined as a species that is likely to be unaffected by the proposed mouse eradication but could be affected by hazing methods.

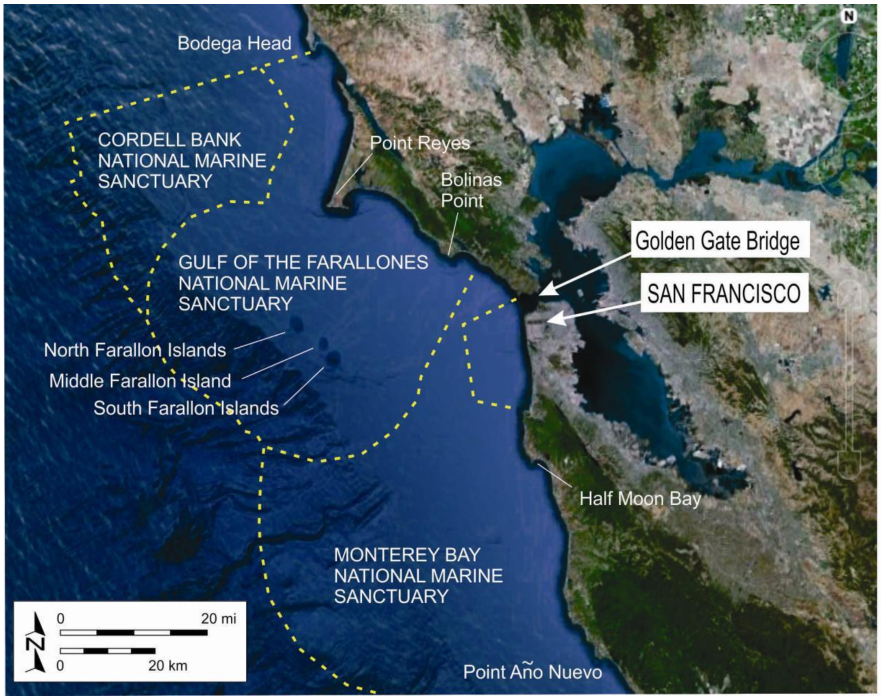

Figure 1. Map showing the location of the South Farallon Islands

The United States Fish and Wildlife Service, which manages the Farallon NWR, has proposed the eradication of introduced mice as part of their continuing effort to restore the islands ecosystem and conserve the populations of native wildlife (USFWS 2013, Draft Environmental Impact Statement (DEIS)). Part of the proposed mouse removal methods includes the island wide application of bait pellets containing rodenticide. This method has proven effective for other island eradication projects worldwide (Howald *et al.* 2007, Keitt *et al.* 2011, Mackay *et al.* 2011) but carries the risk of non-target exposure (USFWS 2013, DEIS).

The occurrence of marine birds on the South Farallon Islands is strongly seasonal, with the greatest number and diversity present during the spring and summer breeding period (Ainley and Boekelheide 1990). The timing of the proposed operations to eradicate mice would therefore likely take place during the late fall when most resident seabirds are not present (USFWS 2013, DEIS). However, long-term data on seasonal occurrence indicates that Western Gulls are likely to be present during this time period (Grout and Griffiths 2012, Pott and Grout 2012). This potentially puts them at risk of lethal exposure to rodenticide through direct ingestion of baited pellets or by scavenging carcasses of poisoned mice.

Previous studies have indicated that the bait pellets likely to be used during the eradication (Conservation-25D Brodifacoum or Diphacinone-50 Conservation) would remain available and palatable to gulls for between 7 and 101 days depending on the intensity of rainfall (Griffiths *et al.* 2013; USFWS 2013, DEIS). The purpose of this study was to demonstrate the ability to minimize the risk of exposure by deterring gulls from the islands for the duration of the period that bait remains available. Non-lethal hazing techniques were selected for the trial to ensure the least impact on the species of concern. Herein, we evaluate the effectiveness of the hazing trial to reduce gull numbers, the relative hazing effectiveness of the different hazing treatments for dissuading gulls and the non-target impact of these treatments on pinnipeds and other bird species present on the island. The knowledge generated has application not only to this project but also to other situations where hazing of birds is required, such as oil spill response operations.

METHODS

Study approach and treatments used

This study was conducted on the South Farallon Islands, Farallon National Wildlife Refuge, between November 27 and December 15, 2012. This period was selected to coincide with the likely timing of the proposed mouse eradication operation when overall marine bird numbers are at their annual minimum and before the start of elephant seal breeding. The South Farallon Islands consist of two main islands, Southeast Farallon Island (SEFI) and West End Island (WE) as well as several smaller offshore islets and rocks totaling approximately 120 acres (Fig 2).

Figure 2. Aerial view of the South Farallon Islands. The two main islands are Southeast Farallon Island (SEFI) and West End Island (WE).

The hazing 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 in order to determine the rate at which gulls resumed normal roosting patterns and to document any lasting impacts on pinnipeds. The impact of hazing activity and individual techniques on pinnipeds was continually assessed throughout the study.

Table 1. Trial Phases

Phase	Scope	Area	Duration	Dates
1	• Assessing the effectiveness of individual hazing methods on gulls and effects on other birds 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

Phase 1 aimed to evaluate the relative efficacy of specific techniques for hazing gulls and to determine the effective range of individual hazing tools. Responses of other bird species in the area were also noted. Each hazing tool was tested up to five times in areas where gulls were present. Phase 2 aimed to simulate likely hazing activity in the event of eradication and to evaluate the overall effectiveness of a gull hazing operation at reducing the number of gulls present on the islands. Anecdotal evidence from Phase 1 trials was used to inform the deployment of the different hazing treatments in order to have the greatest effect. Hazing was conducted continuously from both SEFI and WE whenever gulls were present. Phase 3 continued hazing operations but at a reduced scale and only from SEFI. The goal during phase 3 was to determine if both main islands could be effectively hazed using only ground-based personnel on SEFI. All hazing tools and combinations, with the exception of the helicopter and Zon cannons continued to be used during this phase. Gulls were allowed to roost in certain localized areas where mice may not be present and bait may not need to be applied, including several small off-shore islets and tidally submerged roosts. These areas were treated as temporary refugia for gulls where they may potentially be allowed to roost during a mouse eradication operation.

A total of 21 different avian hazing tools were tested during this study and are listed below along with the standard abbreviations used throughout this report. These included:

- **6 biosonic devices** - Bird Gard Super Pro® with 4 directional speakers (bg), Bird Gard Super Pro® with 4 speaker multidirectional tower (bgm), Bird Gard Super Pro Amp® (bga), LRAD 100x™ (LRAD) , Marine Phoenix Wailer® (Wailer, wail), and Zon® propane cannon (zon);
- **5 pyrotechnic devices** - Starter pistol caps (cap), Bird Bangers®/Bird Bombs® (bangers, bng), Screamer Sirens®/Bird Whistlers® (screamers, scr), Shell crackers® (crackers, crk) and CAPA rockets® (rkt);
- **3 lasers** - Penlight laser pointer (green light) (las1), Avian Dissuader® (red light) (las2) and Aries Bird Phazer Laser® (green light) (las3);
- **5 passive visual deterrents** – kites (kt), balloons (bal), mylar tape (my), owl decoys (owl) and Western Gull effigies (ef);
- **2 active mechanical deterrents** - human presence (hum) and a Robinson R22 helicopter (helo).

A full description of each hazing treatment and how it was used is presented in Appendix 1. In addition, we tested multiple combinations of individual hazing treatments for a grand total of 29 unique hazing treatments. The most common combinations tested were multiple different pyrotechnics (pyro), pyrotechnics in combination with biosonics or helicopter hazing (pyroplus) and helicopter hazing combined with the LRAD (helirad). See Appendix 2 for the complete list of all unique hazing treatments tested along with their standard abbreviations.

Although proposed, permission from the Federal Aviation Authority to deploy Unmanned Aerial Vehicles (UAV) was not obtained in time to include testing of this technology in the trial. However, in our discussion of the results of the trial we infer some aspects of the potential effectiveness of UAV's from data collected on the utility of the helicopter. Dogs are another potential hazing tool (Gilsdorf *et al.* 2002) that may be effective on the Farallones, however the testing of this method was not included because of resource limitations. Lethal hazing techniques such as removing a single individual to dissuade a group from returning to an area although proven effective elsewhere (Jones *et al.* 1996) were not included because of the desire to minimize the impacts of the trial.

Gull distribution and abundance

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 in order to establish a baseline population estimate for gulls on the island during the fall and winter period. These counts were continued in 2012 for the two weeks prior to the hazing trial and again for several weeks after the conclusion of hazing. During the trial, maximum dawn numbers were determined by summing gull counts made during the earliest period of hazing activity in each area on each day. Estimated numbers of individuals for other bird species in the area were also noted. To allow a more detailed assessment of the impact of specific hazing treatments used during the trial, the island was divided into 49 discrete sectors.

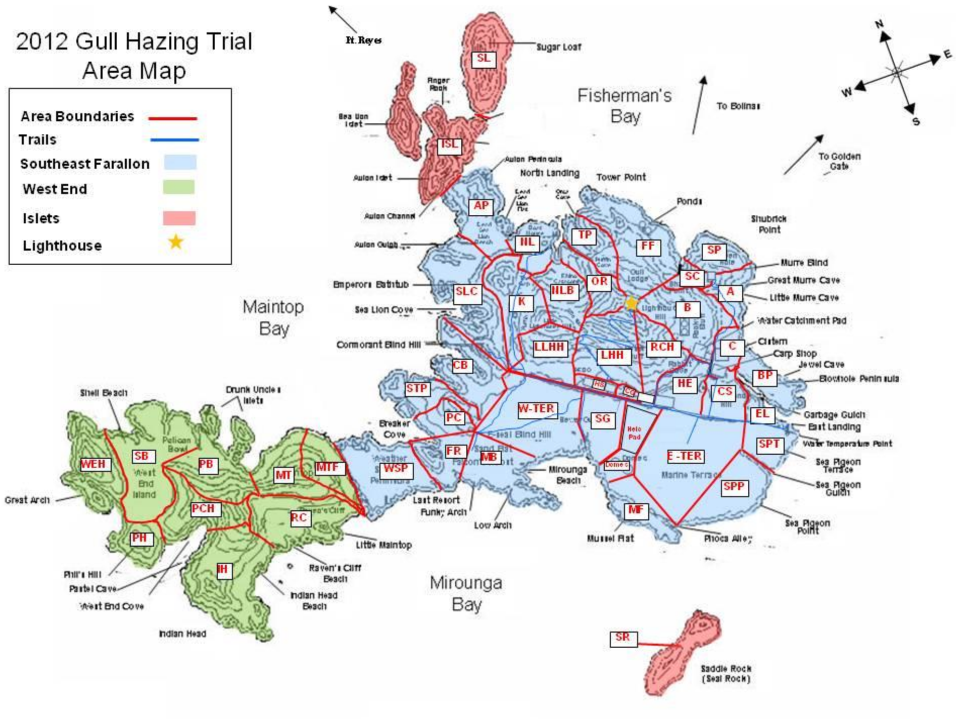

Fig. 3. Sectors used for monitoring gull numbers and behavior during the hazing trial on the South Farallon Islands. The colored areas denote Southeast Farallon Island (blue), West End Island (green) and offshore islets (red).

During all phases of the trial, trained observers recorded gull numbers and their location multiple times per day at regular intervals as well as the number of gulls present in the targeted area prior to application of the hazing treatment. They also identified and enumerated pinnipeds present in the area and all non-targeted avian species. During and after the treatment, observers determined the level of response by visually estimating the proportion of the original number of gulls and other birds which remained after the conclusion of hazing activity. The immediate response of birds to hazing activity was categorized into one of two possible behaviors: 1) no response; and 2) flushed. For those that fell into the 'flushed' category, it was further noted what proportion of those individuals either: 1) immediately departed the area; or 2) circled and returned to the same area to roost.

Analysis

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 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 the 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. Paired t-tests were used to test and evaluate differences in gull numbers between time periods.

We also determined overall 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 regular 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%. We acknowledge that daily counts of gulls prior to and during the trial are not independent i.e. counts are likely influenced by the size of the gull population the previous day. However, this was an unavoidable constraint of the trial design. Paired t-tests were again used to evaluate differences in the effective daily hazing rates between trial phases.

Effectiveness of individual treatments

In order to evaluate the effectiveness of individual hazing treatments, we created a metric called "Hazing Efficiency" which was equal to the product of the proportion of gulls that flushed times the proportion of gulls that departed the area for any given hazing event. So a hazing efficiency of 1 would mean all gulls targeted were flushed from the roost and moved away from the area. Hazing efficiencies of less than 1 indicate that either some gulls did not flush (i.e. were unaffected by the hazing method) or all gulls flushed but some simply circled and returned to the same roost. Since the main objective of this project was to test our ability to move 100% of the gulls from any baited areas, this seemed an appropriate measure.

Individual hazing treatments were evaluated relative to each other based on their mean and median hazing efficiency across all trials for each treatment. Significant differences between treatments were determined using ANOVAs on logit transformed data. The logit transformation was used to transform proportion data in order to run parametric statistical tests. This common transformation reduces the influence of ones and zeroes in the data so that it more closely approximates a normal distribution.

In addition, we evaluated the effect of hazer proximity on the hazing efficiency of the different treatments. GPS locations were collected for each hazing event and projected onto a map using ArcGIS. Linear distances were then calculated from the hazer location to the approximate center of the gull roost. In order to determine the effect of proximity on hazing success, we calculated the mean and maximum distances for each hazing method for which we were 100%

successful in hazing the targeted gulls. Significant differences between treatments were determined using ANOVAs.

We further evaluated the effectiveness of individual pyrotechnics wherever possible. We chose to use a threshold of 90% effective hazing for this analysis due to the fact that sample sizes became too small and eliminated too many groups if the threshold of 100% was employed as above.

Effectiveness of Passive Hazing treatments

Passive hazing treatments are those methods which can be placed in an area and do not need to be attended to in any way. These included the use of Western Gull effigies, plastic Owl decoys, "Big-eye" balloons, mylar tape and raptor-shaped kites. We evaluated the effectiveness of these passive hazing tools by comparing gull counts before and after their deployment in a specific area. Significance of effect was determined using paired t-tests for each deployment area.

Impacts to non-target species

We assessed the impacts of hazing activities on the five species of pinniped that reside on the South Farallon Islands year round: 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*). All hazing activities were conducted in accordance with the Marine Mammal Protection Act and an Incidental Harassment Authorization (IHA) issued by the National Marine Fisheries Service for this trial.

As part of an ongoing research program, weekly surveys of all pinnipeds present on land are conducted throughout the year. Data from the last five years (2007-2011) were averaged to determine 'historical' attendance patterns for each species. We compared these historical numbers with pinniped counts prior to and after the hazing trial to evaluate the impact of hazing activities on pinniped abundance and distribution. We tested for a significant effect of hazing on overall numbers by comparing the pre and post hazing counts (after controlling for seasonal trends) as well as comparing 2012 numbers with the historical mean. Comparisons were made separately for each of the five pinniped species present on the island.

Behavioral responses of pinnipeds to individual hazing activities 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). During analysis, we deemed “disturbance” to be any time that an animal either moved more than one meter or flushed into the water. We did not consider animals being alerted as a significant disturbance.

Although individual species did show some differences in their response, we decided to group all species together for the purpose of this analysis. This allowed us to maintain sufficient sample sizes to allow comparison of hazing treatments. We calculated both the mean and median proportion of pinnipeds disturbed as a result of each hazing treatment and used this as a measure of the relative impact of the treatments. Medians were considered a valuable parameter to consider due to the high occurrence of zeros in the data set which had a disproportionately large impact on mean values.

As with the gull hazing, we also evaluated the effect of hazer proximity on pinniped response by calculating the mean and minimum distances for which there was no pinniped disturbance observed. These distances were calculated for each hazing treatment for which there was a sufficiently large sample size to evaluate differences.

The hazing trial was conducted during the time of year when the majority of seabirds are not present on the island. However, the impact of the trial on other non-target species present was recorded as part of other long term monitoring programs and anecdotal observations, and to inform the Oiled Wildlife Care Network (OWCN) a supporter of this trial, about the potential response of these species if hazed during an oil spill response. Species of interest included Common Murre (*Uria aalge*), Brandt’s Cormorant, Brown Pelican (*Pelecanus occidentalis*), Black Oystercatcher (*Haematopus bachmani*), other shorebirds, and raptors. We noted the presence and number of individuals of these species during deployment of the various hazing techniques and recorded the number of birds affected and the type of response.

RESULTS

Gull abundance and daily hazing effectiveness

Overall gull numbers before the hazing trial were intermediate relative to the previous two years (Fig 4). The average number of gulls on the South Farallon Islands during the 10 days immediately prior to the hazing trial was 3,716 birds in 2012. This is approximately 32% lower than the same period in 2011, but more than three times greater than during 2010.

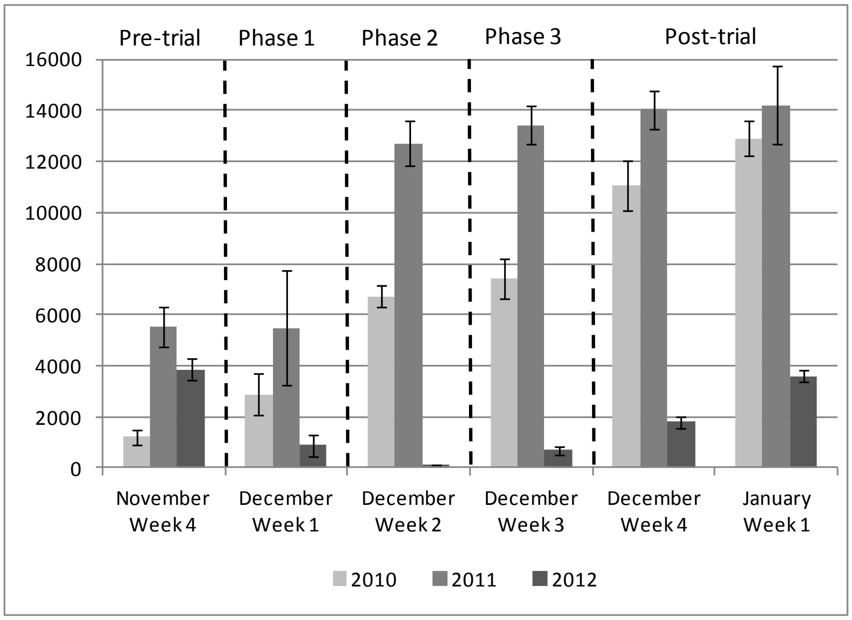

Fig. 4. Mean number of gulls present on the South Farallon Islands during the 2010, 2011 and 2012 fall/winter seasons. Active gull hazing was conducted during the first two weeks of December.

Hazing activity had a significant impact on the numbers of gulls on the South Farallon Islands. Gull numbers were dramatically reduced during Phase 2 and remained low during Phase 3 when hazing was undertaken solely by ground based personnel on SEFI (Fig. 5). Hazing efficacy appeared to remain high during Phase 3 even though the majority of WE was only hazed at dawn and dusk using lasers from the SEFI Lighthouse (Fig. 2). Gull counts during Phase 2 of the trial (the active hazing period) were significantly reduced when compared to the 10-day period immediately preceding hazing activity ($t=10.8225$, $p<0.01$, $df=17$; Fig 5) as well as the 10-day period in early January after hazing had concluded and birds had returned to the islands ($t=-7.3007$, $p<0.01$, $df=18$; Fig 5).

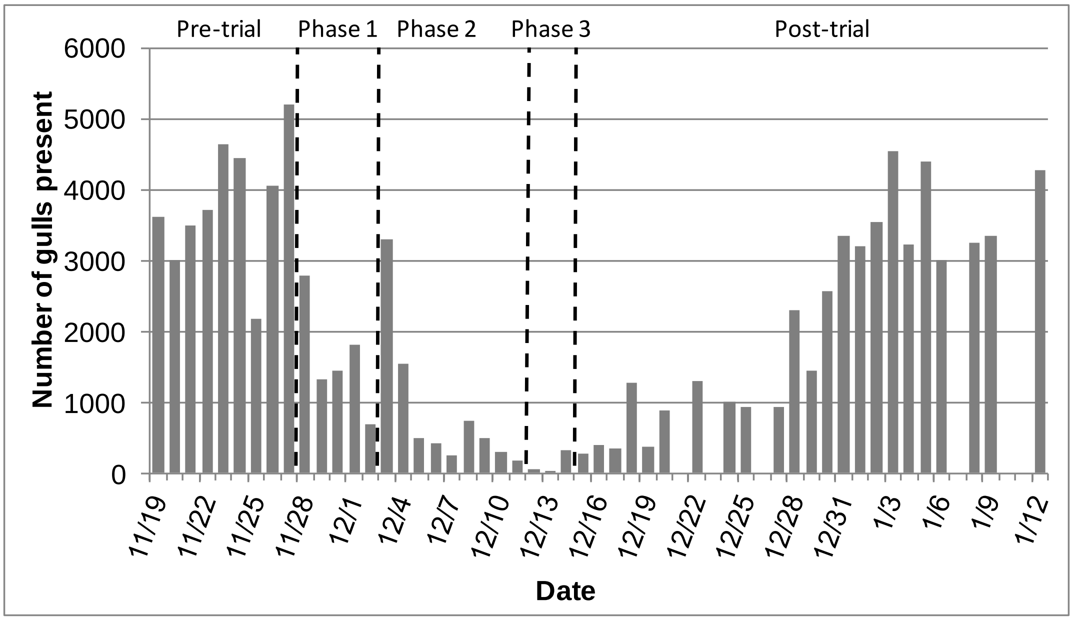

Fig. 5. The maximum number of gulls present at dawn throughout the course of the gull hazing trial. The dashed vertical lines delineate the different phases of the trial (see Table 1). Full island active hazing efforts occurred during Phase 2.

The average number of gulls present on the islands for any length of time during the day for Phase 2 was only 327, compared to 3,700 over the ten days prior to hazing. Gulls were often only present for a brief period (<30 min) prior to hazing or were on isolated roosts not targeted for hazing. In contrast, historical seasonal trends indicate that gull numbers typically increase during this same time period. The average number of gulls present on the island during the same ten day period was 4,795 in 2010 and 9,102 in 2011. This represents a 93% to 96% reduction in the number of gulls present when compared to previous years (Fig 4) and is significantly different from both previous seasons (2010 $t=6.1246$, $p<0.01$, $df=9$; 2011 $t=6.5316$, $p<0.01$, $df=9$).

Daily hazing success

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 be baited during an eradication effort.

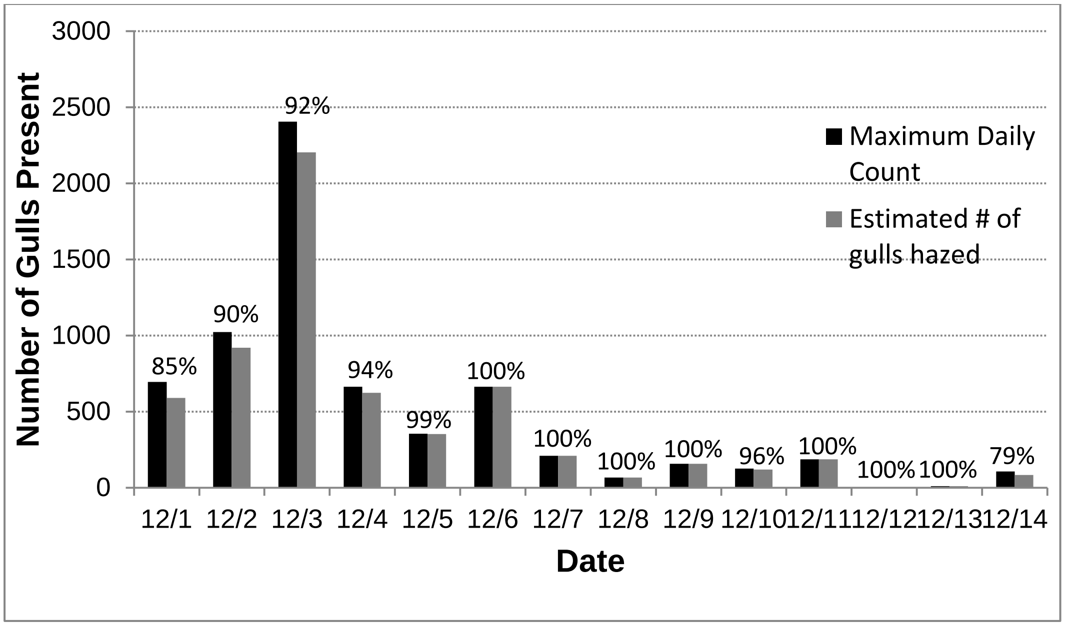

Fig. 6. The maximum number of gulls present on the South Farallon Islands at any given time (based on 1/2 hourly gull counts) and the estimated number that were successfully hazed during a gull hazing trial completed in December 2012. Percentages represent the daily hazing effectiveness. Hazing efforts were reduced on December 14 due to departure of staff.

Changes in gull distribution

There were noticeable changes in the pattern of gull attendance around the islands. During the pre-trial phase gulls were more or less evenly distributed around the common intertidal roost areas as well as in some territorial areas away from the water. By the end of the trial, they were generally restricted to small flocks, farther out in intertidal areas or on offshore islets (Fig. 7). Gull numbers were dramatically reduced and they shifted their distribution towards the extremities of the island during Phase 2. During Phase 3, gulls were confined to small roosts far out in the intertidal and on islets. Islets where gulls were allowed to roost included Sea Lion Islet, Saddle Rock and Sugarloaf (Fig. 7.) and these birds did not appear to attract other gulls.

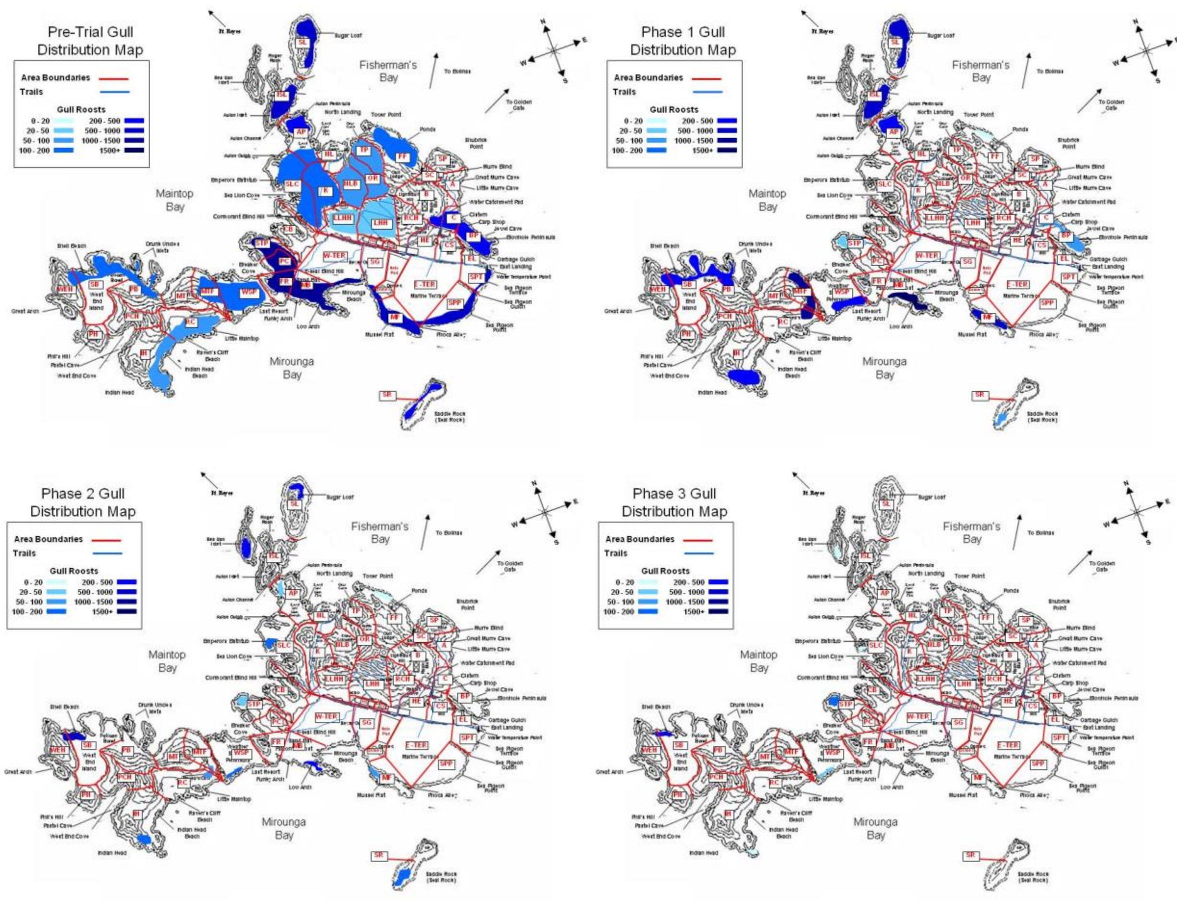

Fig. 7. Location of the main gull roosting sites prior to and during a gull hazing trial completed on the South Farallon Islands. Monitoring began on November 28, 2012.

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. 5). In addition to overall reduced gull abundance, spatial changes in gull distribution were observed during the trial. In general, gulls were kept off 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 Peninsula, Weather Service Peninsula and Study Point Peninsulas (Fig. 7).

Hazing efficiency of individual treatments

We calculated the mean and median hazing efficiency for each of the individual hazing treatments (Appendix 2). However, some treatments were used infrequently and sample sizes were too small to make meaningful comparisons. After visually examining the data, we decided to group similar treatments together if there were no noticeable differences in their hazing effectiveness. For example, there was no difference in median hazing efficiency between the Avian Dissuader and the Aries Phazer (Appendix 2) so these treatments were combined into the category "laser" for the purposes of analysis. We also combined both of the smaller Bird Gard Super Pro 4 speaker biosonic units (combined data hereafter referred to as bg4), all of the pyrotechnics (pyro) and all of the treatments which combined pyrotechnics with additional hazing treatments (pyroplus). This had the effect of reducing the overall number of treatment groups and increasing the sample size within each group, thereby allowing for more robust comparisons.

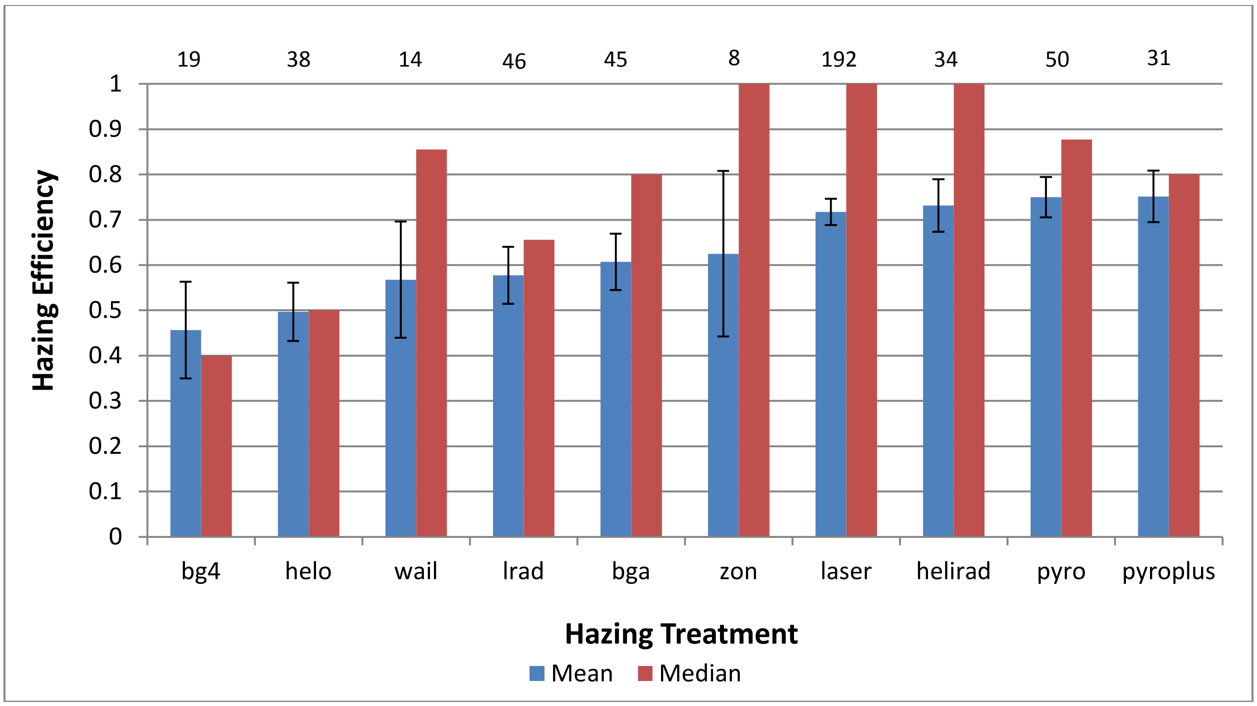

Figure 8: Mean (± standard error) and median hazing efficiency by treatment group. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

There was significant difference between treatments (Anova: F=2.93, df 9; $p<0.002$; Fig. 8) with lasers, helirad, pyrotechnics and pyrotechnic combinations (pyroplus) being, on average, more efficient at hazing gulls than either of the smaller Bird Gard Super Pro units (bg4) and the helicopter by itself. Gulls appeared to be tolerant to the noise and presence of the helicopter limiting its effectiveness as a hazing tool unless it was used in conjunction with other methods e.g. helirad. Other treatment groups were statistically similar to each other. It is worth noting that the Zon propane cannon, though less efficient on average, had a median efficiency of 1. This is likely a result of several malfunctions early in the hazing trial which rendered the treatment ineffective and reduced average efficiency of this method.

Among the individual pyrotechnics employed, CAPA rockets and screamers were on average more efficient than bangers and crackers (Fig. 9). Caps, when used in isolation, were not effective and were not used after the first few tests. When caps are removed from the analysis, there were no significant differences between pyrotechnic types (Anova: F=0.63, p=.7079, df=6). Therefore, we feel justified in grouping all pyrotechnics together for subsequent analyses.

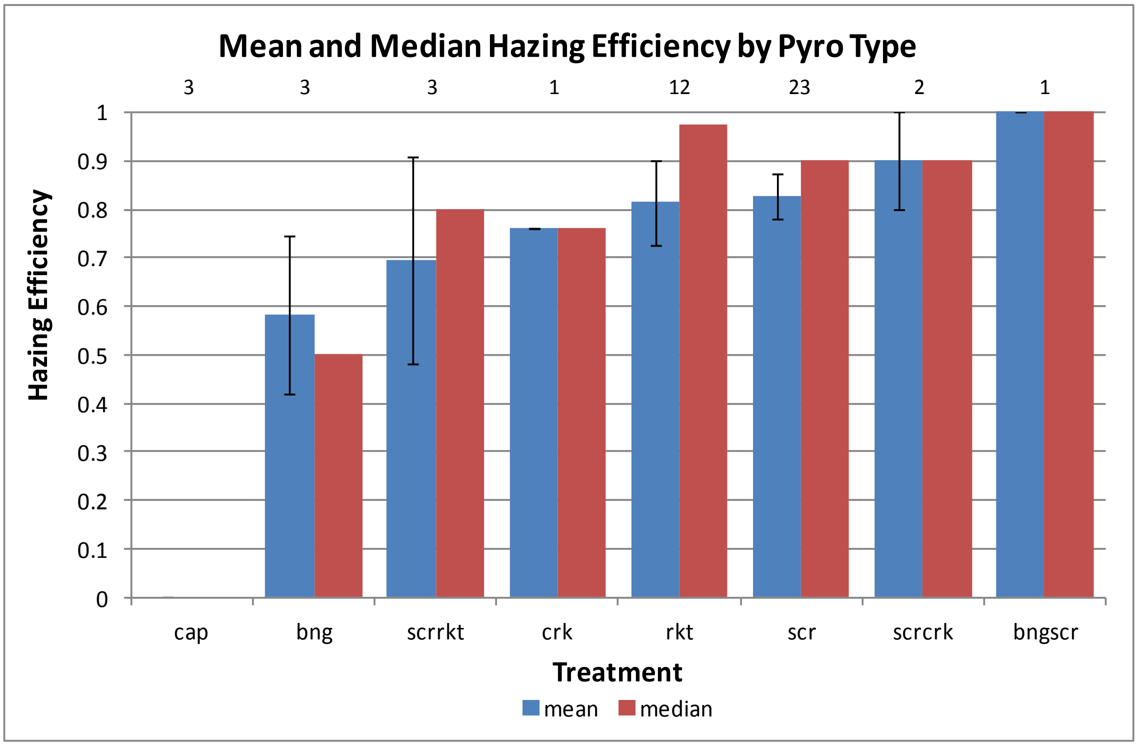

Figure 9: Mean (± standard error) and median hazing efficiency by specific type of pyrotechnic or combination of pyrotechnics used. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

Effective distances of individual treatments

Distance between the hazer and the intended target was not a reliable indicator of success. Regressions of hazing efficiency vs. distance in general and individually for each hazing method revealed no significant relationships.

However, our goal was to determine effective distance for the various hazing treatments tested. In other words, how far away the hazer could be (or conversely how close they needed to be) in order to clear all gulls from a targeted area.

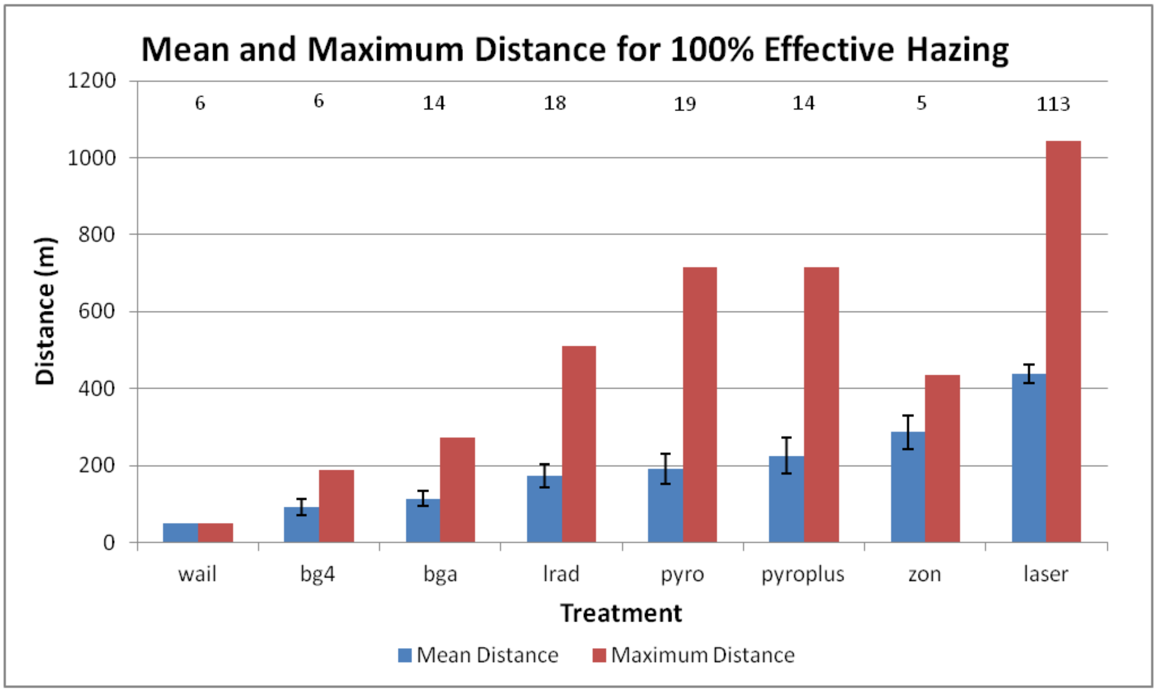

Figure 10: Mean (± standard error) and maximum effective distance by treatment group. See Appendix 2 for treatment legend and description of treatment groups. Values along the top x axis indicate sample size.

There were significant differences between groups (Anova: F=131, 9 df; p<0.0001; Fig. 10). Lasers (when used in low light situations at dawn and dusk) were successful at significantly greater distances than most other treatments whereas the Wailer and Bird Gard biosonic units were only effective over relatively short distances.

Figure (11) below shows the relative effective distances for each of the individual pyrotechnics tested (not including combined pyrotechnic treatments). In general, CAPA rockets and cracker shells were effective at greater distances than screamers and bangers, though there were no statistically significant differences between the different treatments (Anova: F=2.84, p=0.113, df=3).

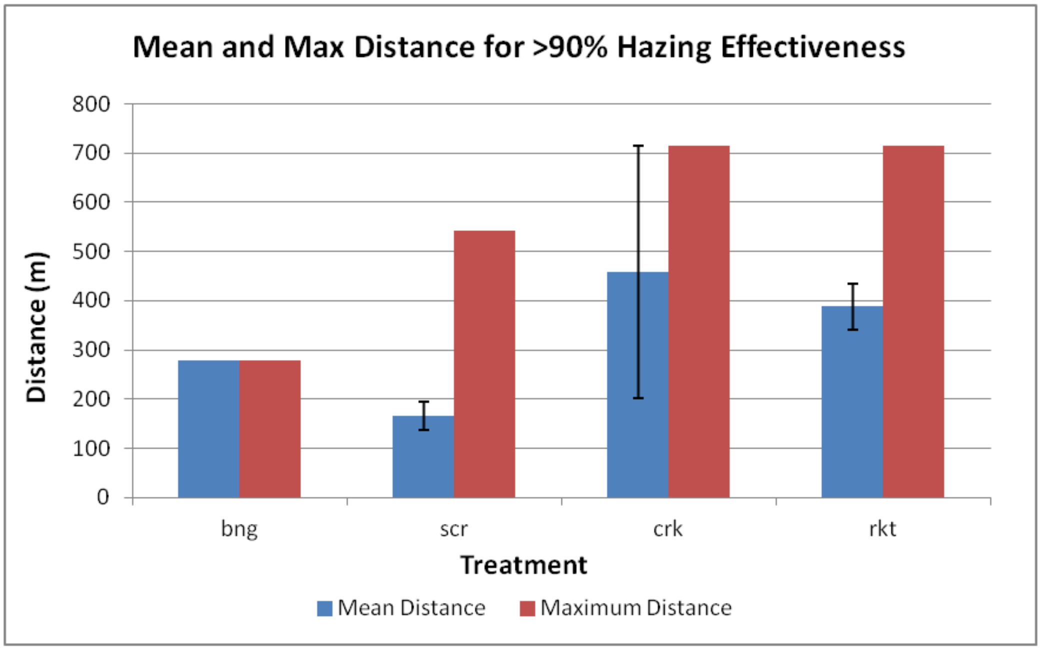

Figure 11: Mean (± standard error.) and maximum distance for which >90% hazing efficiency was achieved for each of the individual pyrotechnic treatment types. See Appendix 2 for treatment legend and description of the different pyrotechnics used.

Non-target impacts of gull hazing treatments

We observed little impacts to non-target birds as a result of the hazing activity. Because the trial was 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. However, in order to assess the potential for hazing other species in an oil spill situation, we did note the presence and numbers of individuals of all bird species that were present when hazing was conducted and made a general estimate of the number of birds affected and the type of response.

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 2 and 3 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. There did not seem to be any difference between the individual hazing treatments in their likelihood to disturb non-target birds. Bird Gards, Helicopter hazing, LRAD, pyrotechnics and lasers all caused disturbance.

The overall impact of gull hazing activities on pinnipeds was also minimal. Pre-trial counts for all species were statistically similar to (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 than (Steller Sea Lion: t=3.751, p=0.001, df=22, Northern Fur Seal: t = 4.125 p < 0.001, df=22) numbers observed during the same period in the previous five years (Fig12). Fur seals in particular were present in greater numbers than the prior five year average owing to their recent and continuing rapid population growth.

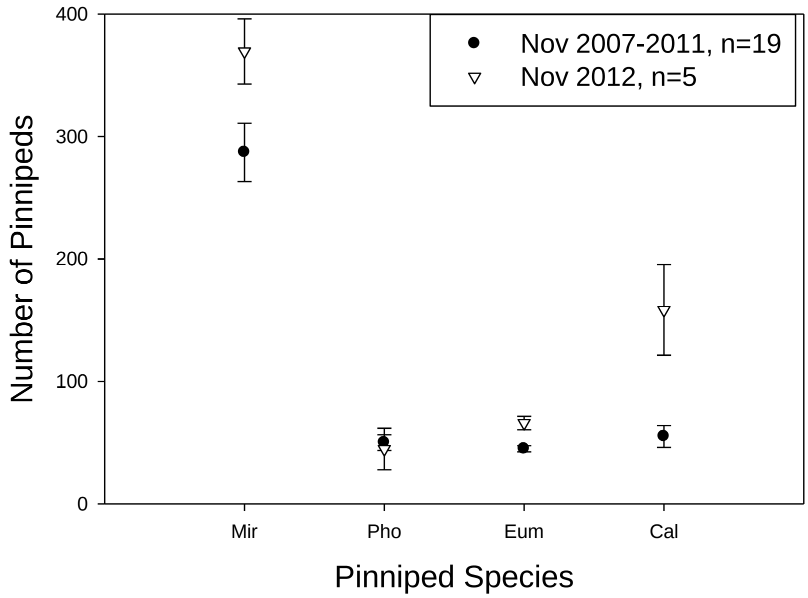

Fig. 12. Pretrial Farallon Pinniped numbers for November. Historic data (2007-2011) compared with pre-trial data from 2012. Mean monthly values with standard errors are plotted. Species shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal)

Likewise, 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) (Fig. 13), and California Sea Lions (t = 1.096, p = 0.309, df=7; Fig. 14). 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 13). 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.

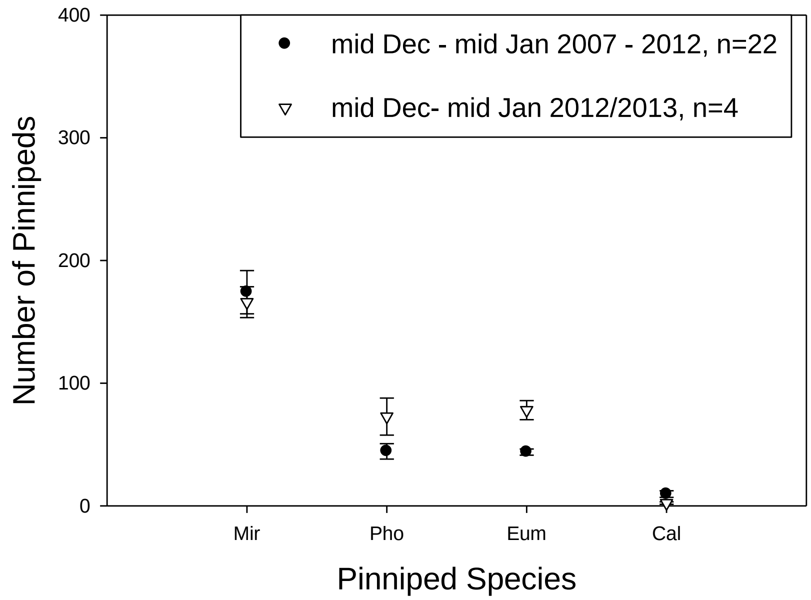

Fig. 13. Post-trial Farallon Pinniped numbers for mid-December to mid-January. Historic data (2007-2011/2) compared with pre-trial data from 2012/2013. Mean monthly values with standard errors are plotted. Species shown are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), and Northern Fur Seal (Cal).

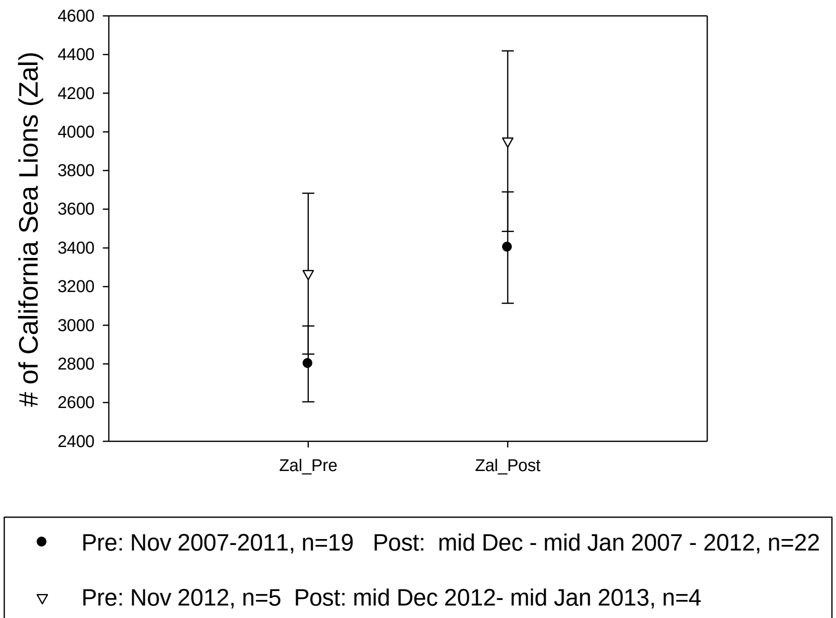

Fig. 14. Pre and Post Trial Farallon California Sea Lion (Zal) numbers. Historic data (2007-2011/2) compared with trial data from 2012/2013. Mean monthly values with standard errors are plotted.

Effect of individual treatments on pinnipeds

Biosonic hazing methods had little effect on pinniped behavior, with no significant disturbance (moving >1m or flushing) observed for elephant seals and harbor seals, and less than 3% of the animals disturbed for all other species when present in hazing target areas (Fig 15).

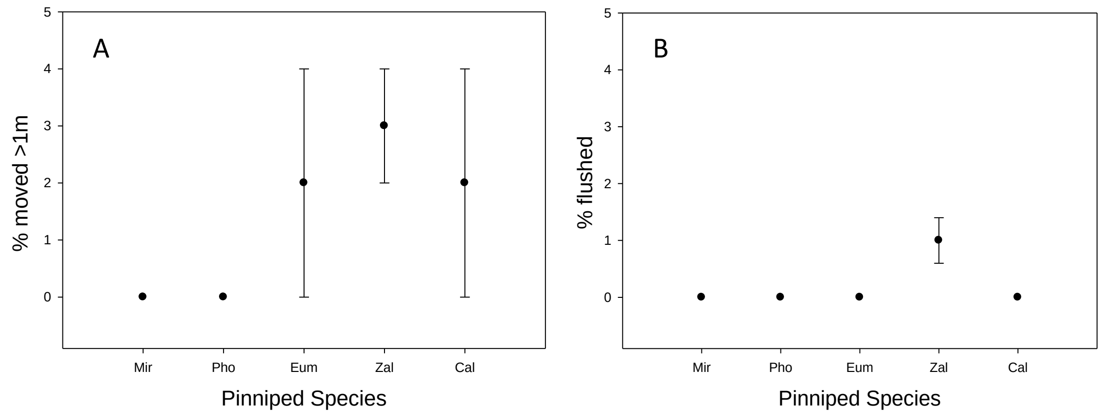

Fig. 15. Biosonic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=103). Methods used include Bird Gard, Wailer, LRAD, and LRAD from Helicopter. A) Percentage of pinnipeds moved >1m with standard error; and B) percentage of pinnipeds flushed with standard error. Species are Northern 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. Greater than 15% of California Sea Lions and approximately 5% of Steller Sea Lions were disturbed when pyrotechnics were employed (Fig. 16). Harbor seal disturbance rates were high with more than 20% of the animals flushing in the presence of pyrotechnics (Fig. 16 B). This response was primarily driven by the loudest of the pyrotechnic devices, the CAPA rocket.

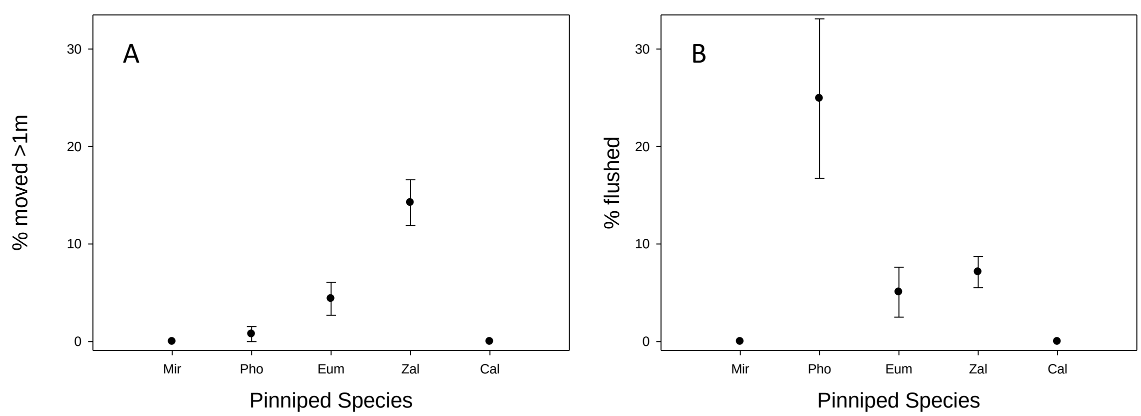

Fig. 16. Pyrotechnic gull hazing tool effects on Farallon Pinnipeds in target areas (total n=91). Methods used include screamers, bangers, and CAPA rockets. A) Percentage of pinnipeds moved > 1m with standard error; and B) Percentage of pinnipeds flushed with standard error. Species are Northern Elephant Seal (Mir), Harbor Seal (Pho), Steller Sea Lion (Eum), California Sea Lion (Zal), and Northern Fur Seal (Cal)

In general, for all hazing treatments, California Sea Lions were the most sensitive to being disturbed while Northern Elephant Seal and Northern Fur Seal were rarely affected.

There was a significant difference in mean pinniped disturbance between treatments (Anova F=128, 10 df; p<0.001) with pyrotechnics and pyrotechnics in combination with other treatments causing the greatest level of disturbance to pinnipeds whereas biosonic hazing methods showed little effect on pinniped behavior (Fig. 17). Lasers consistently had no effect on pinniped behavior and were not included in statistical analyses.

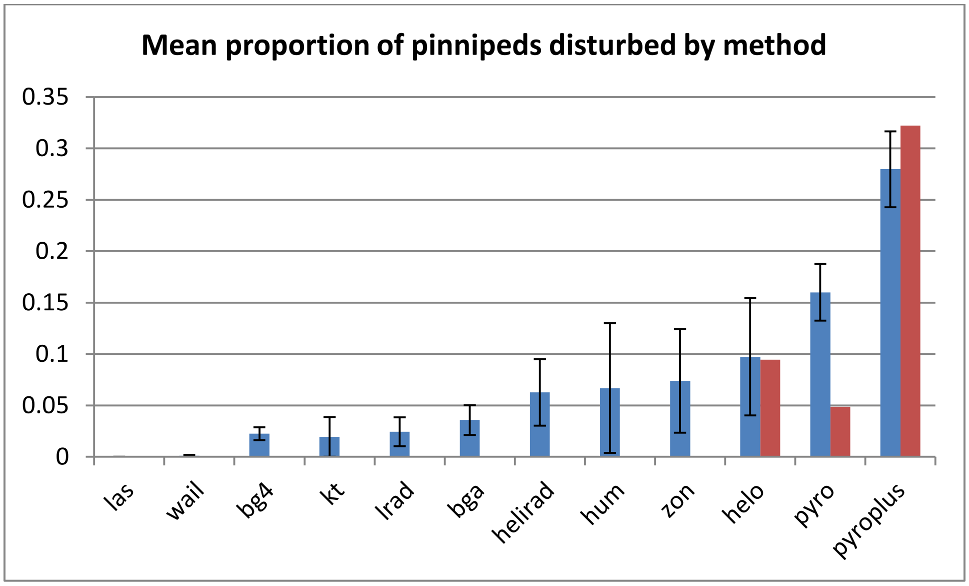

Fig. 17. Effect of individual hazing tools on pinniped disturbance. Presented are mean ± standard error (blue) and median values (red). Data presented for all pinniped species combined. See Table 1 for explanation of treatment abbreviations.

Effect of proximity on disturbance

As with the bird hazing efficiency analysis, there were no direct correlations between linear distance to the nearest pinniped and proportion of animals disturbed. We calculated the mean and minimum distance between the hazer and the nearest pinniped for which no disturbance was recorded. There were no significant differences found between groups but general patterns were observed. Pyrotechnics, LRAD and Zon caused disturbance to pinnipeds at a greater distance, on average, than other methods tested (Fig. 18).

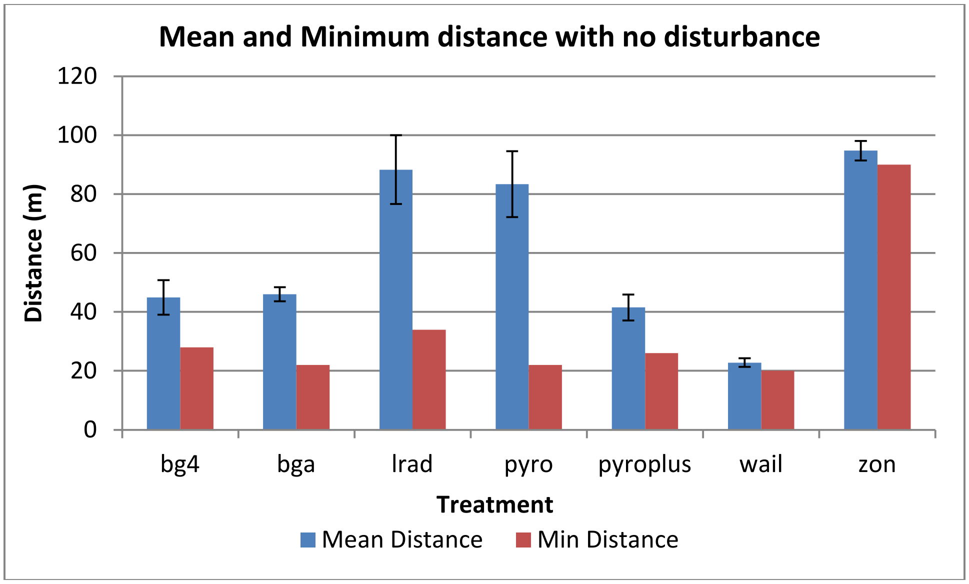

Fig. 18. Mean ± standard error (blue) and minimum distance (red) required for zero disturbance to pinnipeds for different hazing tools. Data presented for all pinniped species combined. See Appendix 2 for explanation of treatment abbreviations.

Passive Hazing Summary

We tested the effectiveness of passive hazing devices such as effigies, owl decoys, kites and mylar tape by comparing gull counts before and after their deployment (Fig. 19). These figures illustrate the reduction in Western Gull numbers when the effigies and other passive hazing devices are present. Counts of gulls prior to hazing treatments were significantly lower in the presence of effigies. Simple T-tests for each area demonstrate significantly lower gull counts when effigies are present (AP t = -3.0575, p = 0.008, df=8; BP t = -2.1985, p=0.0226, df=14; MB t = -2.2406, p=0.0209 df=14; MF t = -2.1085, p=0.0365 df=7; WSP t = -1.8451, p=0.0491, df=9). Other passive hazing methods were not statistically analyzed because they were not used often and the sample sizes were too small to draw any statistically supported conclusions.

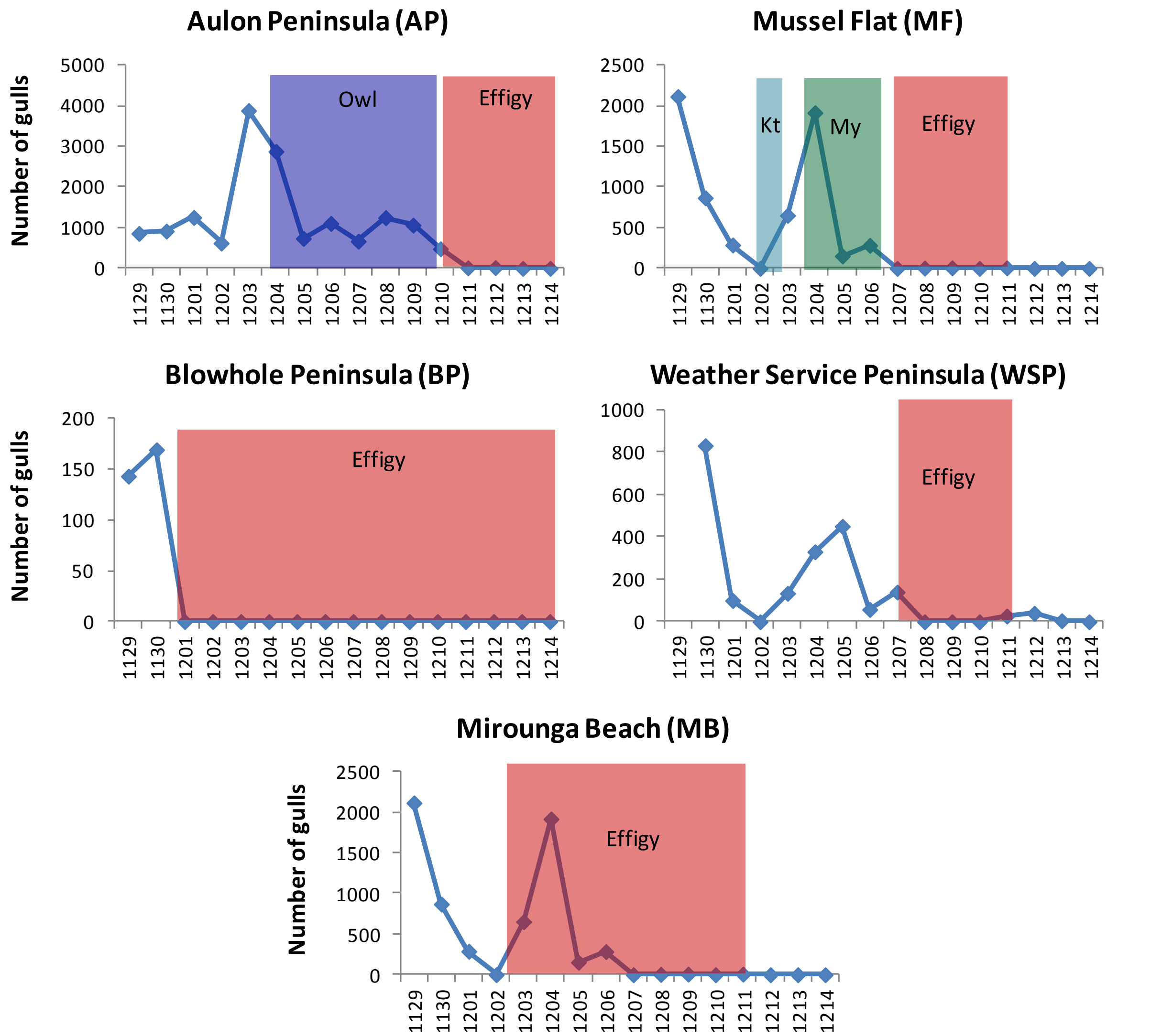

Fig. 19. Western Gull counts in the presence and absence of passive hazing tools for each hazing sector where passive hazing tools were deployed (see Fig. 3 for locations). Passive hazing tools included Western Gull effigies, kites (kt), mylar tape (my) and owl decoys (owl).

DISCUSSION

This study was designed and conducted with two main objectives. The first was to demonstrate that it is possible to keep the majority of Western Gulls off the South Farallon Islands for a period of time in order to minimize their potential exposure to rodenticide during the proposed mouse eradication. In addition, we wished to test the efficacy of a variety of individual hazing techniques and tools in order to assess their utility in future hazing efforts, such as during the mouse eradication or an oil spill. These two objectives sometimes conflicted with each other in which case the overall goal of reducing gull numbers took precedence over testing individual methods. This resulted in some unavoidable compromises in data quantity and quality for individual hazing treatments. However, we believe that the overall results are valid and provide valuable information on the relative effectiveness and impact of the hazing treatments tested both alone and in various combinations.

Overall hazing success

Results from this study clearly demonstrated that a well planned and executed hazing operation can effectively reduce the number of gulls present on the South Farallon Islands and minimize the number of individuals that would be likely to come into contact with rodenticide. Hazing efforts resulted in significantly reduced gull numbers when compared to the same time period in previous years as well as in comparison to pre-trial counts in the same year. Western Gulls roosting on the islands were reduced from an average of approximately 3,700 present on the island prior to the trial to only a few hundred individuals present for any length of time during the day by the end of Phase 2. Daily hazing efficiency also increased as the trial progressed, resulting in 100% of the birds present on the island during any given day being successfully hazed. The high hazing efficiency achieved resulted in effectively no gulls being present for the majority of each day by the end of the hazing period. In addition, gull distribution around the island was significantly altered such that by the end of the trial, birds were only present far out in the intertidal zone and on a few scattered and wave washed offshore islets where they would not be expected to come into contact with rodent bait.

We were not able to conduct comprehensive surveys at night but anecdotal evidence indicates that if gulls were successfully hazed off the island at dusk they did not return until after sunrise. Gulls were not detected during random nighttime searches using a high powered spotlight and they were not heard calling. Furthermore, when we were able to successfully haze all gulls off the island at dusk, our surveys the following morning revealed no roosting birds. It is unlikely that birds that were forced to find a different roost for the night due to our hazing activity would return to the island during the night and depart again before sunrise. This gives us confidence that successful daytime hazing operations, like those we achieved during phase 2 of the trial, will prevent birds from encountering bait, even when no hazing activity occurs at night. We also believe that should more nighttime activity of gulls be detected during the actual rodent removal operation, that lasers could be very effectively used to deter their presence as needed.

Hazing treatments

In all, we tested 21 different individual hazing treatments as well as multiple combinations of these tools throughout the hazing period. Although we were not able to test each method individually in all situations, we were able to demonstrate significant differences in overall hazing efficiency amongst the tools tested. In general, active hazing treatments that involved both sound and motion were more effective than one dimensional treatments or passive treatments. Likewise, there were significant differences in the level of pinniped disturbance caused by the various hazing methods with louder and more active treatments such as pyrotechnics and pyrotechnics combined with biosonics causing greater disturbance than other methods. For all hazing treatments, California Sea Lions were the most sensitive to being disturbed while Northern Elephant Seal and Northern Fur Seal were rarely affected. This likely reflects both relative differences among the species in their response as well as vastly different encounter rates during the trial. For example, sea lions were present in the target area 94% of the time that a hazing treatment was deployed, whereas fur seals were only present 13% of the time. The localized nature and low numbers of fur seals in December prevented them from being exposed to many of these techniques, thereby limiting our ability to evaluate their response.

The least useful tools tested were mylar tape and balloons. These tools were difficult to deploy, often broke down or were ripped off their tethers and lost, and appeared to have little effect on the gulls. Kites were moderately effective when deployed after birds were flushed utilizing other techniques, but they were difficult to keep aloft in strong. As a result, these tools were not tested frequently and were hardly used after the first few days of the trial. While low sample sizes for these treatments make it impossible to make a quantitative assessment of their true effectiveness, there appears to be little evidence to support their use under the conditions typically expected at the South Farallon Islands. The only passive hazing treatments that were routinely effective were the Western Gull effigies. These were particularly effective at dissuading birds from returning to a roosting site after another treatment method had been used to flush them. As depicted in Figure 19, gull numbers were dramatically reduced after the deployment of effigies and remained low for the duration of time they were present. Aside from any disturbance caused during their deployment, effigies had no impact on pinnipeds or other bird species present in the area. Although they are only effective over a short range, effigies proved to be an especially efficient tool during this trial.

Lasers, pyrotechnics and various combinations of pyrotechnics with additional hazing devices were the most effective at dispersing gulls from their roosts. These treatments also had the most substantial effect on other bird species present. These treatments all had mean hazing efficiencies over 70% and were also effective at the greatest distances.

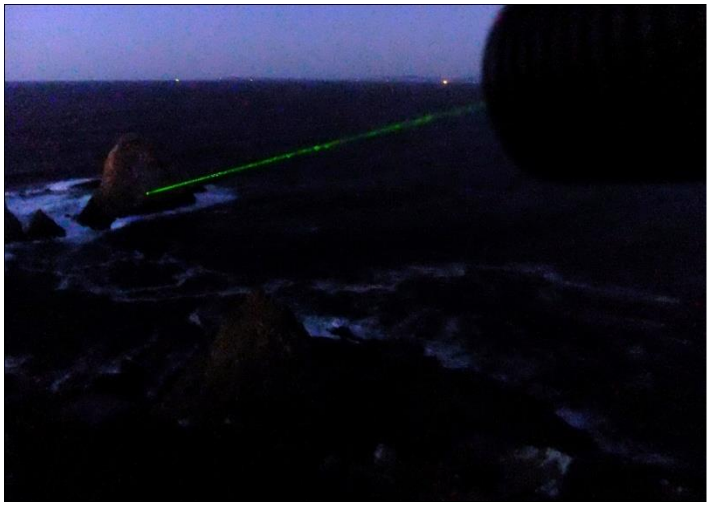

Fig. 20. Aries Phazer being used to haze roosting gulls from Sugarloaf at dusk.

Lasers were especially effective over long distances when used at dawn and dusk while it was still dark enough for the birds to see the beam. They were useful both for clearing roosting gulls and also discouraging them from landing. An added benefit of lasers was that they caused no disturbance to pinnipeds making them both highly efficient and non-disruptive. We tested three different types of lasers with varying power and intensity during the trial. There was no noticeable difference in median hazing efficiency between the Avian Dissuader and the Aries Phazer (Appendix 2). Both were highly effective over distances up to a kilometer. The small penlight laser was less powerful and was typically only effective over a relatively short range.

Pyrotechnics and pyrotechnics combined with other hazing treatments had the highest overall hazing efficiency. They were effective over long distances, up to 700m and unlike the lasers were equally useful during all times of the day. Although there were no statistically significant differences observed among the individual pyrotechnic devices deployed, the general pattern observed was that CAPA rockets and cracker shells were more efficient for longer distances whereas the bangers and screamers were most effective over short to medium ranges. Pyrotechnics and especially pyrotechnics combined with other tools caused the greatest amount of disturbance to pinnipeds of all the tools tested. Screamers (due to no abrupt bang sound) and CAPA rockets (that deployed to a greater height or distance offshore before exploding) appeared to have reduced impact on pinnipeds in comparison to the bangers and cracker shells.

Biosonic hazing devices, including all Bird-Gard units, the Wailer and the LRAD were generally intermediate in both their hazing efficiency and in their level of disturbance to pinnipeds. All amplified biosonics worked over a moderate distance of a few hundred meters and generally caused low levels of disturbance to pinnipeds unless deployed at very close range. These devices worked moderately well on their own, but were considerably more effective when combined with another hazing device such as pyrotechnics or the helicopter. Of all biosonics tested, the LRAD seemed to be the most effective and also offered the ability to directionally project sounds so as to better target individual gull roosts without non-target disturbances. The LRAD was particularly effective when deployed from the helicopter circling over the gull roost. This treatment, termed the helirad, combined the visual stimulus of a mobile, large and unfamiliar object with a predator or distress call to great effect. This treatment was equally as effective as pyrotechnics and pyrotechnic combinations but with lower pinniped disturbance. The helirad was also highly effective in dissuading gulls from returning to the island to roost for the night. Gulls would approach the island in large numbers just before dusk. The helirad was deployed to "intercept" these individuals, causing them to alter direction and depart the island to find an alternative night roost.

Tolerance by gulls to the noise and presence of the R22 helicopter suggests that UAV's are likely to have limited effectiveness as a hazing tool unless they can be deployed in conjunction with other methods such as a LRAD. However, the helicopter proved invaluable as a method of detecting and monitoring gulls in areas that were difficult to observe from the ground. Based on these observations, we see UAV's as offering a highly efficient method for monitoring in real time the effectiveness of future hazing operations especially those that span large areas.

Effect of proximity

One of the objectives of this study was to determine the effective distances for each of the different hazing treatments. We expected that there would be some negative relationships in which the effectiveness of any particular treatment would decrease with linear distance. However, our data did not show this. While there were significant differences between hazing treatments in terms of the average distance for which they were effective, there were no significant relationships between distance and effectiveness for any individual method. There are several possible reasons for this. During the course of the trial, we chose tools specific to the hazing target and did not specifically test each treatment at varying distances. If the gull roost was far from the hazer, then we chose a treatment that was most likely to impact the target. Also, there was a large amount of variation in the effectiveness of each hazing treatment regardless of distance. This may be due to other variables such as weather, temporal proximity to another hazing event or gull density which was not considered during this analysis.

Likewise, there were no significant relationships between hazer proximity and pinniped disturbance. For example, when using the Bird Gard Super Pro Amp (bga) the average distance for which no disturbance was noted was 46m. The minimum distance for which there was no disturbance was 22m (also the minimum distance for which the bga was used). This would seem to suggest that if you use the bga when pinnipeds are more than 50m away there should be relatively little disturbance.

However, disturbance was also noted at far greater distances at times, in some instances up to 136m. In fact the greatest disturbance occurred at the greatest distance. A similar pattern emerges for other hazing methods where there are times when they can be used in relatively close proximity to pinnipeds without any effect and other times where animals that are relatively far away will move or flushes in response. This may have been due to accumulated subtle disturbances from repeated hazing treatments in short periods, or other factors.

As with hazing efficiency, there were general differences between hazing treatments in the average distance required for no disturbance. Pyrotechnics, pyrotechnics combined with another method, LRAD and Zon cannons caused disturbance to pinnipeds at a greater distance, on average, than other methods tested. The results suggest that to minimize impact, hazers should be farther away, on average, from pinnipeds when using Zons, LRAD or pyrotechnics than when using other hazing treatments.

It should also be noted that for those treatments that involved an auditory component, the sound emitted did not always occur at the hazer location. For the biosonics such as the Bird Gard and LRAD units this was typically the case, but for pyrotechnics it could be highly variable. In some cases the sound was generated at a short (i.e. Zons, caps) or medium distance (shell crackers, bangers, screamers) from the hazer. In other cases the sound could actually emit from point a long distance from the hazer as in the case of CAPA's. CAPA's were sometimes intentionally directed at an angle to the birds if they were near pinnipeds in order to get the loud bang but not close to the pinnipeds. Recognizing that it was not possible to obtain data on how close the sound occurred to the birds versus the hazer's physical location, the analysis in this report represents our best effort. However, it should be noted that we were not able to completely account for the effect of distance.

This project set out to do several things and compromises in data quantity and quality were inevitable. Insufficient independent tests of the specific treatments were completed to allow robust quantitative analysis of all of their individual effectiveness. There was also the necessary focus on gulls and relatively few other bird types present. However, the data and analyses presented serve to effectively demonstrate significant differences in the relative effectiveness of the treatment methods tested for gulls and their impact on non-target species. The lessons learned from the Farallones trial will provide valuable guidance to resource managers and oil spill responders for planning and implementing future avian hazing operations.

ACKNOWLEDGEMENTS

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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.

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APPENDIX 1: Hazing methods and product descriptions for all hazing treatments used in a 2012 Gull Hazing Trial on the South Farallon Islands.

Description (*abbreviation*)	**Use**	**Location**
Human Movement *(hum)*		
Movement of people on foot across the island	Monitoring and setting up hazing equipment occasionally flushed gulls from roost sites	Various locations
Effigies *(ef)*		
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 Phases 2 and 3 of the trial.	Various locations at persistent gull roosts (See Figs. 3 & 19)
Mylar Tape *(my)*		
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 (MF) and Blowhole Peninsula (BP) (See Fig. 3)
Kites *(kt)*		
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 raptor shaped standard kite and an Allsopp Helikite helium-filled balloon kite. 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 (E-Ter) or Aulon Peninsula (AP). See Fig. 3.
Balloons *(bal)*		
Inflatable mylar “big-eye”/”scare eye” balloons (Bird-X Inc. 300 N Oakley Blvd. Chicago, IL 60612) are highly reflective and mimic a predator’s eye. They are often tied to poles or suspended from overhanging lines where it can move in the wind and reflect sunlight.	Balloons were used infrequently at a few roost locations to try to discourage gulls from roosting.	Positioned as close to intertidal gull roosts areas as possible on the Marine Terrace (E-Ter) and Mirounga Beach (MB). See Fig. 3.
Lasers *(laser)*		
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 (las1), a red Avian Dissuader™ (Sea Technology, Inc., Albuquerque, NM; las2), and a green Aries Bird Phazer Laser® (JWB Marketing LLC, 2308 Raven Trail, West Columbia, SC 29169) (las3). 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	Lasers were used primarily from Lighthouse Hill and West End locations. See Fig. 3.

	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.	
Zon cannons *(zon)*		
Propane cannons, also called gas exploders, produce a loud, directional blast similar to that emitted by a 12-gauge shotgun.	Zon® Mark 3 cannons (Sutton Ag Enterprises, 746 Vertin Ave, Salinas, CA 93901) were tested but 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 west Marine Terrace (W-Ter) and at Sea-lion Cove (SLC). See Fig. 3.
Bird Gard Units *(bg, bgm, bga, bg4)*		
Biosonics, or bioacoustics, as a hazing method, involves using animal alarm or distress calls to alter the behavior of a target species.	Three different Bird Gard biosonic units (Bird Gard, LLC, 270 E. Sun Ranch Drive, P.O. Box 1690, Sisters, OR 97759) were tested: 1) A Bird Gard Super Pro® with four small speakers (bg); 2) a Bird Gard Super Pro® with a 4 speaker multi-directional speaker tower (bgm) and; 3) a Bird Gard Super Pro-Amp® with 20 amplified multi-directional 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 was triggered on command or randomly to flush gulls or deter them from returning.	Birdgard units were moved around the island and used at many locations.
Marine Phoenix Wailer*(wailer; wail)*		
The Marine Phoenix Wailer is a biosonic device designed to prevent birds from alighting on the water and typically used to discourage birds from landing on oil slicks.	The Marine Phoenix Wailer® (Phoenix Agritech. P.O. Box 10, Truro, Nova Scotia.B2N 5B6,Canada) is a large, multi-speaker biosonic hazing tool. For the trial, the sound-emitting component of the Wailer was removed from its marine floats and placed on the ground above a gull roost. It was programmed to play pre-recorded distress and predator calls.	The Wailer was positioned predominantly within the Marine Terrace area above Mussel Flat (MF). (See Fig. 3)
Long Range Acoustic Device *(LRAD)*		
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. (LRAD Corporation, 16990 Goldentop Road, STE A, San Diego, CA 92127)	Used at several locations across the island and from the air.
Pyrotechnics *(pyro)*		
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 (Bird Bangers®, Screamer Sirens®, and CAPA rockets® (Reed-Joseph International Company, 800 Main Street, Greenville, MS 38701); Bird Bombs®, Bird Whistlers®, and Shell Crackers (Sutton Ag Enterprises, 746 Vertin Ave, Salinas, CA 93901), were tested. Quieter or less disturbing charges were used first when near or close to pinnipeds, to minimize any unnecessary disturbance, to	Various locations around the island

	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.
Helicopter *(helo)*	
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 (Robinson Helicopter Company, 2901 Airport Drive, Torrance, CA 90505) 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

BirdGard and Pyrotechnics *(bgapyro; pyroplus)*

BirdGard units were used in combination with pyrotechnics. Typically the Bird Gard was triggered to play a predator or distress call in order to flush gulls from their roost. This would be followed immediately by the deployment of one or more pyrotechnics to dissuade the gulls from returning.

LRAD and Pyrotechnics *(lradpyro; pyroplus)*

The LRAD unit was used in combination with pyrotechnics. Typically the LRAD was triggered to play a predator or distress call in order to flush gulls from their roost. This would be followed immediately by the deployment of one or more pyrotechnics to dissuade the gulls from returning.

LRAD and Helicopter *(helirad)*

The LRAD unit was used from the helicopter to haze gulls from less accessible locations or to discourage gulls from approaching the island to roost..

Laser and helicopter *(helolas)*

Lasers were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again. This combination was used infrequently because the lasers were only effective in low light conditions when the helicopter could not fly.

Pyrotechnics and helicopter *(pyroplus)*

Pyrotechnics were used to flush roosting gulls from land. Helicopter hazing then followed to disperse gulls and dissuade them from landing again.

APPENDIX 2: Hazing efficiency by treatment type

Listed are the specific hazing treatments or combination of treatments used, the general treatment categories and abbreviations used in the analysis along with the mean (± standard error) and median hazing efficiency for each treatment.

Hazing Treatment	Treatment Category	Specific Treatment Abbreviation	Combined Treatment Abbreviation	Mean Hazing Efficiency	S.E.	Median Hazing Efficiency	N
Bird Gard Super Pro - 4 speaker	Biosonic	bg	bg4	0.33	0.14	0.00	12
Bird Gard Super Pro - Speaker Tower	Biosonic	bgm	bg4	0.67	0.14	0.70	7
Bird Gard Super Pro Amp	Biosonic	bga	bga	0.61	0.06	0.80	45
Long Range Acoustical Device (LRAD)	Biosonic	lrad	lrad	0.58	0.06	0.66	46
Marine Wailer	Biosonic	wail	wail	0.57	0.13	0.86	14
Zon propane cannon	Biosonic	zon	zon	0.63	0.18	1.00	8
Starter pistol cap	Pyrotechnic	cap	pyro	0.00	0.00	0.00	3
Banger	Pyrotechnic	bng	pyro	0.58	0.16	0.50	3
Screamer	Pyrotechnic	scr	pyro	0.83	0.05	0.90	23
Cracker Shell	Pyrotechnic	crk	pyro	0.76	0.00	0.76	1
CAPA Rocket	Pyrotechnic	rkt	pyro	0.81	0.09	0.98	12
Banger with Screamer	Pyrotechnic	bngscr	pyro	1.00	0.00	1.00	1
Screamer with Cracker Shell	Pyrotechnic	scrcrk	pyro	0.90	0.10	0.90	2
Screamer with Rocket	Pyrotechnic	scrrkt	pyro	0.70	0.21	0.80	3
Penlight Laser	Laser	las1	las	0.42	0.30	0.25	3
Avian Dissuader	Laser	las2	las	0.83	0.05	1.00	43
Aries Phaser	Laser	las3	las	0.69	0.03	1.00	146
Helicopter	Mechanical	helo	helo	0.50	0.06	0.50	38
Human	Mechanical	hum	hum	0.57	0.19	0.70	6
Bird Gard with pyrotechnic	Combined	bgapyro	pyroplus	0.61	0.09	0.63	15
LRAD with Pyrotechnic	Combined	lradpyro	pyroplus	0.78	0.16	0.90	4
Helicopter with Pyrotechnic	Combined	pyrohelo	pyroplus	0.92	0.04	1.00	12
Helicopter with LRAD	Combined	helirad	helirad	0.73	0.06	1.00	34
Helicopter with laser	Combined	helolas	helo	0.67	0.17	0.50	3
Big-eye Baloon	Passive visual	bal	bal	na	na	na	3
Kite	Passive visual	kt	kt	na	na	na	2
Mylar tape	Passive visual	my	my	na	na	na	2
Owl Decoy	Passive visual	owl	owl	na	na	na	1
Western Gull Effigy	Passive visual	ef	ef	na	na	na	7

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

30 January 2014

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 particular 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 via ingestion of bait 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 rodenticide 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 other factors 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 theoretical fate (i.e., alive or dead) of 11,000 gulls, which is the peak number of gulls expected on the SFI 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 will 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 is equal to the user selected value for expected

hazing success. Gulls that are not responsive to repeated hazing are assumed to be present each day to forage on SFI.

Based on field data, 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 and weathering if a significant rainfall event occurs shortly after application, and other factors. 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 and diphacinone pose similar risks to non-target western gulls. Although diphacinone is markedly less toxic than brodifacoum, gull behavior, the duration that bait would be available, the greater amount of diphacinone bait applied, and the addition of a third application of diphacinone all serve to bring the relative risk posed by the two scenarios modeled closer together. The modeling analyses 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) (Nur et al. 2012). The modeling analyses also demonstrated that the primary route of exposure (i.e., consumption of pellets) 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 be investigated.

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1.0 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.

1.1 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 km^2 or 310,406 m^2. 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.

1.2 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 FWS Refuge biologists, helped inform many of the parameter estimates of this model.

1.3 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 pinnipeds and most marine birds 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.

However, western gulls would likely be at risk from exposure to a rodenticide due to their omnivorous and aggressive foraging habits. The purpose of this assessment is to assist in estimating the likelihood and magnitude of western gull mortality 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.

2.0 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.

2.1 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). For example bald eagle (*Haliaeetus leucocephalus*) mortality was recorded on Rat Island in Alaska following the eradication of Norway rats (*R. Norvegicus*). Eagles most likely succumbed on Rat Island after consuming rats or glaucous-winged gull (*Larus glaucescens*) carcasses that had eaten rodent bait containing brodifacoum or, in the case of the gulls, poisoned rats (Salmon and Paul, 2010).

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., 2011). No detectable concentrations of brodifacoum in water were found in any of the studies.

2.2 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).

2.3 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 and early summer breeding season (April to August) 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.

2.4 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.

2.5 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.

2.6 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.

3.0 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.

3.1 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 ai/kg body weight (bw), *TDI* is total daily intake of rodenticide (mg ai/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 aerial 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, a combination of weathering and other factors 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.

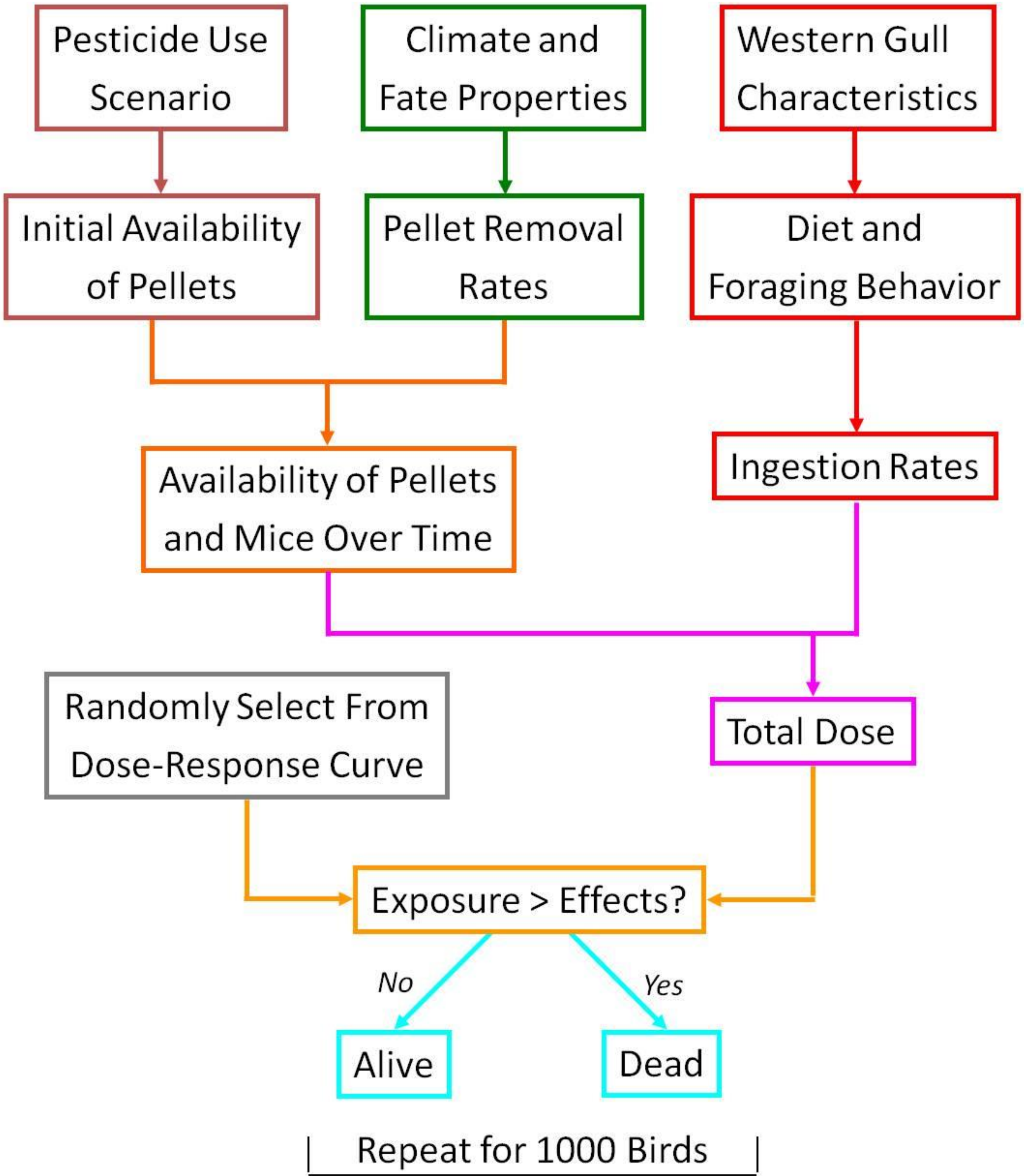

Figure 3-1. Components of western gull risk model for SFI.

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 expire for the primary and secondary routes of exposure 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 nearly constant until a significant rainfall event occurs. A significant rainfall event 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 (brodifacoum)	2		EPA, 2008	Label recommends 2 applications to 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)	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
Number of applications (diphacinone)	3			
Applications interval (diphacinone)	7	days		

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
				being unavailable to mice.
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	Grout 2012	Mean pellet weight determined from a sample of 100 placebo 3/8-inch diameter pellets.
Pellet half-life (1st application)	1	day	Grout 2012	Nov 2010 trials showed that most pellets from 1^{st} 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 2^{nd} application (brodifacoum)	14, 30, or 99	days	Griffiths et al., 2013	Data from Griffiths et al. (2013) indicate that brodifacoum bait takes average of 16, 32, or 101 days to degrade in high, average and drought rainfall years to an unpalatable condition following application. These values were integrated with the "time to removal of bait following significant rainfall event" parameter to model the length of time from application to unpalatability in high, average and drought rainfall years.
Time to significant rainfall event following 2^{nd} application (diphacinone)	96	days	Griffiths et al., 2013	Data from Griffiths et al. (2013) indicate that diphacinone bait takes 98 days to degrade to an unpalatable condition following application. These values were integrated with the "time to removal of bait following significant rainfall event" parameter to model the length of time from application to unpalatability.
Time to removal of bait following significant rainfall event	2	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. There is generally little pellet left to be consumed 2 days after a significant rainfall event. Model assumes lowest 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 in Pitt et al. (2011) list bait consumption and weights of mice killed by diphacinone-treated pellets (50 mg ai/kg pellet). Upper bound residue concentrations were calculated for each mouse and a mean and standard deviation determined.
Standard deviation (SD) for diphacinone concentration in mice	13.0			

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
				Assumed underlying lognormal distribution in model.
Proportion of gulls removed by hazing	User choice. In this assessment, model runs were conducted for hazing success rates of 75-98%. The baseline rate was 90%. An average hazing success rate of 98% was achieved in the December 2012 trial undertaken on SFI (Warzybok et al. 2013).			
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 sub adults and non-breeding adults.
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. It is possible for gulls to exceed their daily energetic requirements on any given day, but such a situation is not likely over many days and the great majority of affected mice will be underground.	
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.	

Table 3-1. Input values used in western gull risk models for brodifacoum and diphacinone.

Variable	Value	Units	Source	Notes
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	0.87		Taylor, 1993; Howald, 1997; Buckalew et al., 2008	Mice generally retreat to burrows following onset of symptoms stemming from exposure to brodifacoum. 87% value was generated from rat data.
Lowest LD50 for brodifacoum	0.26	mg/kg bw	FWS, 2007	LD50 for mallards (EPA, 1998a) used in Rat Island EA (FWS, 2007). This is the lowest LD50 available for birds.
Probit slope for brodifacoum	2.32		Wildlife International, 1979a,b	Values generated from probit regression conducted on raw data for laughing gulls in the reports. Laughing gull should be a reasonable surrogate for western gulls.
Lowest LD50 for diphacinone	0.82	mg/kg bw	Rattner et al., 2012	This value is based on a 7-day dietary study for Eastern screech owls (*Megascops asio*) and represents the lowest lethal dose for mortality. No higher doses/concentrations were tested. Thus, this value is highly conservative.
Probit slope for diphacinone	6.69		Rattner et al., 2010	Values generated from log-probit regression conducted by study authors for most sensitive species tested to date, the American kestrel (*Falco sparverius*).
Half-life for elimination from bird- brodifacoum	217	days	Erickson and Urban, 2004	Calculated mean retention time in the liver from available studies.
Half-life for elimination from bird - diphacinone	7.8	days	Rattner et al., 2011	Half-life for American kestrels.

3.2 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 were treated as deterministic variables (i.e., one value per variable). Those variables that are variable or have high uncertainty were 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).

3.2.1 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 48 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.

3.2.2 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.

3.2.3 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. Thus, high rainfall, average rainfall and drought years were modeled for brodifacoum, and a minimum rainfall period was modeled for diphacinone. Based on data compiled by Griffiths et al. (2013), it is expected that brodifacoum bait will take 16, 32, or 101 days to degrade to unpalatable conditions following its application in high, average, and drought rainfall years. For diphacinone, only a minimum rainfall value of 98 days was available and modeled. Because data were not available for the degradation of diphacinone bait in high and average rainfall years, this parameter is conservative. Because the western gull risk model only simulates the first 90 days after initial application, the analyses for diphacinone and drought years for brodifacoum essentially assume no removal of pellets following the second and/or third applications for the duration of the simulations.

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 2-day value for time to removal of pellets following a significant rainfall event.

3.2.4 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
	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

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
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.

3.2.5 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).

3.2.6 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 mitigation measure 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, its long-term effectiveness as a tool on SFI can only be inferred from the trials that have been conducted. 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%. An extensive hazing trial was conducted in December 2012 at SFI to evaluate hazing techniques and quantify effective hazing rates in the field over a 2 week period. Hazing efforts were on average 98% effective at keeping gulls off the island and away from areas that would be baited during an eradication effort (Warzybok et al. 2013).

3.2.7 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 ~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.

3.2.8 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 the 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 and diphacinone. 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). Similarly, EPA (1998) noted that mice may experience symptoms within 3 days of exposure to diphacinone and die within 9 days of continuous exposure. Dead or dying mice that have retreated to burrows 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:

$$y = 0.0116\,x^2 - 0.215\,x + 1\ (worst\,case)$$

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%).

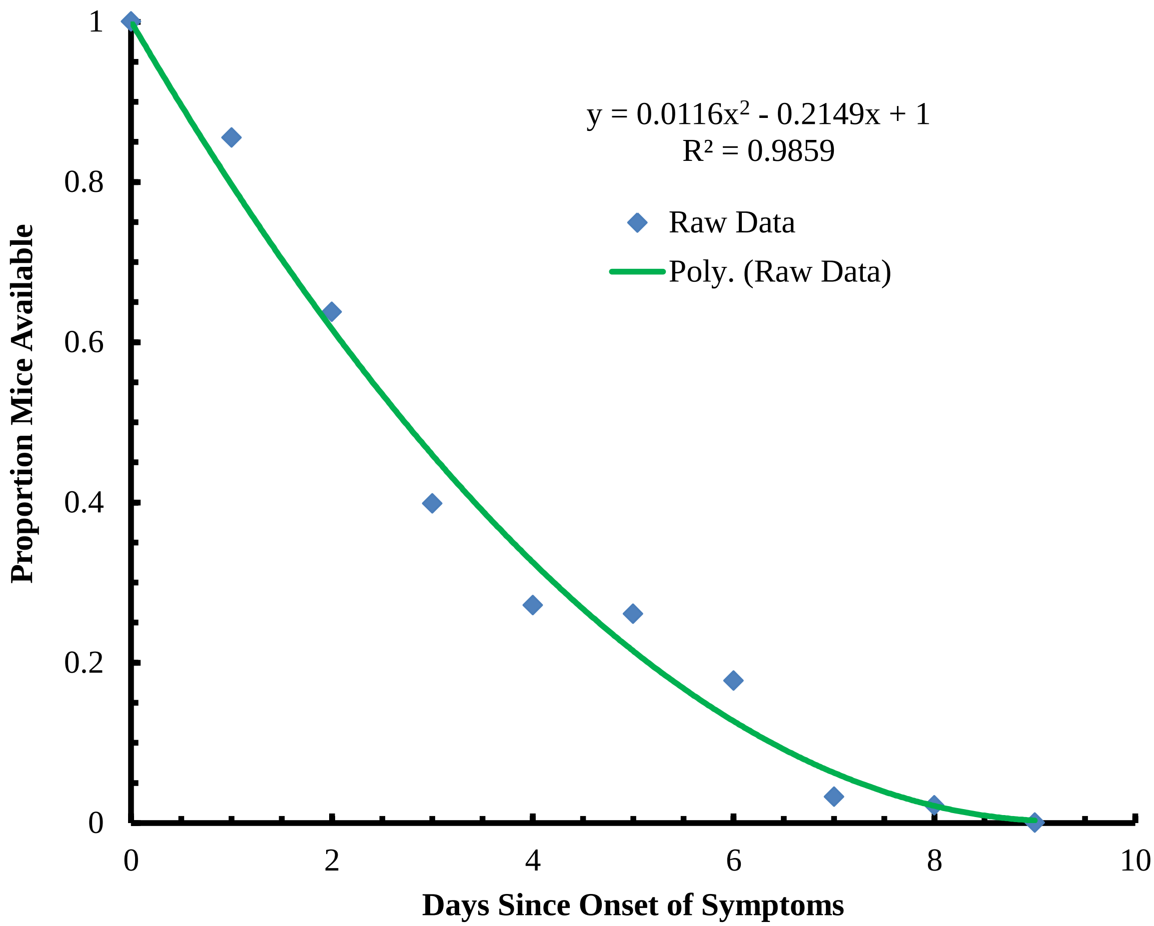

Figure 3-2. Proportion of mice available for consumption by western gulls following application of brodifacoum on SFI. Raw data are from Fisher (2009). The fitted model is a 2nd order polynomial model. Symptoms begin 5 days after initial application with death following 2 days after onset of symptoms.

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 likely, on average, over many days and the likelihood of such an event will be further diminished by the majority of mice dying underground.

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 included 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).

We incorporated the rates of metabolism and elimination of brodifacoum and diphacinone 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. Assuming first-order kinetics, the resulting fraction of brodifacoum retained in gull tissues on a daily basis is 0.997. For diphacinone, Rattner et al. (2011) determined a half-life of 7.8 days in American kestrels. Assuming first-order kinetics, the resulting fraction of diphacinone retained in gull tissues on a daily basis is 0.915.

4.0 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.

4.1 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
[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).

For this assessment, the lowest LD50 available, 0.26 mg a.i./kg bw (EPA, 1998a) for mallards, was used to be conservative because there was no accepted LD50 for gulls. This value was also used by FWS (2007) in the environmental assessment for Rat Island. Raw toxicity data were unavailable from the mallard study to generate a probit slope of dose-response for the model. Thus, the probit slope was calculated from a gull toxicity study, as described below.

The sensitivity of western gulls to brodifacoum exposure is most likely 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 were <0.75 mg ai/kg bw for the southern black-backed gull (*Larus dominicanus*) and <5 mg ai/kg bw for the black-billed gull (*Larus bulleri*). For both species, however, the lowest dose tested resulted in 100% 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.

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 (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).

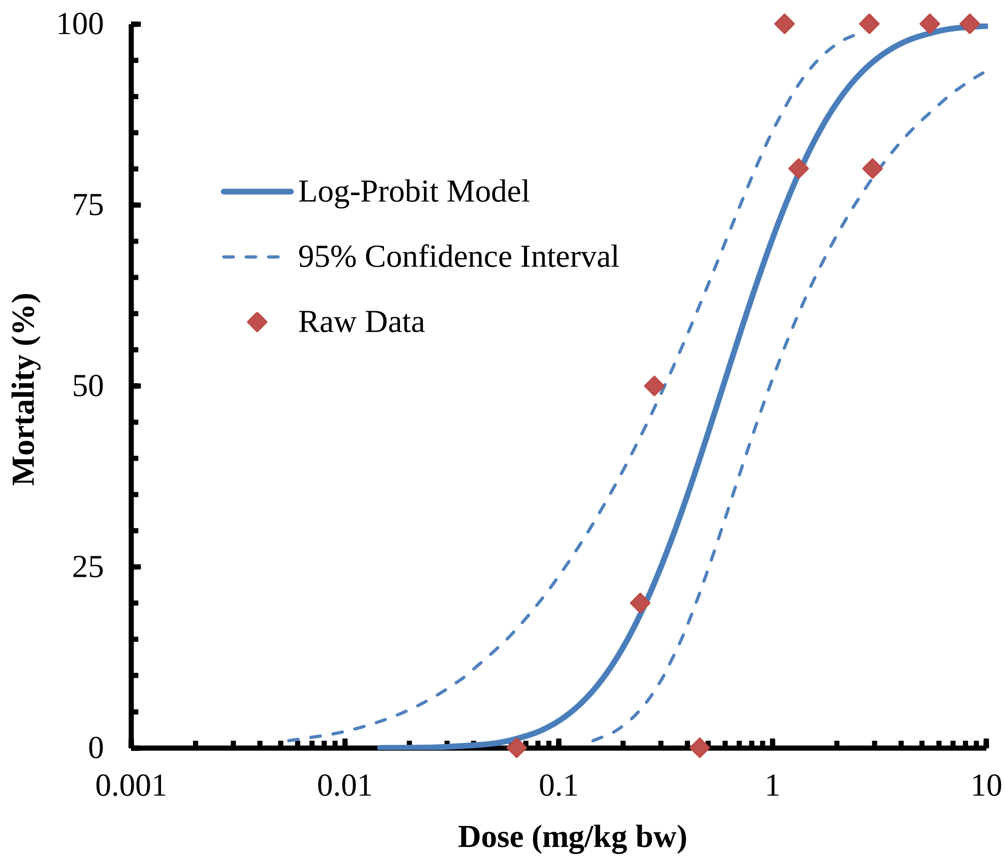

Figure 4-1. Dose-response relationship for effects of brodifacoum on laughing gulls.

4.2 EFFECTS METRICS FOR DIPHACINONE

Avian toxicity studies have been conducted for diphacinone, but none have involved gull species (EPA, 1998a; Erickson and Urban, 2004; Rattner et al., 2010, 2011, 2012). Additionally, acute oral gavage studies may underestimate toxicity for diphacinone because multiple feedings are typically required to evoke lethality (Vyas and Rattner, 2012). For this assessment, we used data from a screech owl dietary toxicity study (Rattner et al., 2012). Owls were exposed to diphacinone in the diet for seven days and observed for toxicity. At the highest concentration tested, 22.6 mg a.i./kg diet, 33% mortality was observed. This result served both as the LC33 and the lowest lethal dose (LLD). Using body weight and food consumption data, the authors calculated a cumulative LLD of 5.75 mg/kg, which is more than an order of magnitude less than the LLD (171 mg/kg) they observed in acute toxicity trials and which equates to a daily dose of 0.82 mg a.i./kg bw/day (Rattner et al., 2012). This latter value was used in the model. Because an LD50 was not available, the effects metric used is considered conservative. To generate a probit slope, we used the results for American kestrels from Rattner et al. (2010, 2011) 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.

4.3 ORAL GAVAGE VERSUS DIETARY EXPOSURE STUDIES

Often oral gavage studies differ in estimates of toxicity 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). 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 (Erickson and Urban, 2004). There are significant differences between toxicity results from oral gavage and dietary exposure studies for diphacinone (and other first generation anticoagulant rodenticides) given the mode of action and time course for toxicity (Vyas and Rattner, 2012). Acute oral toxicity studies can underestimate toxicity when multiple feedings are necessary to evoke lethality (Rattner et al., 2012).

5.0 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.

5.1 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%[1], the time to the first significant rainfall event after the second and final application of 28 days, and 4.5 days of bait availability following a significant rainfall event. 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 of gulls at SFI experiencing mortality had a wide range of 0.0780 to 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).

[1] 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.

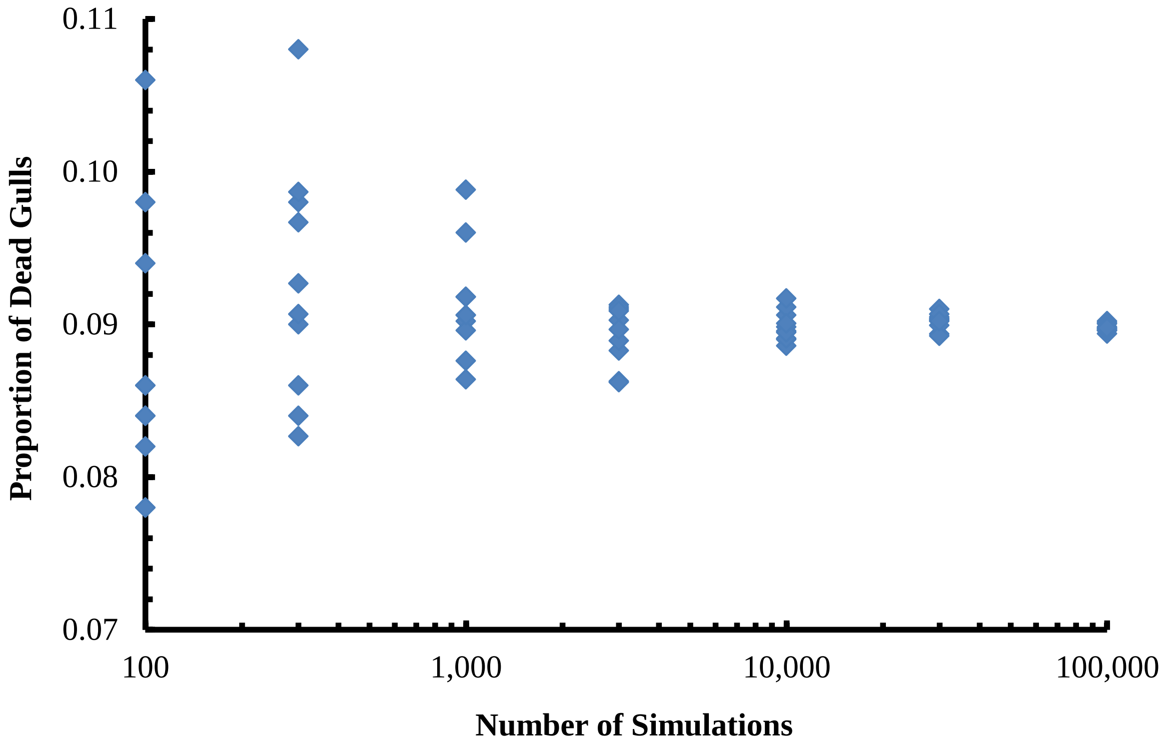

Figure 5-1. Results of the model stability analysis for proportion of dead western gulls exposed to brodifacoum in relation to the number of simulations. The analyses assumed a start date of November 29, a hazing success rate of 90%, and a time to first significant rainfall event after the final application of 28 days. All other assumptions are listed in Table 3-1.

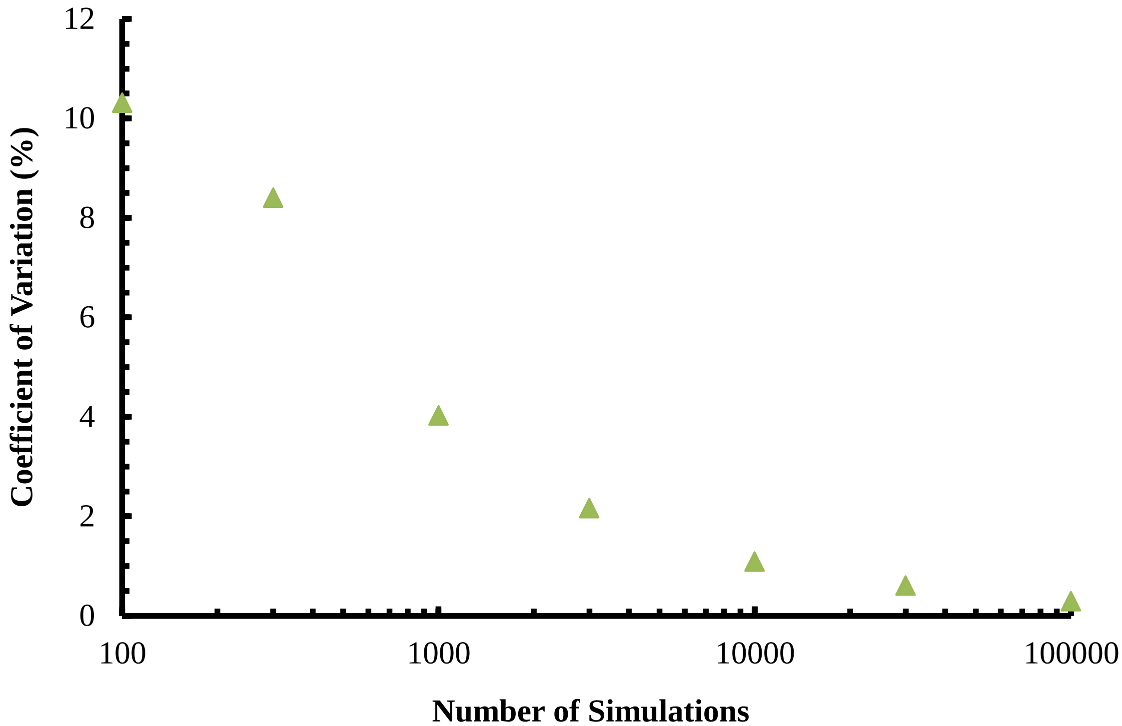

Figure 5-2. Results of the model stability analysis for the coefficient of variation of proportion of dead gulls exposed to brodifacoum in relation to number of simulations. The analyses assumed a start date of November 29, a hazing success rate of 90%, and a time to first significant rainfall event after the final application of 28 days. All other assumptions are listed in Table 3-1.

5.2 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, assuming a population of 11,000 western gulls. The text and figures below provide examples from the various possible scenarios.

5.2.1 Initial Application Date

Model runs were performed to determine how initial application date of brodifacoum affected the proportion of (Figure 5-3, Appendix A) and number of western gulls dying from rodenticide exposure (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 30 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. There is little difference in gull mortality with initial application date in models from drought years (Appendix A).

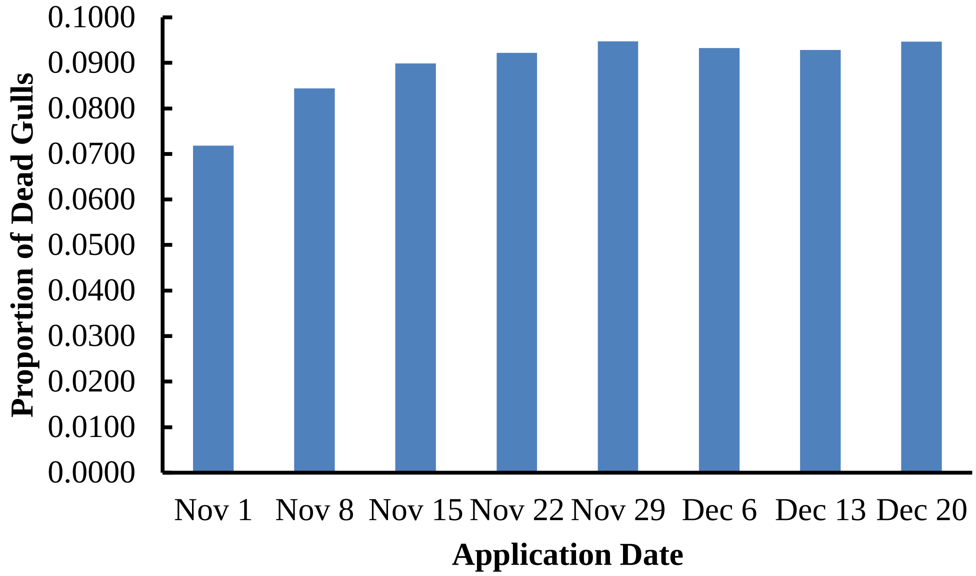

Figure 5-3. Model results for proportion of 11,000 western gulls dying as a result of varying initial application date for brodifacoum, assuming 90% hazing effectiveness and 30 days until the first significant rainfall. See Table 3-1 for other input values and Appendix A for other model scenarios.

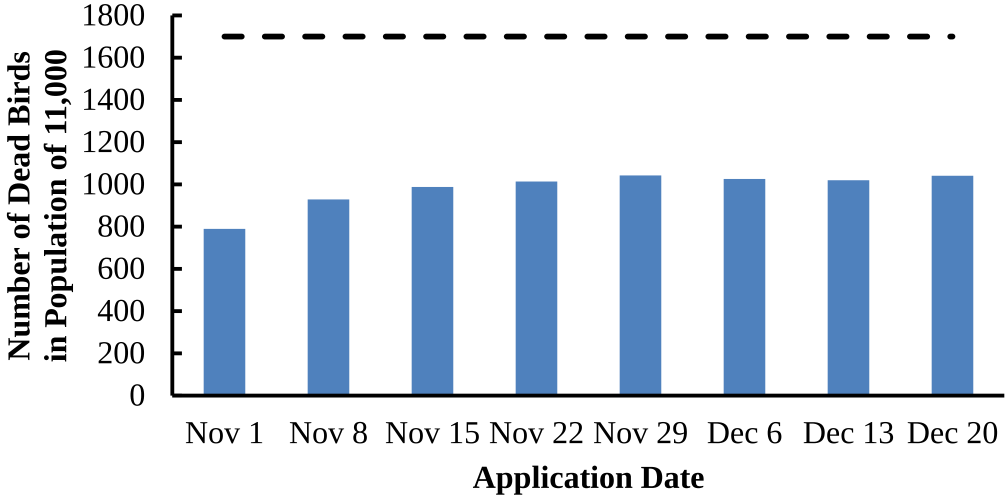

Figure 5-4. Model results for number of gulls dying as a result of varying initial application date for brodifacoum, assuming a population of 11,000 gulls, 90% hazing effectiveness and 30 days until the first significant rainfall. The dashed line represents 1700 dead gulls, the number considered the maximum possible without affecting long-term population viability. See Table 3-1 for other input values and Appendix A for other model scenarios.

5.2.2 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 30 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.

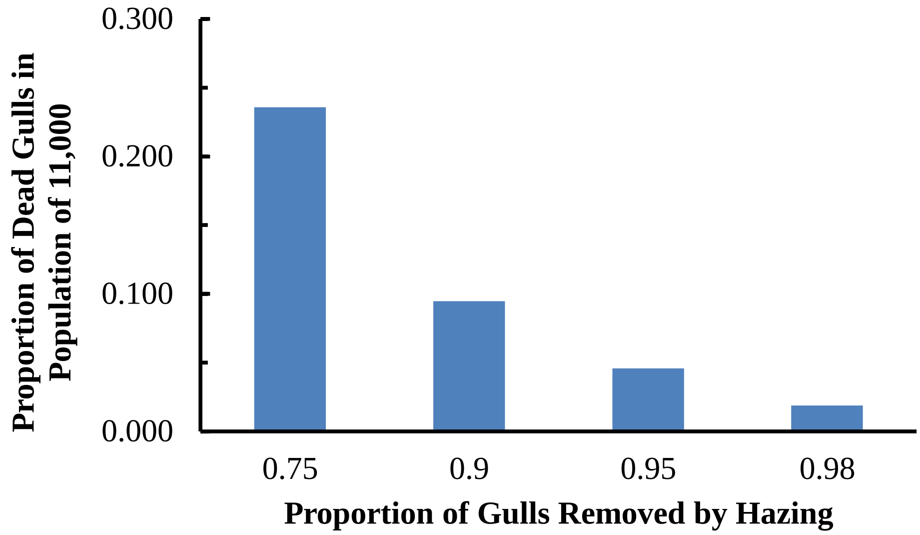

Figure 5-5. Model results for proportion of 11,000 gulls dying as a function of hazing success, assuming November 29th date of first application of brodifacoum and 30 days until the first significant rainfall. See Table 3-1 for other input values and Appendix A for other model scenarios.

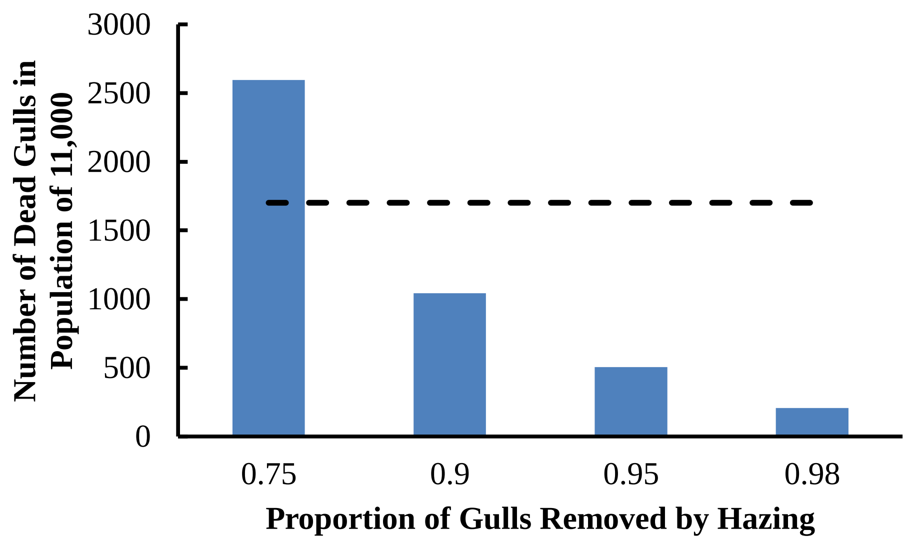

Figure 5-6. Model results for number of gulls dying as a function of hazing success, assuming November 29th date of first application of brodifacoum and 30 days until the first significant rainfall. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix A for other model scenarios.

5.2.3 Time to Significant Rainfall Event

A significant rainfall event is one in which sufficient rain falls to degrade remaining bait pellets. 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 at least 90% hazing success (Appendix A).

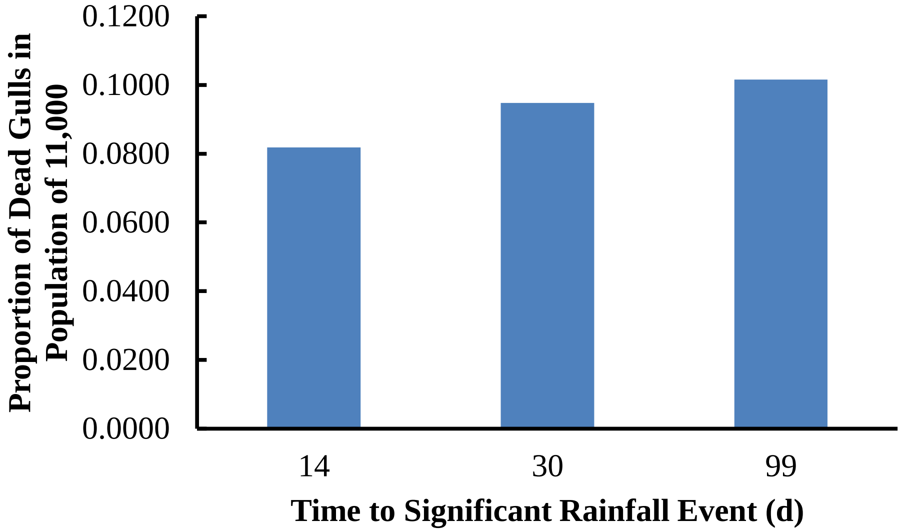

Figure 5-7. Model results for proportion of 11,000 gulls dying as a function of time to significant rainfall after the second application of brodifacoum, assuming November 29th date of first application and 90% hazing effectiveness. See Table 3-1 for other input values and Appendix A for other model scenarios.

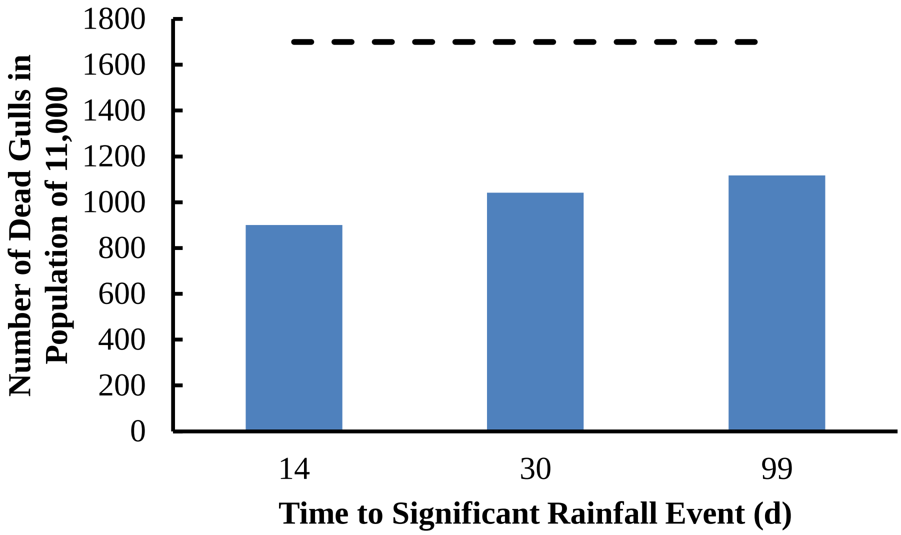

Figure 5-8. Model results for number of gulls dying as a function of time to significant rainfall after the second application of brodifacoum, assuming November 29th date of first application and 90% hazing effectiveness. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix A for other model scenarios.

5.2.4 Number of Applications

Based on the greater gull mortalities modeled with 2 applications compared to a single application, it is clear that the greatest risk to gulls is from ingestion of pellets remaining after the second application (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 30 days until the first significant rainfall for the scenario involving two applications (see Table 3-1 for other inputs). Approximately 5 times more gulls died when two applications took place. However, applying only one application would not be best practice and that would likely compromise the effectiveness of the mouse eradication, which requires 100% lethal exposure to all mice.

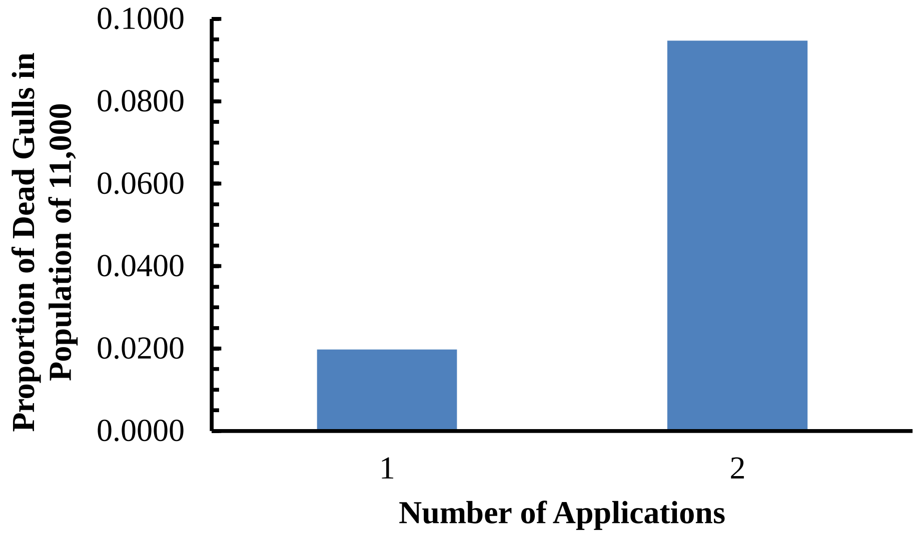

Figure 5-9. Model results for proportion of 11,000 gulls dying as a function of number of applications of brodifacoum, assuming an initial application date of November 29th, 90% hazing effectiveness, and 30 days until the first significant rainfall. See Table 3-1 for other input values and Appendix A for other model scenarios.

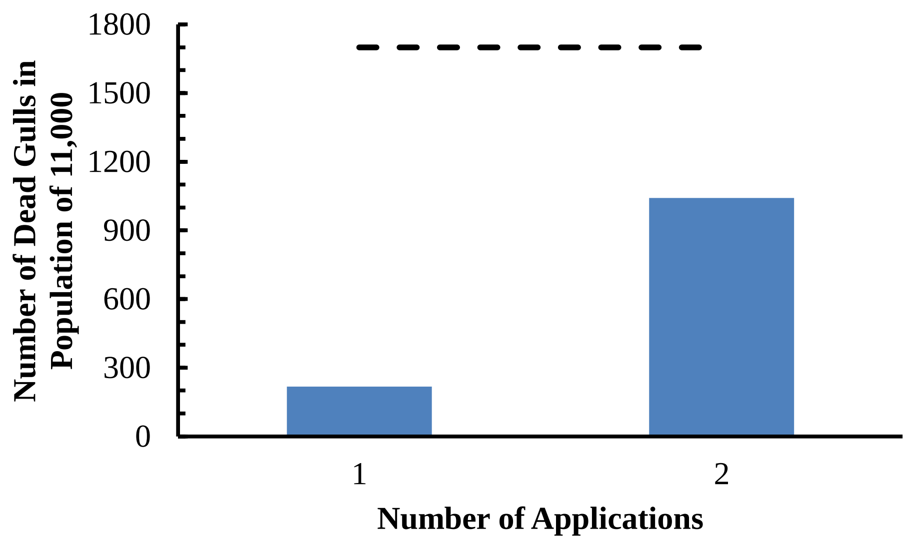

Figure 5-10. Model results for number of gulls dying as a function of number of applications of brodifacoum, assuming an initial application date of November 29th, 90% hazing effectiveness, and 30 days until the first significant rainfall. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix A for other model scenarios.

5.2.5 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 30 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 given the greater risk from ingestion of remaining pellets.

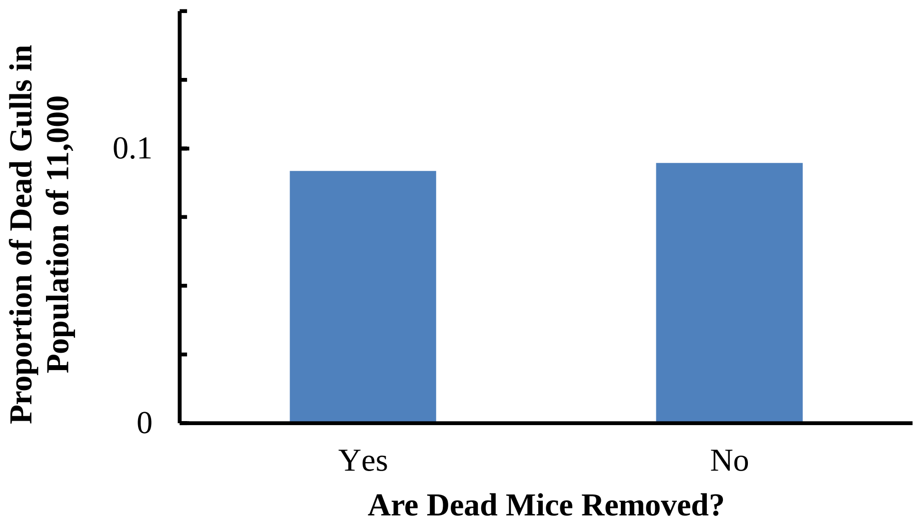

Figure 5-11. Model results for proportion of 11,000 gulls dying as a function of whether or not dead mice are removed, assuming an initial application date for brodifacoum of November 29th, 90% hazing effectiveness, and 30 days until the first significant rainfall. See Table 3-1 for other input values and Appendix A for other model scenarios.

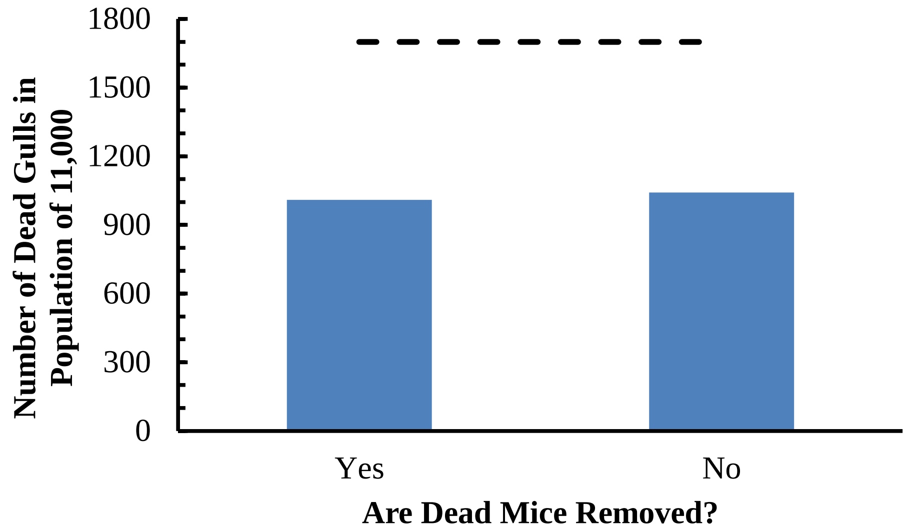

Figure 5-12. Model results for number of gulls dying as a function of whether or not mice are removed, assuming an initial application date for brodifacoum of November 29th, 90% hazing effectiveness, and 30 days until the first significant rainfall. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix A for other model scenarios.

5.3 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, assuming a population of 11,000 western gulls. The text and figures below provide examples from the various possible scenarios.

5.3.1 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 gulls dying. The results presented in Figures 5-13 and 5-14 assumed a hazing effectiveness of 90% and that the first rainfall event occurred 96 days after the second application (see Table 3-1 for other inputs). As with the brodifacoum model under drought conditions, there is little difference in gull mortality with initial application date (Appendix B).

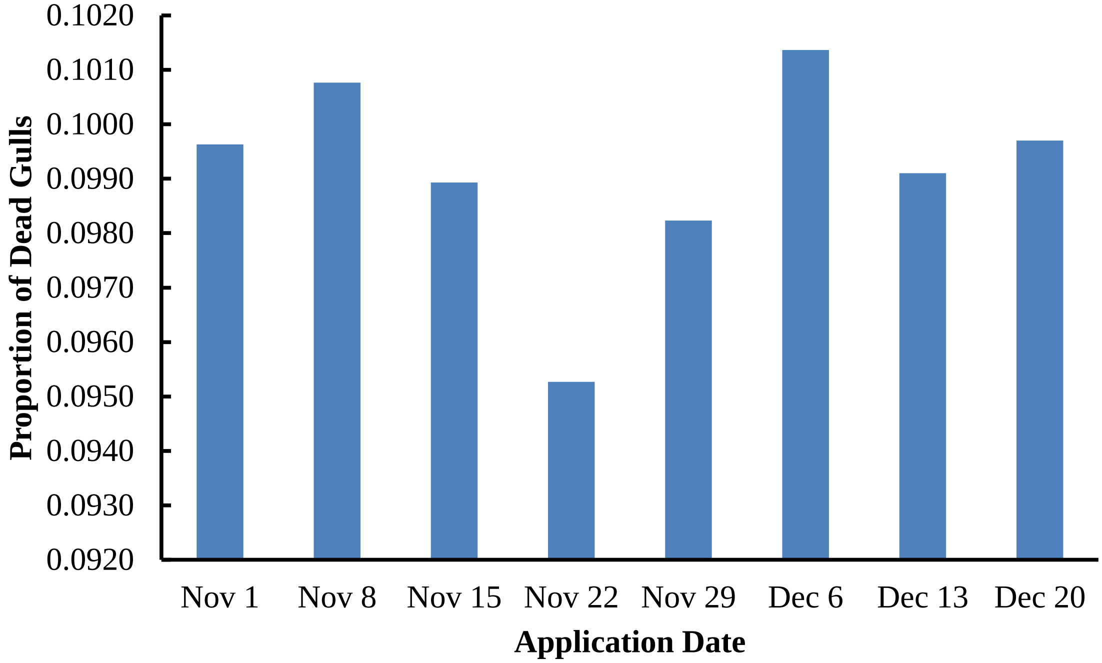

Figure 5-13. Model results for proportion of 11,000 gulls dying as a result of varying initial application date for diphacinone, assuming an initial application date of November 29th, 90% hazing effectiveness, and 96 days until the first significant rainfall. See Table 3-1 for other input values and Appendix B for other model scenarios.

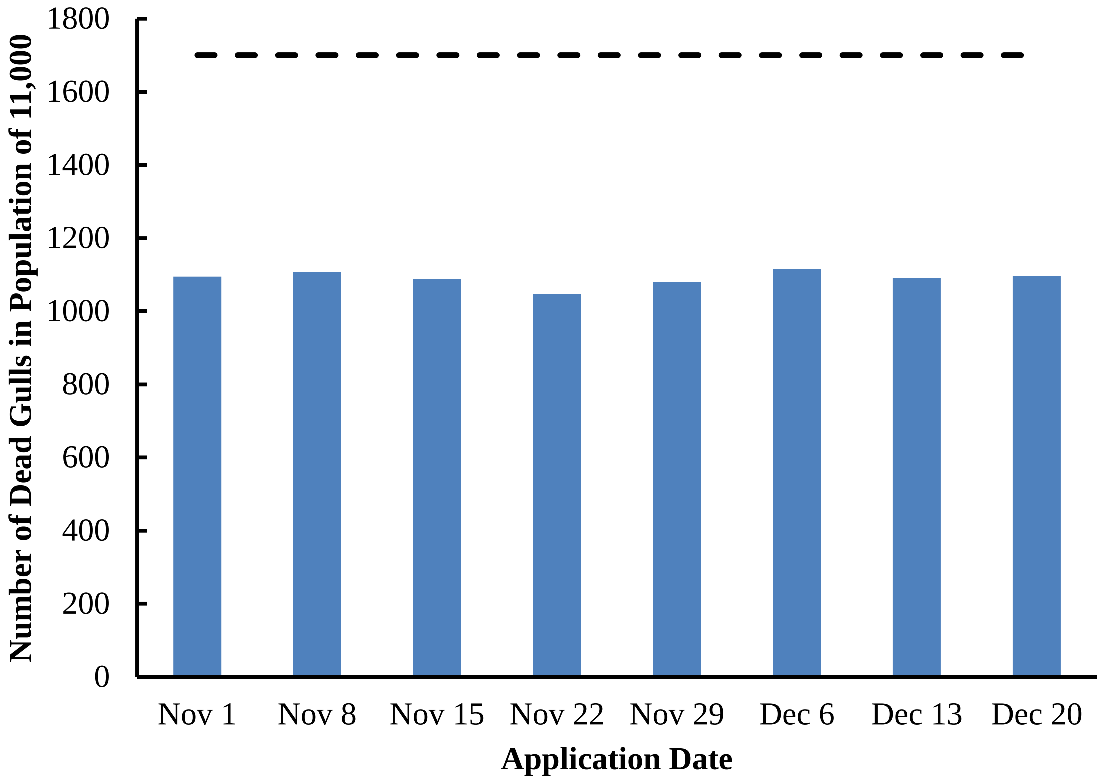

Figure 5-14. Model results for number of dead gulls as a result of varying initial application date for diphacinone, assuming an initial application date of November 29th, 90% hazing effectiveness, and 96 days until the first significant rainfall. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix B for other model scenarios.

5.3.2 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 96 days after the second application of diphacinone (see Table 3-1 for other inputs and Appendix B for results of other model scenarios). As expected, the proportion and number of gulls dying decreased as hazing effectiveness increased. At 75% hazing effectiveness, the number of dead gulls was above the threshold of 1700.

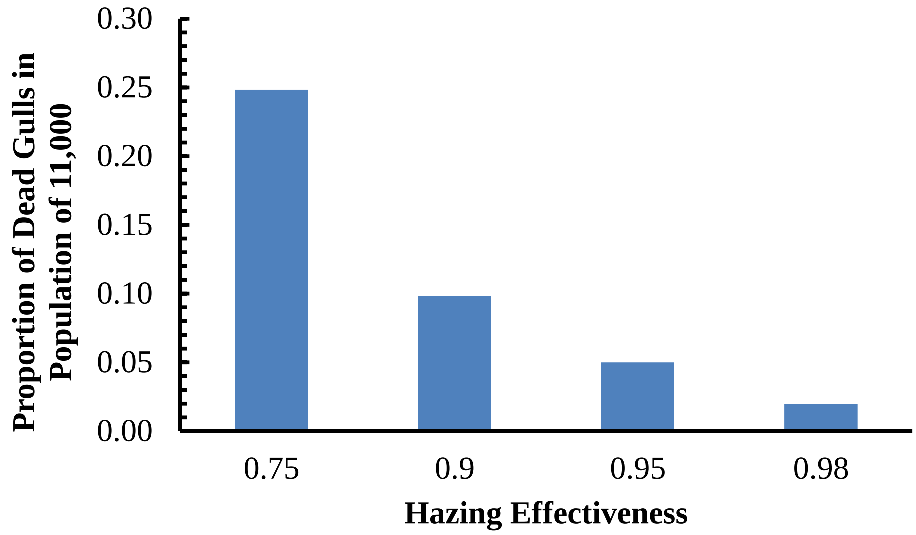

Figure 5-15. Model results for proportion of 11,000 gulls dying as a function of hazing success, assuming an initial application date for diphacinone of November 29th, and 96 days until the first significant rainfall. See Table 3-1 for other input values and Appendix B for other model scenarios.

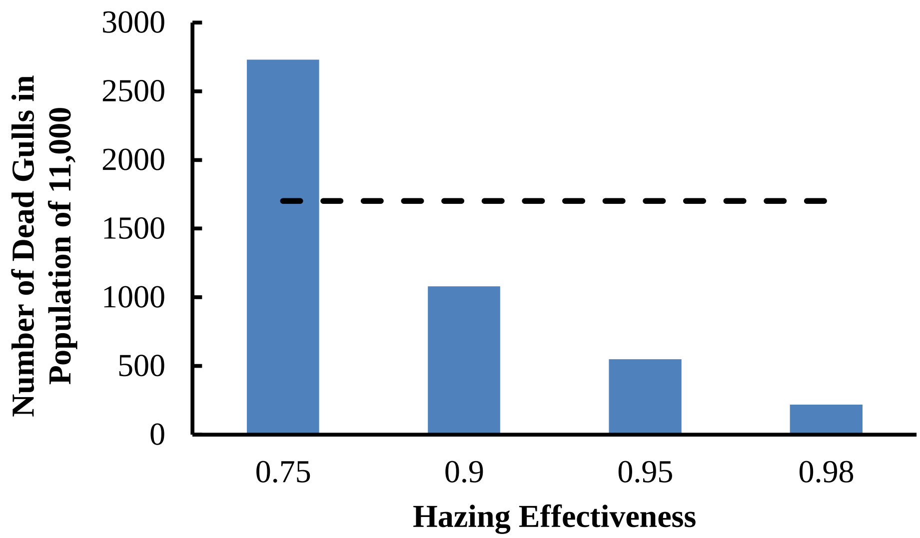

Figure 5-16. Model results for number of gulls dying as a function of hazing success, assuming an initial application date of November 29th and 96 days until the first significant rainfall. The dashed line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix B for other model scenarios.

5.3.3 Time to Significant Rainfall Event

The impact of time to a significant rainfall event after the second application was not evaluated for diphacinone because only one value was available, i.e., 96 days between application and degradation.

5.3.4 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 96 days until the first significant rainfall event after the second application (see Table 3-1 for other inputs). The results indicate that the greatest risk to gull mortality occurs after the second application.

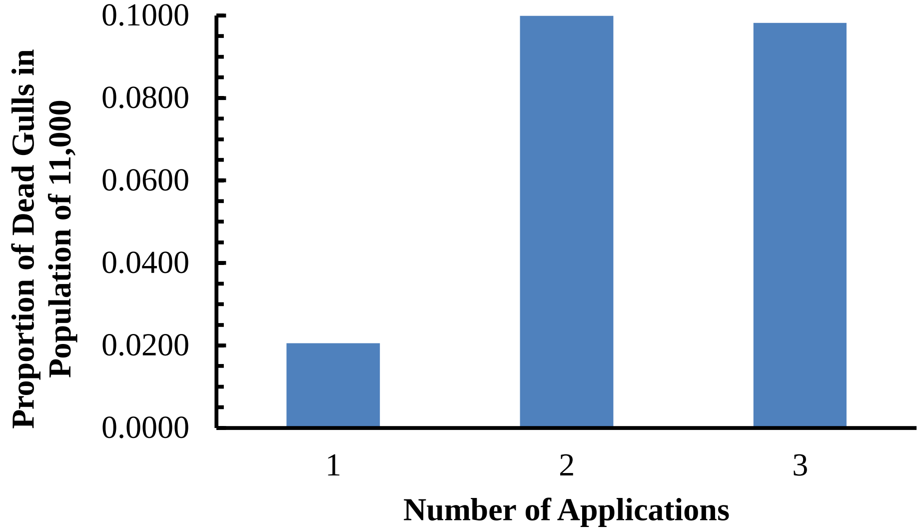

Figure 5-19. Model results for proportion of 11,000 gulls dying as a function of number of applications of diphacinone, assuming an initial application date of November 29th, 96 days to first significant rainfall, and 90% hazing effectiveness. See Table 3-1 for other input values and Appendix B for other model scenarios.

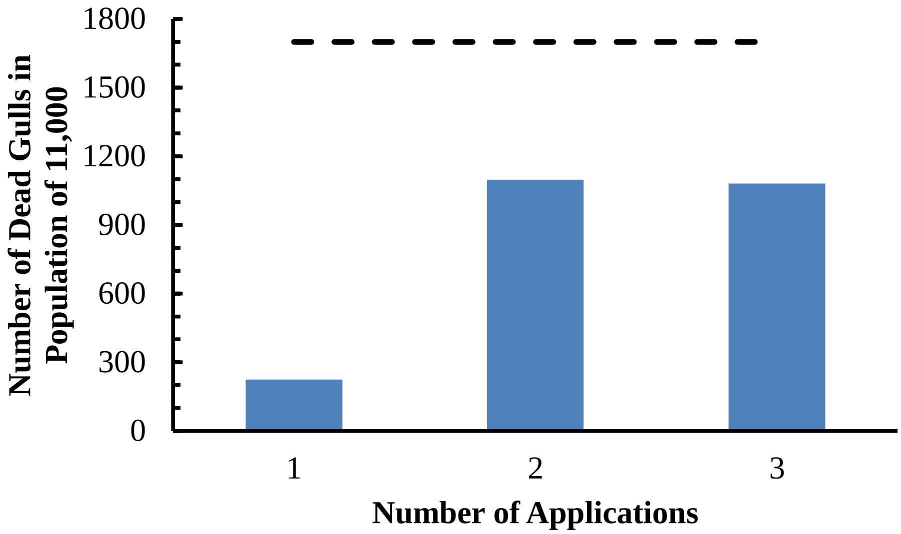

Figure 5-20. Model results for number of gulls dying as a function of number of applications of diphacinone, assuming an initial application date of November 29th, 96 days to first significant rainfall, and 90% hazing effectiveness. The dash line represents 1700 dead gulls. See Table 3-1 for other input values and Appendix B for other model scenarios.

5.3.5 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 96 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 exposed to diphacinone given the greater risk from ingestion of pellets.

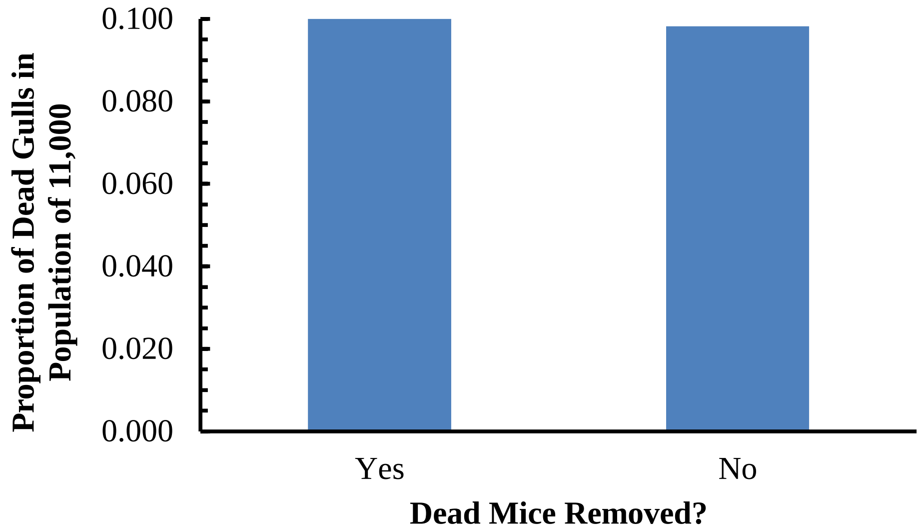

Figure 5-21. Model results for proportion of 11,000 gulls dying as a function of whether or not mice are removed, assuming an initial application date for diphacinone of November 29th, 96 days to first significant rainfall, and 90% hazing effectiveness. See Table 3-1 for other input values and Appendix B for other model scenarios.

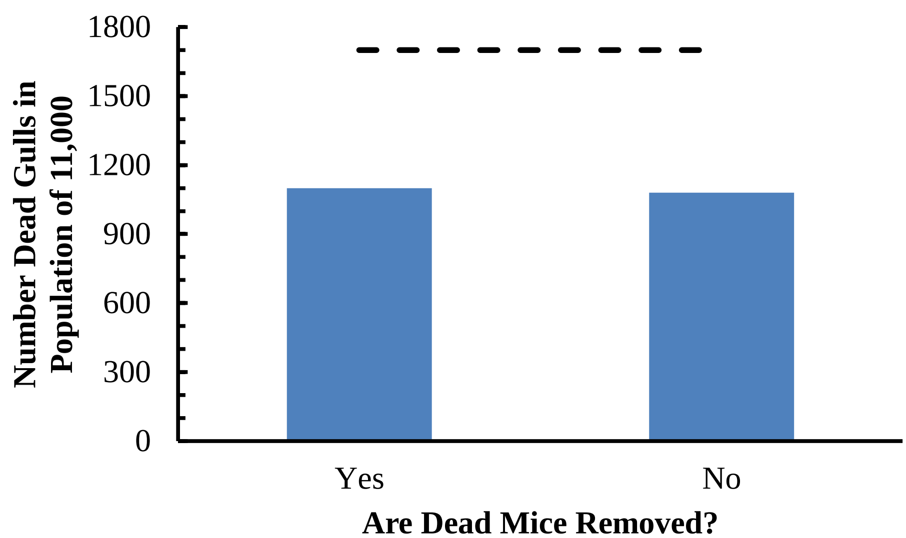

Figure 5-22. Model results for number of gulls dying as a function of whether or not mice are removed. The dashed line represents 1700 dead gulls, assuming an initial application date for diphacinone of November 29th, 96 days to first significant rainfall, and 90% hazing effectiveness. See Table 3-1 for other input values and Appendix B for other model scenarios.

5.4 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)
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 Draft EIS (FWS, 2012). 1 application is likely to be ineffective at eradicating mice.
Number of applications - diphacinone	1, 2, 3	3 applications is maximum indicated in Draft EIS (FWS, 2013). 1 or 2 applications are likely to be ineffective at eradicating mice.
Hazing effectiveness	0.75, 0.98	Range suggested by Warzybok et al. 2013.
Pellet half-life (1st application)	0.5, 2 days	2010 SFI field trial (Pott & Grout 2012) and available literature indicate this approximate range.
Time to significant rainfall event after 2nd application - brodifacoum	14, 99 days	Best and worst case scenarios are14 and 99 days, respectively.
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, 0.935, 1	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	0.26 - 0.588 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), but lowest LD50 for mallards, 0.26 mg/kg bw used as minimum value.
LD50 - diphacinone	0.82 - 97 mg/kg bw	No gull toxicity studies are available. Used range observed for screech owl (0.82 mg/kg bw; Rattner et al., 2012) and American kestrel (97 mg/kg bw; Rattner et al., 2010).

5.4.1 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. 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) and a hazing trial conducted on SFI in December, 2013 achieved an average hazing efficiency of 98% providing confidence that hazing efficiencies of 90% or higher could be achieved for an extended period of time (Warzybok et al., 2013). Time to the first significant rainfall event following the second application is also significant because rain reduces availability of the pellets from gull exposure in the model, 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 risk 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 risk 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 the daily probability of gulls ingesting pellets from 0.22 to 0.25 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.

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.

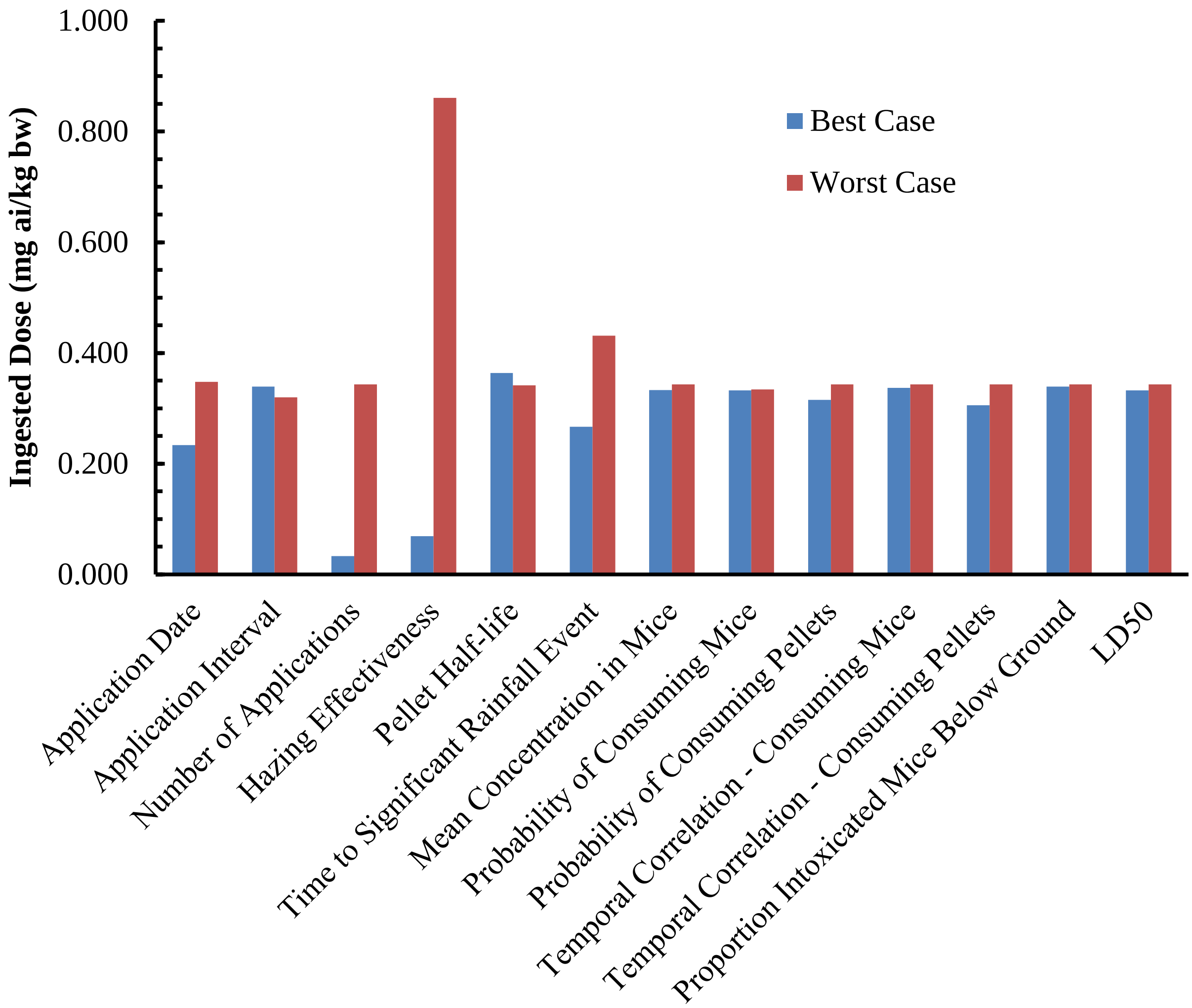

Figure 5-23. Results of sensitivity analysis for brodifacoum for maximum tissue concentration in western gulls exposed to brodifacoum.

The results of the sensitivity analysis for proportion and number of gulls dying were similar to the results for gull exposure

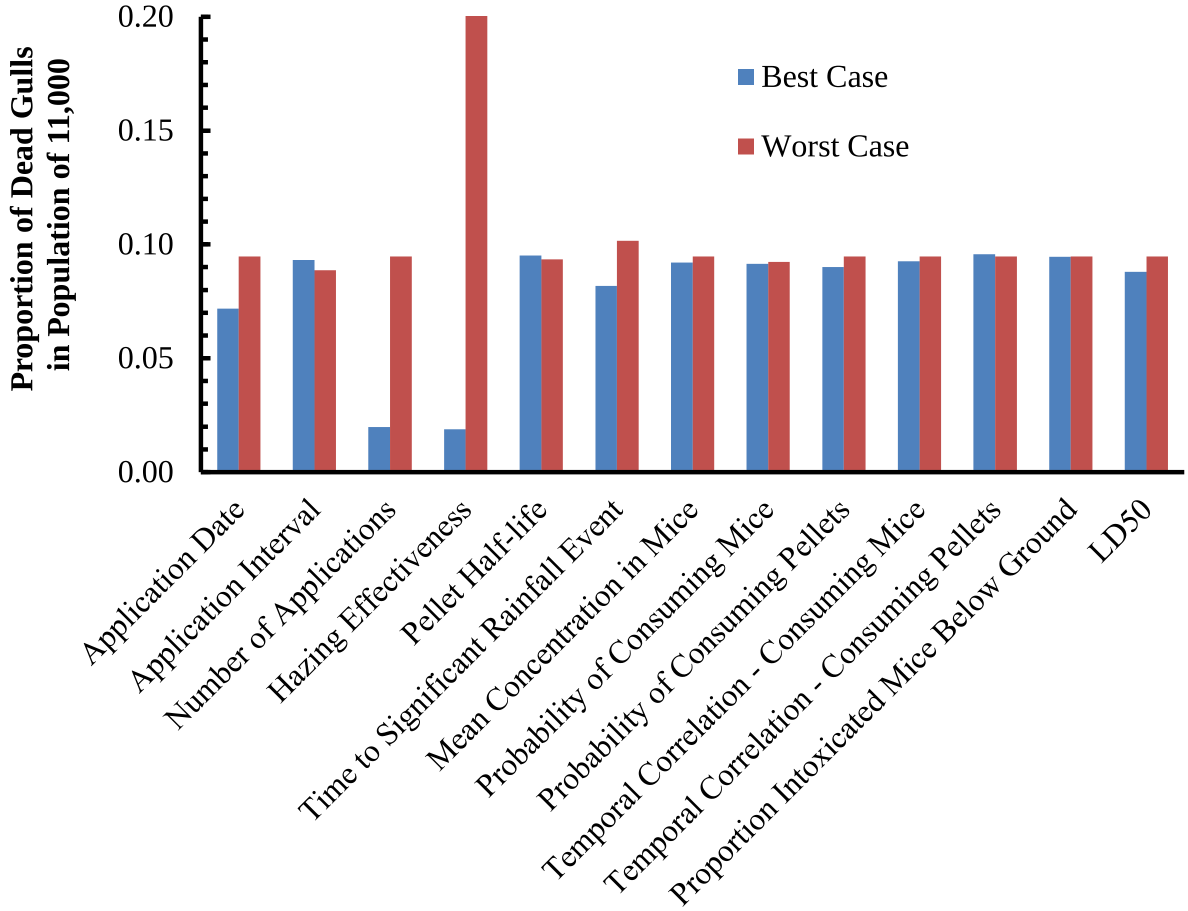

Figure 5-24. Results of sensitivity analysis for proportion of 11,000 western gulls dying from exposure to brodifacoum.

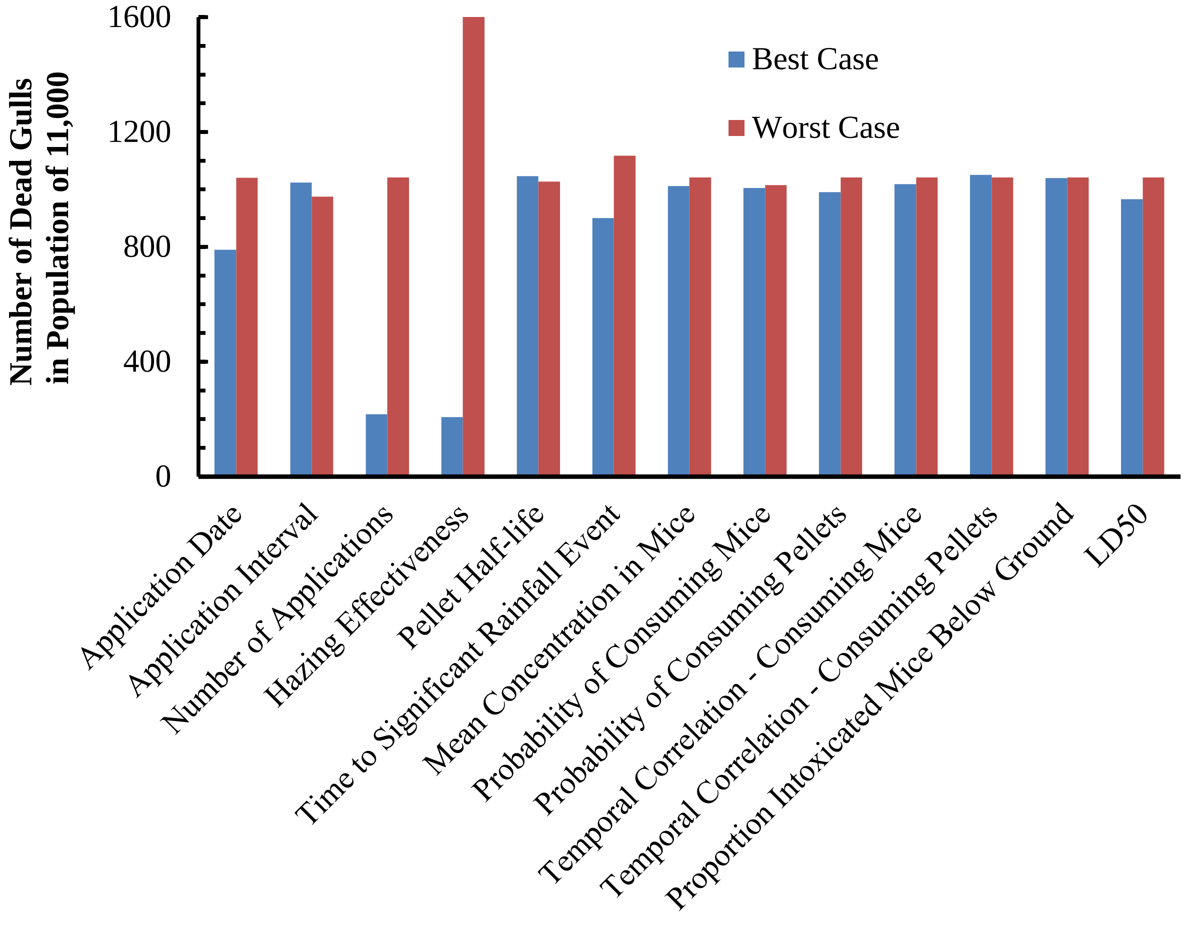

Figure 5-25. Results of sensitivity analysis for number of western gulls dying from exposure to brodifacoum.

5.4.2 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 two notable differences. First, only one time (i.e., 98 days) was modeled for rainfall events. The second notable difference was the highly influential 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 0.82 mg ai/kg bw for screech owls (Rattner et al., 2012) led to predictions of significant mortality for western gulls (Figures 5-27 and 5-28). However, assuming the LD50 for American kestrels (97 mg ai/kg bw; Rattner et al., 2010) resulted in predictions of low mortality 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.

As with brodifacoum, hazing effectiveness and the number of applications impacts gull exposure and mortality. One reason that gull impacts are greater with multiple 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.

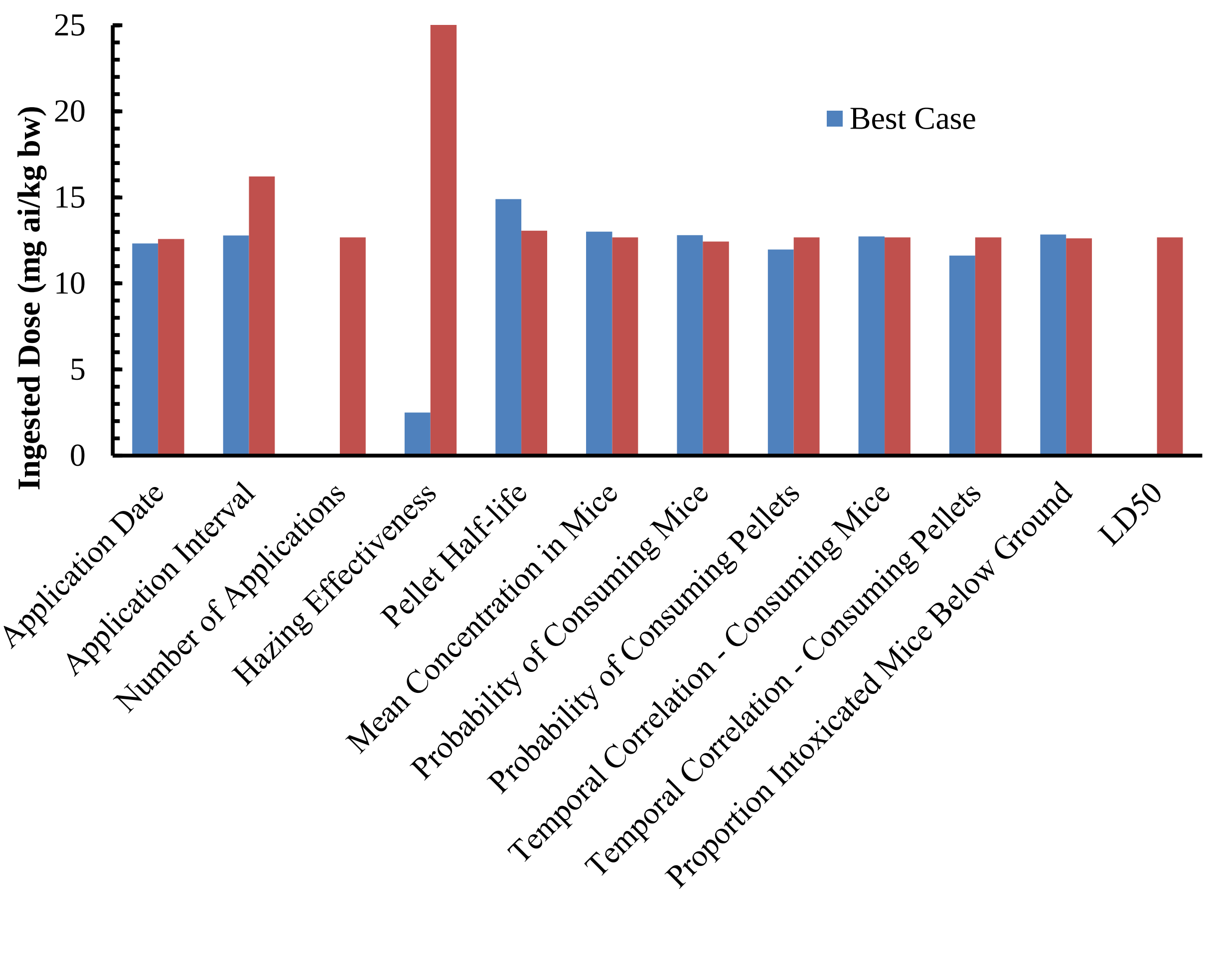

Figure 5-26. Results of sensitivity analysis for diphacinone for maximum tissue concentration in western gulls exposed to diphacinone.

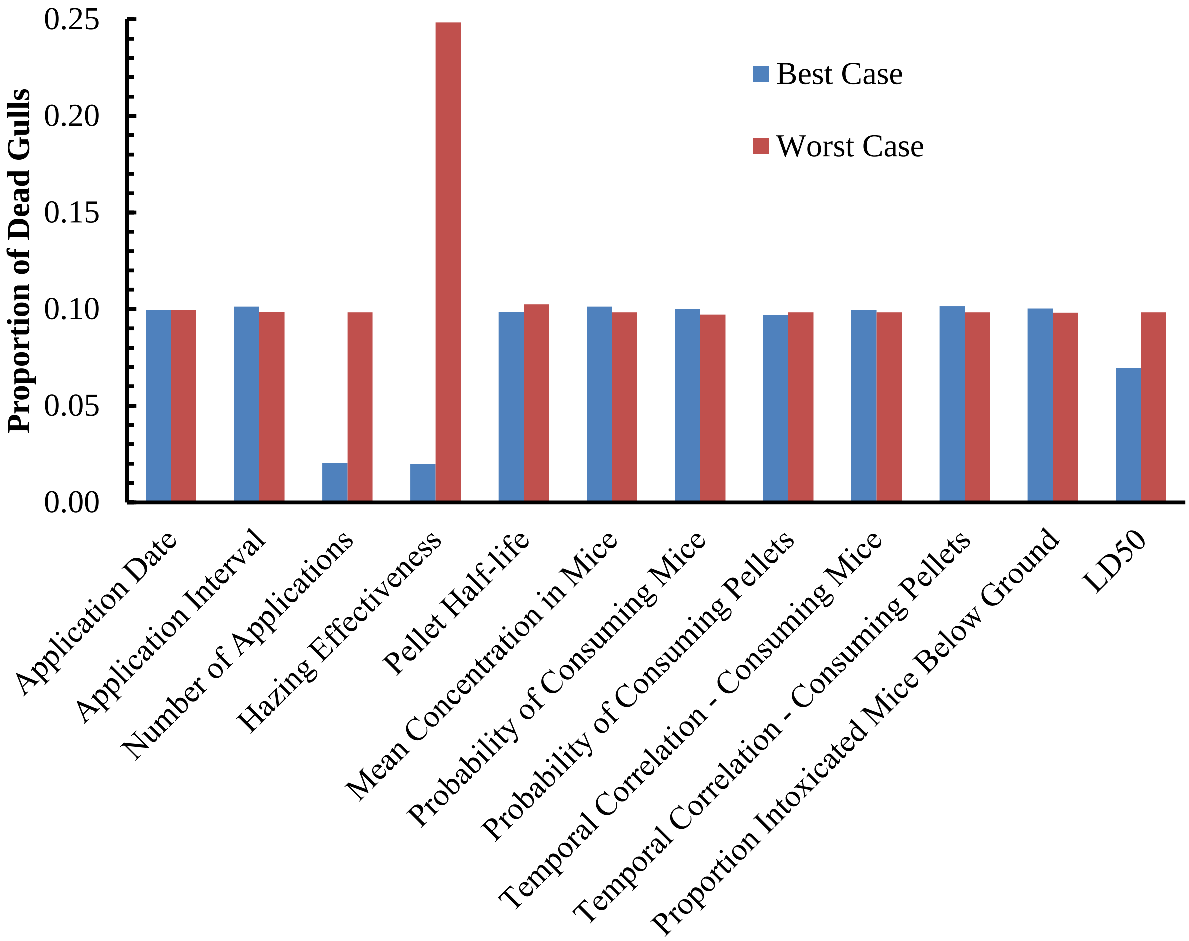

Figure 5-27. Results of sensitivity analysis for proportion of 11,000 western gulls dying from exposure to diphacinone.

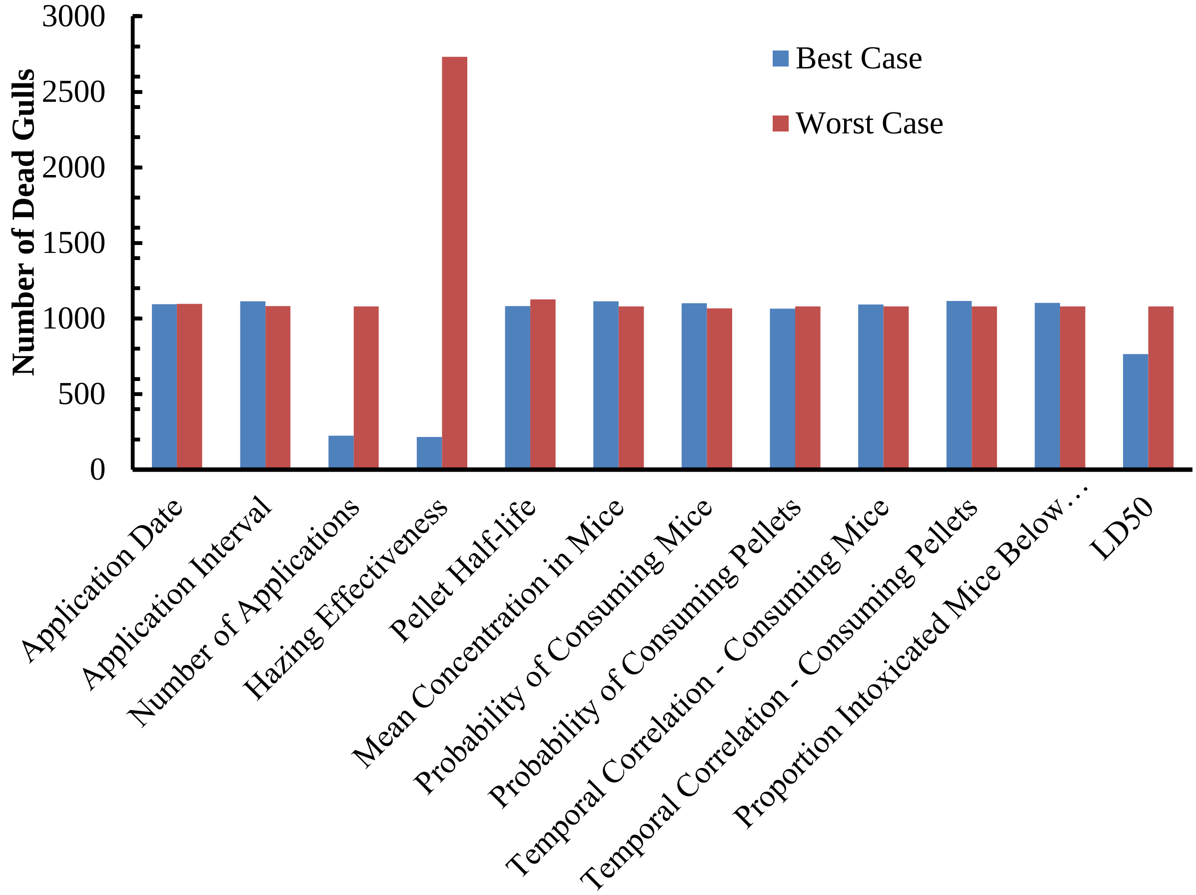

Figure 5-28. Results of sensitivity analysis for number of western gulls dying from exposure to diphacinone.

5.4.3 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 over extended (multi month) periods
- 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 10,300 breeding birds; Carter et al., 1992) 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). Mortality of glaucous-winged gulls was recorded on Rat Island after an aerial application of bait containing brodifacoum (Salmon and Paul, 2010), but no detectable change to the overall population was recorded and five years later the species is more abundant on the island (Newton et al., 2014). 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 rodenticide 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:

- 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.
- The lack of dense vegetation and the rocky substrate of SFI will render rodent bait more visible and accessible to gulls than on other islands.
- 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.
- 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.

5.5 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 both assessments were highly conservative and based on data with low certainty for some input variables. For example, the LD50s assumed for both compounds were based on species unrelated to western gulls (i.e., mallard and screech owl) and were highly conservative relative to other tested bird species (although gull species may be sensitive to these rodenticides). Also, information was not available on bait degradation for diphacinone during wet years.

The results from the western gull risk model clearly show that both chemicals pose risks at similar hazing efficiencies (Appendices A and B). If hazing success is 90% or higher, neither rodenticide is likely to cause 1700 or greater gull mortalities, given the model assumptions.

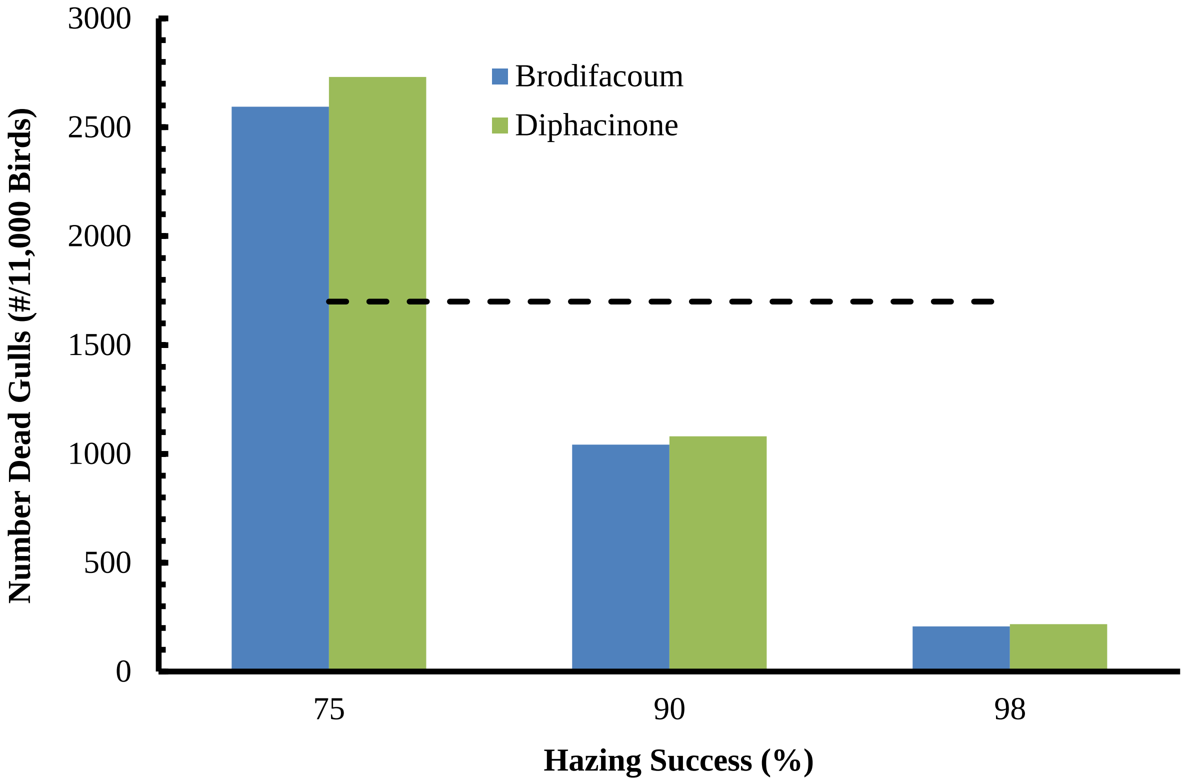

Figure 5-29. Effects of hazing success on predicted gull mortality for brodifacoum and diphacinone assuming an initial application date of November 29. The dashed line represents 1700 dead gulls.

6.0 CONCLUSIONS

The likelihoods of brodifacoum and diphacinone applications achieving total eradication of mice on SFI were not considered in this assessment. Based on the model results, both brodifacoum and diphacinone pose risks to unhazed western gulls. To most effectively reduce gull mortalities, it would be advisable to consider implementing 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 plant cover increases rapidly shortly after the first significant rainfall of the season, usually in November or December. High plant cover hid many placebo bait pellets in trials conducted in early December 2012 (Grout & Griffiths 2012). If seasonal plant cover is high by the time of application or shortly thereafter, 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	14	2	No	0.136	0.0431	474
Nov 8	0.75	14	2	No	0.369	0.121	1331
Nov 15	0.75	14	2	No	0.446	0.138	1516
Nov 22	0.75	14	2	No	0.589	0.187	2061
Nov 29	0.75	14	2	No	0.647	0.202	2221
Dec 6	0.75	14	2	No	0.654	0.203	2229
Dec 13	0.75	14	2	No	0.676	0.211	2319
Dec 20	0.75	14	2	No	0.674	0.210	2308
Nov 1	0.9	14	2	No	0.057	0.0184	202
Nov 8	0.9	14	2	No	0.141	0.0465	511
Nov 15	0.9	14	2	No	0.171	0.0540	594
Nov 22	0.9	14	2	No	0.236	0.0736	809
Nov 29	0.9	14	2	No	0.267	0.0818	900
Dec 6	0.9	14	2	No	0.264	0.0811	892
Dec 13	0.9	14	2	No	0.278	0.0860	945
Dec 20	0.9	14	2	No	0.262	0.0827	909
Nov 1	0.95	14	2	No	0.0294	0.00927	101
Nov 8	0.95	14	2	No	0.0765	0.0249	273
Nov 15	0.95	14	2	No	0.0876	0.0276	303
Nov 22	0.95	14	2	No	0.121	0.0382	420
Nov 29	0.95	14	2	No	0.127	0.0396	435

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	0.95	14	2	No	0.129	0.0403	442
Dec 13	0.95	14	2	No	0.130	0.0409	449
Dec 20	0.95	14	2	No	0.132	0.0418	460
Nov 1	0.98	14	2	No	0.0131	0.00390	42
Nov 8	0.98	14	2	No	0.0279	0.00913	100
Nov 15	0.98	14	2	No	0.0364	0.0110	121
Nov 22	0.98	14	2	No	0.0483	0.0150	165
Nov 29	0.98	14	2	No	0.0499	0.0159	174
Dec 6	0.98	14	2	No	0.0543	0.0169	186
Dec 13	0.98	14	2	No	0.0527	0.0165	181
Dec 20	0.98	14	2	No	0.0544	0.0169	185
Nov 1	0.75	30	2	No	0.586	0.182	2002
Nov 8	0.75	30	2	No	0.706	0.207	2275
Nov 15	0.75	30	2	No	0.778	0.221	2425
Nov 22	0.75	30	2	No	0.811	0.226	2488
Nov 29	0.75	30	2	No	0.861	0.236	2594
Dec 6	0.75	30	2	No	0.849	0.233	2565
Dec 13	0.75	30	2	No	0.852	0.235	2580
Dec 20	0.75	30	2	No	0.865	0.237	2611
Nov 1	0.9	30	2	No	0.234	0.0718	790
Nov 8	0.9	30	2	No	0.285	0.0844	928
Nov 15	0.9	30	2	No	0.316	0.0899	988
Nov 22	0.9	30	2	No	0.331	0.0922	1014
Nov 29	0.9	30	2	No	0.343	0.0947	1042
Dec 6	0.9	30	2	No	0.341	0.0933	1025

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 13	0.9	30	2	No	0.336	0.0928	1020
Dec 20	0.9	30	2	No	0.348	0.0947	1041
Nov 1	0.95	30	2	No	0.115	0.0357	393
Nov 8	0.95	30	2	No	0.142	0.0416	457
Nov 15	0.95	30	2	No	0.152	0.0432	475
Nov 22	0.95	30	2	No	0.163	0.0452	496
Nov 29	0.95	30	2	No	0.167	0.0459	504
Dec 6	0.95	30	2	No	0.169	0.0461	507
Dec 13	0.95	30	2	No	0.166	0.0456	501
Dec 20	0.95	30	2	No	0.173	0.0479	527
Nov 1	0.98	30	2	No	0.0486	0.0149	163
Nov 8	0.98	30	2	No	0.0610	0.0182	200
Nov 15	0.98	30	2	No	0.0579	0.0166	182
Nov 22	0.98	30	2	No	0.0712	0.0200	220
Nov 29	0.98	30	2	No	0.0690	0.0189	207
Dec 6	0.98	30	2	No	0.0657	0.0180	198
Dec 13	0.98	30	2	No	0.0643	0.0174	191
Dec 20	0.98	30	2	No	0.0698	0.0190	209
Nov 1	0.75	99	2	No	1.02	0.248	2725
Nov 8	0.75	99	2	No	1.05	0.252	2772
Nov 15	0.75	99	2	No	1.04	0.245	2696
Nov 22	0.75	99	2	No	1.05	0.249	2743
Nov 29	0.75	99	2	No	1.05	0.248	2730
Dec 6	0.75	99	2	No	1.03	0.243	2678
Dec 13	0.75	99	2	No	1.03	0.246	2702

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 20	0.75	99	2	No	1.03	0.247	2719
Nov 1	0.9	99	2	No	0.409	0.0990	1089
Nov 8	0.9	99	2	No	0.424	0.102	1119
Nov 15	0.9	99	2	No	0.416	0.0993	1091
Nov 22	0.9	99	2	No	0.411	0.0969	1065
Nov 29	0.9	99	2	No	0.431	0.102	1117
Dec 6	0.9	99	2	No	0.426	0.102	1117
Dec 13	0.9	99	2	No	0.409	0.0970	1066
Dec 20	0.9	99	2	No	0.412	0.0983	1081
Nov 1	0.95	99	2	No	0.196	0.0479	526
Nov 8	0.95	99	2	No	0.210	0.0507	557
Nov 15	0.95	99	2	No	0.202	0.0475	522
Nov 22	0.95	99	2	No	0.201	0.0482	530
Nov 29	0.95	99	2	No	0.213	0.0504	554
Dec 6	0.95	99	2	No	0.206	0.0488	537
Dec 13	0.95	99	2	No	0.212	0.0500	550
Dec 20	0.95	99	2	No	0.206	0.0503	553
Nov 1	0.98	99	2	No	0.0863	0.0210	231
Nov 8	0.98	99	2	No	0.0791	0.0193	212
Nov 15	0.98	99	2	No	0.0826	0.0200	219
Nov 22	0.98	99	2	No	0.0883	0.0205	225
Nov 29	0.98	99	2	No	0.0815	0.0194	213
Dec 6	0.98	99	2	No	0.0850	0.0202	222
Dec 13	0.98	99	2	No	0.0769	0.0186	204
Dec 20	0.98	99	2	No	0.0793	0.0192	211

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)
Sensitivity Analysis [a]							
Nov 29	0.9	30	1	No	0.0332	0.0198	217
Nov 29	0.9	30	2	Yes	0.330	0.0918	1009

[a] These results were included to emphasize the effects that alterations of inputs have on the model

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	96	3	No	31.1	0.250	2750
Nov 8	0.75	96	3	No	31.9	0.251	2765
Nov 15	0.75	96	3	No	32.5	0.253	2781
Nov 22	0.75	96	3	No	31.8	0.247	2713
Nov 29	0.75	96	3	No	31.7	0.248	2731
Dec 6	0.75	96	3	No	31.4	0.246	2708
Dec 13	0.75	96	3	No	31.4	0.249	2742
Dec 20	0.75	96	3	No	30.8	0.246	2709
Nov 1	0.9	96	3	No	12.3	0.0996	1095
Nov 8	0.9	96	3	No	12.8	0.101	1108
Nov 15	0.9	96	3	No	12.7	0.0989	1088
Nov 22	0.9	96	3	No	12.2	0.0953	1047
Nov 29	0.9	96	3	No	12.7	0.0982	1080
Dec 6	0.9	96	3	No	13.0	0.101	1115
Dec 13	0.9	96	3	No	12.5	0.0991	1090
Dec 20	0.9	96	3	No	12.6	0.0997	1096
Nov 1	0.95	96	3	No	5.97	0.0484	532
Nov 8	0.95	96	3	No	6.15	0.0485	533
Nov 15	0.95	96	3	No	6.29	0.0489	537
Nov 22	0.95	96	3	No	6.34	0.0500	550
Nov 29	0.95	96	3	No	6.35	0.0499	548

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	0.95	96	3	No	6.36	0.0500	550
Dec 13	0.95	96	3	No	6.49	0.0510	561
Dec 20	0.95	96	3	No	6.36	0.0505	555
Nov 1	0.98	96	3	No	2.54	0.0201	220
Nov 8	0.98	96	3	No	2.65	0.0205	225
Nov 15	0.98	96	3	No	2.36	0.0183	201
Nov 22	0.98	96	3	No	2.51	0.0199	218
Nov 29	0.98	96	3	No	2.50	0.0198	217
Dec 6	0.98	96	3	No	2.51	0.0194	213
Dec 13	0.98	96	3	No	2.68	0.0207	227
Dec 20	0.98	96	3	No	2.31	0.0185	203
Sensitivity Analysis[a]							
Nov 29	0.75	96	1	No	0.0691	0.0205	225
Nov 29	0.75	96	2	No	3.20	0.100	1098
Nov 29	0.75	96	3	Yes	12.8	0.100	1100

[a] These results were included to emphasize the effects that alterations of inputs have on the model

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		0.234	0.0718	790
	Nov 8		0.285	0.0844	928
	Nov 15		0.316	0.0899	988
	Nov 22		0.331	0.0922	1014
	Nov 29		0.343	0.0947	1042
	Dec 6		0.341	0.0933	1025
	Dec 13		0.336	0.0928	1020
	Dec 20		0.348	0.0947	1041
Applications Interval	5	days	0.320	0.0887	975
	12	days	0.343	0.0947	1042
	21	days	0.340	0.0932	1024
Number of Applications	1		0.0332	0.0198	217
	2		0.343	0.0947	1042
Hazing Effectiveness	0.75		0.861	0.236	2594
	0.9		0.343	0.0947	1042
	0.95		0.167	0.0459	504
	0.98		0.0690	0.0189	207
Pellet Half-life	0.5	days	0.364	0.0952	1046
	1	days	0.343	0.0947	1042
	2	days	0.342	0.0934	1027
Time to Significant Rainfall Event After 2nd Application	14	days	0.267	0.0818	900
	30	days	0.343	0.0947	1042
	99	days	0.431	0.102	1117
Mean (SD) Concentration in Mice	2.71 (0.7)	mg/kg ww	0.333	0.0920	1012
	4.9 (1.26)	mg/kg ww	0.343	0.0947	1042
Daily Probability of Consuming Mice Prior to Brodifacoum Application	0.01		0.333	0.0914	1005
	0.125		0.343	0.0947	1042
	0.15		0.334	0.0923	1015
Daily Probability of Consuming Pellets Following Brodifacoum	0.22		0.316	0.0901	991
	0.25		0.343	0.0947	1042

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Gulls (#/11,000 Gulls)
Application					
Conditional Probability for Consuming Mice	0.5		0.337	0.0926	1018
	0.7		0.342	0.0945	1039
	0.9		0.343	0.0947	1042
Conditional Probability for Consuming Pellets	0.5		0.305	0.0956	1051
	0.7		0.309	0.0947	1041
	0.9		0.343	0.0947	1042
Proportion of Mouse Population Below Ground Following Onset of Symptoms	0.87		0.343	0.0947	1042
	0.935		0.343	0.0954	1049
	1		0.339	0.0946	1040
LD50	0.26	mg/kg bw	0.343	0.0947	1042
	0.424	mg/kg bw	0.336	0.0916	1007
	0.588	mg/kg bw	0.332	0.0879	966

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		12.3	0.0996	1095
	Nov 8		12.8	0.101	1108
	Nov 15		12.7	0.0989	1088
	Nov 22		12.2	0.0953	1047
	Nov 29		12.7	0.0982	1080
	Dec 6		13.0	0.101	1115
	Dec 13		12.5	0.0991	1090
	Dec 20		12.6	0.0997	1096
Applications Interval	3	days	16.2	0.0985	1083
	7	days	12.7	0.0982	1080
	10	days	12.8	0.101	1114
Number of Applications	1		0.0691	0.0205	225
	2		3.20	0.0999	1098
	3		12.7	0.0982	1080
Hazing Effectiveness	0.75		31.7	0.248	2731
	0.9		12.7	0.0982	1080
	0.95		6.35	0.0499	548
	0.98		2.50	0.0198	217
Pellet Half-life	0.5	days	14.9	0.0984	1082
	1	days	12.7	0.0982	1080
	2	days	13.1	0.102	1126
Mean (SD) Concentration in Mice	30 (7.5)	mg/kg ww	13.0	0.101	1114
	51.5 (13)	mg/kg ww	12.7	0.0982	1080
Daily Probability of Consuming Mice Prior to Diphacinone Application	0.01		12.8	0.100	1101
	0.125		12.7	0.0982	1080
	0.15		12.4	0.0971	1068
Daily Probability of Consuming Pellets Following Diphacinone Application	0.22		12.0	0.0969	1066
	0.25		12.7	0.0982	1080
Conditional	0.5		12.7	0.0994	1093

Varied Parameter	Value	Units	Mean Total Ingested Dose (mg ai/kg bw)	Proportion Dead Gulls	Number of Dead Birds (#/11,000 birds)
Probability for Consuming Mice	0.7		13.3	0.103	1130
	0.9		12.7	0.0982	1080
Conditional Probability for Consuming Pellets	0.5		11.6	0.101	1115
	0.7		11.6	0.100	1103
	0.9		12.7	0.0982	1080
Proportion of Mouse Population Below Ground Following Onset of Symptoms	0		12.6	0.0982	1080
	0.87		12.7	0.0982	1080
	1		12.8	0.100	1103
LD50	0.82	mg/kg bw	12.7	0.0982	1080
	48.91	mg/kg bw	12.9	0.0987	1085
	97	mg/kg bw	12.7	0.0695	764

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: **Eradication of Invasive House Mice on the South Farallon Islands**

MRDG Step 1: Determination

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 Islands National Wildlife Refuge off the central California coast. Mice were introduced by 19th century visitors to the islands. All of the islands, except the largest and only inhabited island, Southeast Farallon Island, are included in the Farallon Wilderness. The Farallon Wilderness was designated by Congress in 1974. P.L. 93-550, Title 1, §101, 102, 88 Stat. 174 (1974). The Farallon Wilderness comprises about 141 acres, of which about 50 acres or 35% are infested with house mice.

The mice occur both inside and outside the Farallon Wilderness. The Farallones host a unique island ecosystem that includes populations of about 350,000 birds of 13 species including about half of the world population of the rare ashy storm-petrel (*Oceanodroma homochroa*), as well as the endemic Farallon arboreal salamander (*Aneides lugubris farallonensis)* and the endemic Farallon camel cricket (*Farallonophilus cavernicolus*). The Refuge is closed to the public.

House mice are adversely impacting the native Farallon ecosystem, including ashy storm-petrels, salamanders, crickets, other terrestrial invertebrates, and plants. The nature and extent of these impacts are explained in the accompanying South Farallon Islands House Mouse Eradication Project Final Environmental Impact Statement (FEIS).

The purpose of this analysis is to determine if management action to address the impacts of invasive house mice is necessary in wilderness in order to preserve wilderness character and administer the Farallon Wilderness for wilderness purposes (Step 1) and, if so, what the minimum required action is (Step 2). Results of this analysis will be used to help select a Preferred Alternative in the FEIS.

Options Outside of Wilderness
Can action be taken outside of wilderness that adequately addresses the situation?

☐ YES **STOP – DO NOT TAKE ACTION IN WILDERNESS**

☒ NO **EXPLAIN AND COMPLETE STEP 1 OF THE MRDG**

Explain:

Actions taken outside the wilderness will not adequately address the situation.

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 and their impacts would remain in wilderness. While eradication of house mice only outside the wilderness (Southeast Farallon Island) would have benefits temporarily, narrow channels separating the wilderness from non-wilderness can 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:

There are no valid existing rights in the Farallon Wilderness. The eradication of invasive house mice is not being proposed to satisfy any special statutory provision related to the designation of the Farallon Wilderness.

Section 4.(d)(1) of the Wilderness Act states that, "In addition, such measures may be taken as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable." Service wilderness policy states that we will follow an integrated pest management (IPM) approach to prevent, control, or eradicate invasive species, pests, and diseases. While these laws and policies authorize action to eradicate invasive species, they do not require the Service to act. Specific actions that may be taken will be identified and evaluated in Step 2.

B. Requirements of Other Legislation

Is action necessary to meet the requirements of other federal laws? Cite law and section.

☐ YES ☒ NO

Explain:

There are no federal statutes that specifically require management action in the Farallon Wilderness to address invasive mice. However, Executive Orders have the force of law in providing direction to federal agencies. 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. It also directs the creation of a federal invasive species council, the development of a national Invasive Species Management Plan and Invasive Species information clearinghouse, and the participation of federal agencies in the council and to implement the Invasive Species Management Plan.

C. Wilderness Character

Is action necessary to preserve one or more of the five qualities of wilderness character?

UNTRAMMELED

☐ YES ☒ NO

Explain:

It is not necessary to take action to preserve this quality. The definition of the Untrammeled quality is the lack of manipulation or control of natural processes by humans, which if allowed to occur, would eventually affect wilderness character. This quality is typically preserved when no action is taken to control, hinder, or manipulate the natural functioning of the ecosystem.

Any treatment to prevent or address the invasive mouse infestation would be a manipulation of the natural processes of wilderness, and a trammeling, even though the house mouse is non-native and treatment may ultimately help restore natural conditions. The potential impacts of any proposed treatment methods will be addressed in the Step 2 alternatives.

UNDEVELOPED

☐ YES ☒ NO

Explain:

It is not necessary to take action to preserve this quality. Preserving this quality keeps areas free from “expanding settlement and growing mechanization” and “with the imprint of man’s work substantially unnoticeable” and without structures, installations, temporary or permanent roads, or use of motorized equipment, mechanical transport, or landing or aircraft as required by the Wilderness Act. The Undeveloped quality is preserved when wilderness retains its "primeval character and influence," and is essentially "without permanent improvements" or modern human occupation.

There is no need to take action to prevent adverse impacts to the Undeveloped quality from installations, structures, motorized equipment, or the use mechanical transport devices. The potential impacts of any proposed treatment methods will be addressed in the Step 2 alternatives.

NATURAL

☒ YES ☐ NO

Explain:

It is necessary to take action to preserve this quality. The Wilderness Act states that a wilderness area is to be "protected and managed so as to preserve its natural conditions" meaning that wilderness ecological systems are substantially free from the effects of modern civilization. To preserve this quality and address the conservation public purposes of wilderness, it may be necessary to take action to correct unnatural conditions even if they were present at the time of designation. Any impacts resulting from the influence of modern civilization, such as by invasive house mice, affect both the Natural quality of wilderness character and the conservation public purposes of the Farallon Wilderness.

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 in the wilderness. The removal of mice would reverse the degradation caused by mice to the Natural quality of wilderness and allow the Farallon Wilderness to be more influenced by natural forces.

SOLITUDE OR PRIMITIVE & UNCONFINED RECREATION

☐ YES ☒ NO

Explain:

It is not necessary to take action to preserve this quality. The Wilderness Act defines wilderness as having "outstanding opportunities for solitude or a primitive and unconfined type of recreation." This quality is preserved when the *opportunity* for people to experience wilderness in terms of the visitor's sense of solitude, and their expectation for an undeveloped environment with minimal restrictions is available. Because the Farallon Islands National Wildlife Refuge, including the Farallon Wilderness, is closed to the public, no actions are necessary to preserve opportunities for solitude and primitive recreation. In the same vein, the closure of the refuge to public visitation means that the recreational purpose of the Farallon wilderness in subordinate to other wilderness purposes.

OTHER FEATURES OF VALUE AND WILDERNESS PURPOSES

☒ YES ☐ NO

Explain:

FEATURES OF VALUE:
Action is necessary to preserve other features of value in the Farallon Wilderness.

The Farallon Islands National Wildlife Refuge was established by Executive Order 1043 in 1909 as a "…preserve and breeding ground for native birds." The Refuge was expanded in 1969 to include the South Farallon islands.

In the early 1970s, the Service evaluated whether any lands within the refuge were suitable for wilderness designation. The Farallon Wilderness proposal forwarded to Congress recognized that "…wilderness designation of all or part of this refuge would be entirely compatible with the purposes for which it was established, and would be in keeping with the existing management objective of preserving physical and biological qualities in a natural condition for optimum wildlife use and productivity." Legislation establishing the Farallon Wilderness was enacted in 1974. The Senate Report accompanying the Farallon Wilderness bill cited the importance of the refuge as a nesting area for 11 species of sea birds including Cassin's auklet, western gulls, ashy storm petrels and the largest cormorant colony complex on the Pacific Coast outside Alaska. The presence of many native plant species and haul out sites for pinnipeds also contributed to the wilderness designation of the islands. S.Rep. 93-1221 (Oct. 4, 1974). The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is therefore a feature of value for the Farallon Wilderness.

The South Farallon Islands host the largest breeding colony of seabirds in the contiguous United States, including about 50% of the rare ashy storm-petrel population, which is adversely impacted by mouse presence on the Farallones. While the Service found that listing the ashy storm-petrel under the Endangered Species Act is not warranted, the species is listed as a Service Bird of Conservation Concern and by the State of California as a Bird Species of Special Concern. The Refuge's Comprehensive Conservation Plan (CCP) identified the eradication of house mice as an important conservation action for the Service to undertake to preserve the islands' ashy storm-petrels and other native resources and indicated that the Service would initiate a step-down planning process to consider eradication methods.

WILDERNESS PURPOSES:

This history discussed above underscores the fact that conservation of native species is an important purpose behind the establishment of the Farallon Wilderness. In the current context, the Service has determined that conservation of native species is of greater importance that the other public purposes of wilderness (e.g., scenic, scientific, educational, recreational and historical) because of the degree to which non-native mice adversely impact the integrity, diversity and health of the refuge. While any feasible eradication effort will result in temporary impacts to all aspects of wilderness character through the deployment of personnel and tools and the use of rodenticide, myriad long-term benefits will result. The eradication of mice will remove the visual presence of a non-native species; enhance the natural quality of wilderness and its special features by restoring native species habitat and removing unnatural predator-prey relationships; and support scientific and educational opportunities through the re-establishment of more natural ecosystem dynamics.

Step 1 Determination
Is administrative action necessary in wilderness?

Criteria for Determining Necessity

A.	Existing Rights or Special Provisions	☐ YES	☒ NO
B.	Requirements of Other Legislation	☐ YES	☒ NO

C. Wilderness Character

Untrammeled	☐ YES	☒ NO
Undeveloped	☐ YES	☒ NO
Natural	☒ YES	☐ NO
Solitude/Primitive/Unconfined	☐ YES	☒ NO
Other Features of Value	☒ YES	☐ NO

Is administrative action necessary in wilderness?

☒ YES	**EXPLAIN AND PROCEED TO STEP 2 OF THE MRDG**
☐ NO	**STOP – DO NOT TAKE ACTION IN WILDERNESS**

Explain:

Some type of action is necessary in wilderness to address the threat of invasive house mice both within and outside the Farallon Wilderness. Non-native house mice negatively impact the Natural conditions and special features of the Farallon Wilderness, including native birds, salamanders, invertebrates, and plants. Because of the ease with which mice could re-infest non-wilderness areas, eradication only in non-wilderness portions of the refuge would not preserve the Natural quality of wilderness or the area's special features of value. Taking no action in wilderness to eliminate the adverse effects of mice is incompatible with the conservation purpose of the Farallon Wilderness.

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 **DESCRIBE OTHER DIRECTION**

☐ NO **SKIP AHEAD TO TIME CONSTRAINTS BELOW**

Describe Other Direction:

There is no special provision language in legislation or other Congressional direction that explicitly allows consideration of a prohibited use for management of invasive species such as house mice in the Farallon Wilderness. However, Section 4(d)(1) of the Wilderness Act states that, "In addition, such measures may be taken as may be necessary in the control of fire, insects, and diseases, subject to such conditions as the Secretary deems desirable." This provision applies to actions that may be taken for management of invasive species such as house mice.

Fish & Wildlife Service (Service) policy (610 FW 2) provides that native wildlife and plants are essential components of wilderness. This policy permits management of invasive species, pests, and diseases in wilderness when: 1) we have 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; 2) they pose a significant threat to the health of humans, and the U.S. Public Health Service (which includes the Centers for Disease Control) has advised us to control them; or 3) we have demonstrated that they pose a significant threat to the health of fish, wildlife, plants, or their habitats.

When natural ecosystem processes have been altered by invasive species, Service policy authorizes action to eradicate invasive species and restore biological integrity and wilderness character, provided that the action is the minimum required to administer the wilderness and achieve refuge purposes. For eradication actions involving chemical treatments, Service policy directs the Service to select the agent that will have the least impact on non-target species and the wilderness environment.

Time Constraints
What, if any, are the time constraints that may affect the action?

Efficacy of mouse eradication is greatest when the mouse population is at or near an annual low, or at least when breeding activity is low to nonexistent. To minimize impacts to non-target wildlife, eradication is best when potential non-target populations are at or near annual minimums. The mouse population crashes in late fall or early winter and reaches an annual minimum between mid-winter and early spring. Research has shown that mouse breeding activity nearly ceases in November. Potential non-target populations are at annual lows in early to mid-fall but remain at relatively low levels through late fall.

Based on available information, the best timing for high eradication efficacy and minimizing non-target impacts is in October-December, with preferred timing in November-December.

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, supplies and equipment.
Component 3:	Gull hazing tools, tent camp.
Component 4:	Condition of the site after project completion.

Proceed to the alternatives.

Refer to the **MRDG Instructions** regarding alternatives and the effects to each of the comparison criteria.

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 and they would continue to impact the natural character and special features of value of the Farallon Wilderness. Other ongoing invasive species management programs on the Refuge would continue. The Service currently conducts limited manual control of invasive plants in the wilderness. The Service would also continue management activities focused on protecting and restoring storm-petrel breeding habitats, but this activity is limited to non-wilderness areas. If mice were allowed to remain on the islands, ongoing negative impacts are anticipated affecting seabird, plant, salamander 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 impacted by foraging by mice.

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 more invasive vertebrates would be hampered by the presence of mice since they can mask the ability to detect other rodent invasions. Taking No Action to address the effects of non-native mice would be contrary to the purpose of the Refuge as a reserve for native birds and other Service policies for conservation and restoration of natural biodiversity, removal of invasive species, and management of the natural character and special features of value of 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, supplies and equipment.	No transportation of personnel, supplies and equipment for eradication purposes will occur.
3	Gull hazing tools, tent camp.	No gull hazing tools will be used.
4	Condition of the site after project completion.	Condition of the site will be unchanged; house mice are still present.

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, supplies and equipment will occur.	☐	☐	☒
3	No gull hazing tools will be used.	☐	☐	☒
4	Condition of the site will be unchanged; house mice are still present.	☐	☐	☒
Total Number of Effects		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 no action would be taken in the wilderness and 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, supplies and equipment for eradication purposes will occur.	☐	☐	☒
3	No gull hazing tools will be used.	☐	☐	☒
4	Condition of the site will be unchanged; house mice are still present.	☐	☐	☒
Total Number of Effects		0	0	NE
Undeveloped Total Rating		**0**		

Explain:

The presence of mice does not affect the undeveloped character of the wilderness. Therefore, because no action would be taken in the wilderness, 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, supplies and equipment for eradication purposes will occur.	☐	☐	☒
3	No gull hazing tools will be used.	☐	☐	☒
4	Condition of the site will be unchanged; house mice are still present.	☐	☒	☐
Total Number of Effects		0	-1	NE
Natural Total Rating		**-1**		

Explain:

Under the No Action alternative, mice would not be eradicated from the South Farallon Islands. Mice alter the natural character of wilderness by impacting native species including ashy storm-petrels, arboreal salamanders, Farallon camel crickets and other invertebrates, and maritime goldfields and other native plants. Under this alternative, the negative impacts of mice on the natural character of wilderness would continue.

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, supplies and equipment for eradication purposes will occur.	☐	☐	☒
3	No gull hazing tools will be used.	☐	☐	☒
4	Condition of the site will be unchanged; house mice are still present.	☐	☐	☒
	Total Number of Effects	0	0	NE
	Solitude or Primitive & Unconfined Rec. Total Rating	**0**		

Explain:

The refuge is closed to public visitation. 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, supplies and equipment for eradication purposes will occur.	☐	☐	☒
3	No gull hazing tools will be used.	☐	☐	☒
4	Condition of the site will be unchanged; house mice are still present.	☐	☒	☐
	Total Number of Effects	0	-1	NE
	Other Features of Value Total Rating	**-1**		

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Relatedly, conservation of native species is one of the purposes for which the Farallon Wilderness was established.

By not removing invasive house mice, mice would continue to impact the ashy storm-petrel, a Service Bird Species of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander and Farallon camel cricket, would also continue to be impacted. These impacts would continue for the foreseeable future.

Summary Ratings for Alternative 1[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**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

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 2: Brodifacoum 25-D Conservation, non-mechanical hazing methods

In Alternative 2, house mice would be eradicated from the South Farallones using an aerial (helicopter) application of Brodifacoum-25D Conservation rodent bait pellets as the primary application method. Brodifacoum-25D Conservation is a compressed cereal grain pellet that weighs approximately 0.35 oz (1 g). 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. The specific bait product used for this alternative is registered by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA) with the U.S. EPA (EPA Reg. No. 56228-37). In consultation with USDA and EPA, supplemental label may be acquired if necessary to modify methods for baiting certain areas. Bait would be applied in compliance with the EPA and FIFRA bait label or supplemental label. The main differences between Brodifacoum and Diphacinone (Alternatives 5-8) is Brodifacoum's greater potency; mice typically need only one feeding to reach a lethal dose. Thus, the period of bait availability is less for Brodifacoum than Diphacinone, thus reducing the period of availability for ingestion by non-target species. Also, Brodifacoum has been shown to be more palatable to mice than Diphacinone, increasing the likelihood of ingestion of bait by mice.

The operation would strictly follow the principals of IPM. Application would occur in the fall between October and December (most likely November-December) when the risk to non-target wildlife is minimal. Bait would need to be applied to every mouse territory. Bait application would follow the EPA registration label or supplemental label. Bait would be broadcast in two 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 the second application, for a total of 24 lb/acre (27kg/ha). 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). For the two bait applications, estimated helicopter flight time over all islands is about 6 hours (3 hours per application). Certain areas that are either not accessible by aircraft, considered highly sensitive habitat, or where aerial baiting may pose a risk to human safety, would be baited by hand. The helicopter would fly over wilderness but not land in wilderness.

At estimated application rates, the total amount of bait needed would be about 1,200 lb for the wilderness. This amount of rodent bait contains about 0.48 oz of brodifacoum, in total. Approximately 800 lb of bait pellets would be delivered into wilderness during the first application and approximately 400 lb during the second application. Each application would require approximately two hours of helicopter flight time over the entirety of the operational area, with about one hour of time flying over wilderness. 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.

For ground-based operations, personnel would access West End Island, the largest island in the wilderness, from SE Farallon across the narrow Jordan Channel. If necessary, 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 the mouse population.

Studies have shown that western gulls 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. Based on a study (Appendix F of the FEIS), the Service determined that non-target mortality of no more than 1,700 western gulls would be necessary to avoid long-term adverse impacts to their population. To minimize these risks, gulls will be actively hazed from the islands for a period beginning about one week prior to the first bait application and for a period of time until the risk of rodenticide exposure is considered to be negligible. Rodent bait is projected to be available to gulls for up to 5 weeks; thus, the expected period for gull hazing would be about 6 weeks. Since bait disintegrates quickly in heavy rain, this period could be either shorter or longer depending upon the time between the second bait drop and the first significant rainfall. In severe drought conditions, undisturbed bait could remain for up to 101 days.

Because birds can habituate to hazing, a variety of techniques are usually necessary to successfully haze for long periods of time. Gull hazing techniques allowed under this Alternative are limited to non-mechanized means and might include gull effigies, flushing by human approach, hand-held lasers, hand-held spotlights, and lethal removal. It is recognized that the use of only non-mechanized hazing techniques may compromise the success the hazing efforts. Lasers and spotlights would be hand-held and battery-operated; these would only be used in low light conditions to haze gulls that have either landed on the islands or are flying towards the islands. Lethal gull removal would be used only if deemed absolutely necessary, and would involve removal by shotgun of small numbers of birds. 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 an expected total of about 22 trips on 11 separate days over six weeks. Human foot traffic would cause unavoidable disturbances to large numbers of resting seals and sea lions both inside and outside wilderness during each trip.

Bait application will likely result in the disturbance of all birds and pinnipeds present on the islands. In addition, considerable short-term disturbance will occur while accessing West End Island for gull hazing activities because under this alternative, all personnel would travel by foot resulting in more frequent trips. Based on data from 34 foot-based trips to West End Island between 2009 and early 2013, an average of 797 pinnipeds were disturbed per trip-day, including 468 animals flushed and 329 animals moved. Based on an estimated 11 foot-based trip-days in this alternative for gull hazing, 8,767 total pinniped takes would occur, including 5,148 flushed and 3,619 moved. This short-term disturbance to pinnipeds will require a Marine Mammal Incidental Harassment Authorization from the National Marine Fisheries Service.

A temporary boat and aircraft closure within about 0.5 miles of the islands will be jointly developed by the Service, FAA and the State of California during aerial bait application operations; however, since the wilderness is closed to the public, these measures will not impact wilderness access.

Following project implementation, periodic monitoring would be conducted for about two years to confirm project success. Monitoring tools may include traps, track plates, chew blocks, and portable video cameras. These tools would be deployed on foot and mounted temporarily in place. They would be removed immediately following each monitoring session, which would last from two days to two weeks.

A project safety plan or Job Hazard Analysis (JHA) will be prepared and implemented to meet Service requirements.

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 Brodifacoum, possibly some hand-baiting.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported on foot to West End Island.

		Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.
4	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.

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 Brodifacoum, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating			**-3**	

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-2	NE
Undeveloped Total Rating		**-2**		

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. While aircraft used for dropping bait would not land in wilderness, low-level flights for management of wilderness is treated as landing of aircraft and is considered an impact to the undeveloped quality.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

The use of gull effigies, hand-held lasers, hand-held spotlights, and lethal gull removal by the use of legal firearms is not considered an impact to the undeveloped quality.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐

3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	-3	NE
Natural Total Rating		**-2**		

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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 Brodifacoum, possibly some hand-baiting.	☐	☒	☐

2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-1	NE
Solitude or Primitive & Unconfined Rec. Total Rating		**-1**		

Explain:

Low-flying helicopters over the wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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 Brodifacoum, possibly some hand-baiting.	☐	☐	☒
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

The presence of invasive mice disrupts natural ecosystem functions by adversely impacting native habitat and breeding conditions as well as altering predator-prey relationships. By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 2[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-2
Natural	-2
Solitude or Primitive & Unconfined Recreation	-1
Other Features of Value	1
Wilderness Character Summary Rating	**-7**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

Alternative 3: Brodifacoum 25-D Conservation with bait stations, mechanical hazing methods

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 the same as 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 unacceptably high. Because bait is enclosed in the bait stations, it is inaccessible to gulls. Bait stations would be placed in grids two to four meters apart per EPA label recommendations. 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 initially filled with up to 4.2 oz (120 g) of bait and kept at this level for the duration of their deployment; this requires inspection and re-filling every 2-4 days. Bait stations would be removed upon the completion of the project (approximately 6 weeks).

Because birds can become habituated, it is usually necessary to employ a variety of techniques to continue to haze gulls successfully. The techniques used will depend upon the success rate of less adverse techniques and the expert opinions of hazing staff. Additional gull hazing techniques might include propane cannons, biosonics, and an assortment of hand-launched pyrotechnics. 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 be 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 Brodifacoum and possibly some hand-baiting and bait stations.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.
4	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.

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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating			**-3**	

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, short-term actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Undeveloped Total Rating			**-3**	

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. While aircraft used for dropping bait would not land in wilderness, low-level flights for management of wilderness is treated as landing of aircraft and is an impact to the undeveloped quality.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

Although they will be deployed only for the duration of the project, the deployment and/or use of propane cannons, pyrotechnics, and biosonics is considered an impact to the undeveloped quality.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	-3	NE
Natural Total Rating		**-2**		

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-2	NE
Solitude or Primitive & Unconfined Rec. Total Rating			**-2**	

Explain:

Low-flying helicopters over the wilderness and the use of biosonics, pyrotechnics, and propane cannons within wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☐	☒
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☒

Total Number of Effects	1	0	NE
Other Features of Value Total Rating		**1**	

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 3[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-3
Natural	-2
Solitude or Primitive & Unconfined Recreation	-2
Other Features of Value	1
Wilderness Character Summary Rating	**-9**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

Alternative 4:	Brodifacoum 25-D Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings (Alternative B in the FEIS)

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 the same as Alternative 3 except for the following:

Personnel, supplies and equipment for mouse removal and gull hazing would be transported to and from West End Island by helicopter. For these operations, a relatively small one to two passenger helicopter such as an R-22 would be used because of its greater maneuverability for landing in tight places and for its relatively quiet rotor which minimizes disturbance to pinnipeds and noise pollution. Results from a hazing trial in 2012 found that an R-22 helicopter was effective at hazing gulls from areas that were otherwise inaccessible, with minimal disturbance to marine mammals. Up to two low overflights per day may be conducted to haze gulls.

For gull hazing and mouse removal operations, about three helicopter landings would be necessary every fourth day to transport personnel and gear. Assuming a 6-week operational period, a total of about 35 helicopter landings on 11 separate days would occur in the wilderness.

Based on data from December 2012 gull hazing trials, an average of 48 pinnipeds were disturbed per day from helicopter trips to deliver personnel and gear to West End Island, including 16 animals flushed and 32 animals moved. Based on an estimated 11 helicopter days for this task in this alternative, 528 total pinniped takes would occur, including 176 flushed and 352 moved. The total number of animals disturbed is about 94% less using helicopter transport than foot transport (Alternatives 2, 3).

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 Brodifacoum and possibly some hand-baiting and bait stations.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.
4	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.

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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating			**-3**	

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Undeveloped Total Rating			**-3**	

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. In this alternative, aircraft would be used for dropping bait, hazing gulls, and transporting personnel and gear.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

Although they will be deployed only for the duration of the project, the deployment and/or use of propane cannons, pyrotechnics, and biosonics is considered an impact to the undeveloped quality. All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	-3	NE
Natural Total Rating			**-2**	

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Solitude or Primitive & Unconfined Rec. Total Rating			**-3**	

Explain:

Low-flying helicopters over the wilderness and the use of biosonics, pyrotechnics, and propane cannons within wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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 Brodifacoum and possibly some hand-baiting and bait stations.	☐	☐	☒
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☐	☒

4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 4[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-3
Natural	-2
Solitude or Primitive & Unconfined Recreation	-3
Other Features of Value	1
Wilderness Character Summary Rating	**-10**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

Alternative 5: Diphacinone-50 Conservation, non-mechanical hazing methods

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, house mice would be eradicated from the South Farallones using an aerial (helicopter) application of Diphacinone-50 Conservation rodent bait pellets as the primary application method. The rodenticide Diphacinone-50 Conservation is a cereal grain pellet available in approximately 0.35 oz to 0.70 oz (1-2 g) pellets with an added fish flavor. The bait contains 50 ppm or 0.005 percent diphacinone, a first-generation anticoagulant. Pellets are dyed dark green, which has been shown to make them less attractive to birds and reptiles. The specific bait product used for this alternative is registered with the EPA (EPA Reg. No. 56228-35) and would be applied in compliance with the EPA and FIFRA bait label; a supplemental label would be acquired if desired bait application rate(s) would exceed EPA label rates. The main difference between Diphacinone and Brodifacoum (Alternatives 2-4) is Diphacinone's lower potency; thus, mice must consume bait multiple times over several days to reach a lethal dose. For this reason, bait must be available for a longer time period with Diphacinone than with Brodifacoum. Also, Diphacinone has been shown to be less palatable to mice than Brodifacoum.

The operation would strictly follow the principals of IPM. Application would occur in the fall between October and December (mostly likely November-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 three applications about seven days apart. Application rates would be up to 12.5 lb/acre (13.8 kg/ha) in each application, for a total of 37.5 lb/acre (41.4 kg/ha). 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 three bait applications, estimated helicopter flight time over all islands is about 9 hours (2 hours per application). Certain areas that are either not accessible by aircraft, considered highly sensitive habitat, or where aerial baiting may pose a risk to human safety (such as around dwellings), would be baited by hand.

At estimated application rates, the total amount of bait needed would be about 625 lb per application for the wilderness, or 1,875 lb in total. This amount of rodent bait contains about 1.5 oz of diphacinone, in total. Each application would require just over two hours of helicopter flight time over the entirety of the operational area, or a total of about seven hours over three applications. About one hour of time per application would be spent flying over wilderness, for a total of about 3.0-3.5 hours over three applications. 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 be completed within 1-2 days.

For ground-based operations, personnel would access West End Island, the largest island in the wilderness, from SE Farallon across the narrow Jordan Channel. If necessary, 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 the mouse population.

Studies have shown that western gulls and other species of gulls are at a moderate risk of mortality if they are exposed to Diphacinone 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. Based on a study (Appendix F of the FEIS), the Service determined that non-target mortality of no more than 1,700 western gulls would be necessary to avoid long-term adverse impacts to their population. To minimize these risks, gulls will be actively hazed from the islands for a period beginning about one week prior to the first bait application and for a period of time until the risk of rodenticide exposure is considered to be negligible. Rodent bait is projected to be available to gulls for up to 15 weeks; thus, the expected period for gull hazing would be about 16 weeks. Since bait disintegrates quickly in heavy rain, this period could be either shorter or longer depending upon the time between the second bait drop and the first significant rainfall. In severe drought conditions, undisturbed bait could remain for up to 101 days.

Because birds can habituate to hazing, a variety of techniques are usually necessary to successfully haze for long periods of time. Gull hazing techniques allowed under this Alternative are limited to non-mechanized means and might include gull effigies, flushing by human approach, hand-held lasers, hand-held spotlights, and lethal removal. It is recognized that the use of only non-mechanized hazing techniques may compromise the success the hazing efforts. Lasers and spotlights would be hand-held and battery-operated; these would only be used in low light conditions to haze gulls that have either landed on the island or are flying towards the island. Lethal gull removal would be used only if deemed absolutely necessary, and would involve removal by shotgun of small numbers of birds. 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 an expected total of about 56 trips on 28 separate days over 16 weeks. Human foot traffic would cause unavoidable disturbances to large numbers of resting seals and sea lions both inside and outside wilderness during each trip.

Bait application will likely result in the disturbance of all birds and pinnipeds present on the islands. In addition, considerable short-term disturbance will occur while accessing West End Island for gull hazing activities. Based on data from 34 trips to West End I. between 2009 and early 2013, an average of 797 pinnipeds were disturbed per trip-day, including 468 animals flushed and 329 animals moved. Based on an estimated 28 trip-days in this alternative for gull hazing, 22,316 total pinniped takes would occur, including 13,104 flushed and 9,212 moved. This short-term disturbance to pinnipeds will require a Marine Mammal Incidental Harassment Authorization from the National Marine Fisheries Service. 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.

A temporary boat and aircraft closure within about 0.5 miles of the islands will be jointly developed by the Service, FAA and the state during aerial bait application operations; however, since the wilderness is closed to the public, these measures will not impact wilderness access.

Following project implementation, periodic monitoring would be conducted for about two years to confirm project success. Monitoring tools may include traps, track plates, chew blocks, and portable video cameras. These tools would be deployed on foot and mounted temporarily in place. They would be removed immediately following each monitoring session, which would last from two days to two weeks.

A project safety plan or Job Hazard Analysis (JHA) will be prepared and implemented to meet Service requirements.

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, possibly some hand-baiting.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.

4	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.

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, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating		**-3**		

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone, possibly some hand-baiting.	☐	☒	☐

2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-2	NE
Undeveloped Total Rating		**-2**		

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. While aircraft used for dropping bait would not land in wilderness, low-level flights for management of wilderness is treated as landing of aircraft and is an impact to the undeveloped quality.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

The use of gull effigies, hand-held lasers, hand-held spotlights, and lethal gull removal by the use of legal firearms is not considered an impact to the undeveloped quality.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐

Total Number of Effects	1	-3	NE
Natural Total Rating	**-2**		

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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, possibly some hand-baiting.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒

4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-1	NE
Solitude or Primitive & Unconfined Rec. Total Rating		**-1**		

Explain:

Low-flying helicopters over the wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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, possibly some hand-baiting.	☐	☐	☒
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers and spotlights, lethal gull removal, small tent camp.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 5[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-2
Natural	-2
Solitude or Primitive & Unconfined Recreation	-1
Other Features of Value	1
Wilderness Character Summary Rating	**-7**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

Alternative 6:	Diphacinone-50 Conservation with bait stations, mechanical hazing methods

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 the same as 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 unacceptably high. Because bait is enclosed in the bait stations, it is inaccessible to gulls. Bait stations would be placed in grids two to four meters apart per EPA label recommendations. 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 initially filled with up to 4.2 oz (120 g) of bait and kept at this level for the duration of their deployment; this requires inspection and re-filling every 2-4 days. Bait stations would be removed upon the completion of the eradication operation (approximately 6 weeks).

Because birds can become habituated, it is usually necessary to employ a variety of techniques to continue to haze gulls successfully. The techniques used will depend upon the success rate of less adverse techniques and the expert opinions of hazing staff. Additional gull hazing techniques might include propane cannons, biosonics, and an assortment of hand-launched pyrotechnics. 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 be 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 and possibly some hand-baiting and bait stations.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.
4	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.

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 and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating			**-3**	

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Undeveloped Total Rating			**-3**	

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. While aircraft used for dropping bait would not land in wilderness, low-level flights for management of wilderness is treated as landing of aircraft and is an impact to the undeveloped quality.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

Although they will be deployed only for the duration of the project, the deployment and/or use of propane cannons, pyrotechnics, and biosonics is considered an impact to the undeveloped quality.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	-3	NE
Natural Total Rating			**-2**	

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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 and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-2	NE
Solitude or Primitive & Unconfined Rec. Total Rating			**-2**	

Explain:

Low-flying helicopters over the wilderness and the use of biosonics, pyrotechnics, and propane cannons within wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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 and possibly some hand-baiting and bait stations.	☐	☐	☒
2	Personnel, supplies and equipment transported on foot to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☐	☒
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐

Total Number of Effects	1	0	NE
Other Features of Value Total Rating		1	

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 6[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-3
Natural	-2
Solitude or Primitive & Unconfined Recreation	-1
Other Features of Value	-1
Wilderness Character Summary Rating	**-9**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Alternatives

Alternative 7: Diphacinone-50 Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings (Alternative C in the FEIS)

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 the same as Alternative 6 except for the following:

Personnel, supplies and equipment for mouse removal and gull hazing would be transported to and from West End Island by helicopter. For these operations, a relatively small one to two passenger helicopter such as an R-22 would be used because of its greater maneuverability for landing in tight places and for its relatively quiet rotor which minimizes disturbance to pinnipeds and noise pollution. Results from a hazing trial in 2012 found that an R-22 helicopter was effective at hazing gulls from areas that were otherwise inaccessible, with minimal disturbance to marine mammals. Up to two low overflights per day may be conducted to haze gulls.

For gull hazing and mouse removal operations, about three helicopter landings would be necessary every fourth day to transport personnel and gear. Assuming a 16-week operational period, a total of about 86 helicopter landings on about 28 separate days would occur in the wilderness.

Based on data from December 2012 gull hazing trials, an average of 48 pinnipeds were disturbed per day from helicopter trips to deliver personnel and gear to West End Island, including 16 animals flushed and 32 animals moved. Based on an estimated 28 helicopter days for this task in this alternative, 1,344 total pinniped takes would occur, including 448 flushed and 896 moved. The total number of animals disturbed is about 94% less using helicopter transport than foot transport (Alternatives 5, 6). An additional benefit of helicopter transport is reduced safety risk than having personnel haul supplies and equipment on foot 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 and possibly some hand-baiting and bait stations.
2	Transportation of personnel, supplies and equipment.	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.
3	Gull hazing tools, tent camp.	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.
4	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.

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 and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Untrammeled Total Rating		**-3**		

Explain:

The Untrammeled quality is impacted when there is manipulation or control of the natural processes in wilderness. Even though house mice are non-native and invasive, actions to eradicate them are a trammeling even if the actions ultimately help restore natural conditions. All of the actions that would cause trammeling impacts are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

UNDEVELOPED

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Undeveloped Total Rating			**-3**	

Explain:

Section 4(c) of the Wilderness Act generally prohibits temporary roads, motor vehicles, motorized equipment, motorboats, mechanical transport, and the landing of aircraft. In this alternative, aircraft would be used for dropping bait, hazing gulls, and transporting personnel and gear.

Although motorized boats would not move through or land in wilderness, their use to deliver personnel directly to wilderness is considered mechanical transport and an impact to the undeveloped quality.

Although they will be deployed only for the duration of the project, the deployment and/or use of propane cannons, pyrotechnics, and biosonics is considered an impact to the undeveloped quality.

All of the actions related to development are temporary in nature. There would be no long-term impacts to this aspect of wilderness character.

NATURAL

Component Activity for this Alternative		Positive	Negative	No Effect
X	*Example: Personnel will travel by horseback*	☐	☐	☒
1	Primarily aerial broadcast of Diphacinone and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	-3	NE
Natural Total Rating		**-2**		

Explain:

This alternative would result in both beneficial and adverse impacts on the natural quality of wilderness.

The use of rodenticide in the wilderness negatively impacts the natural quality by introducing a toxin that would remain present in the environment until it degrades after several months. There would also be short-term adverse impacts to non-target organisms (such as gulls and some other birds). Some non-target take of birds, especially gulls, will almost certainly occur. Gull hazing, raptor capture and salamander capture will be conducted to minimize non-target impacts to a level below that at which there would be any long-term population level impacts.

Operations associated with aerial and hand-broadcast of rodenticide bait, gull hazing and foot access to, from and within the wilderness will result in a substantial amount of short-term disturbance to birds and pinnipeds (seals and sea lions). This disturbance will only last for the duration of application activities. Minimization of time spent near important resting areas and training of personnel on pinniped behavior will be conducted to minimize disturbance.

Mouse eradication would result in several significant benefits to the natural quality, including benefits to populations of several native species including ashy storm-petrels, Farallon arboreal salamanders, Farallon camel crickets, and maritime goldfields. Thus, if mouse eradication was successful and impacts to non-target resources kept below long-term significance levels, then the short-term adverse effects of the eradication and associated activities are outweighed by the long-term benefits of eradicating non-native house 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 and possibly some hand-baiting and bait stations.	☐	☒	☐
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☒	☐
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☒	☐
4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☐	☐	☒
Total Number of Effects		0	-3	NE
Solitude or Primitive & Unconfined Rec. Total Rating			**-3**	

Explain:

Low-flying helicopters over the wilderness and the use of biosonics, pyrotechnics, and propane cannons within wilderness are considered an adverse effect on solitude, even though the wilderness is closed to the public.

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 and possibly some hand-baiting and bait stations.	☐	☐	☒
2	Personnel, supplies and equipment transported by helicopter to West End Island. Drop off by small motorized boat to other areas; no boat landing.	☐	☐	☒
3	Gull effigies, human approach, hand-held lasers, hand-held spotlights, lethal removal, propane cannons, pyrotechnics, biosonics.	☐	☐	☒

4	Invasive house mice will have been eradicated. All project equipment will have been removed; bait will have degraded.	☒	☐	☐
Total Number of Effects		1	0	NE
Other Features of Value Total Rating		**1**		

Explain:

The importance of the Farallon Islands as a preserve and breeding site for seabirds and other native species is a feature of value for the Farallon Wilderness. Preserving these features furthers the conservation purpose of the Farallon Wilderness.

By removing invasive house mice, mice would no longer impact the ashy storm-petrel, a Service Bird of Conservation Concern of which nearly 50% of the world population occurs on the South Farallones. Other unique wildlife species, including the Farallon arboreal salamander, Farallon camel cricket, and maritime goldfield, would also no longer be impacted by mice.

Summary Ratings for Alternative 7[1]

Wilderness Character	
Untrammeled	-3
Undeveloped	-3
Natural	-2
Solitude or Primitive & Unconfined Recreation	-3
Other Features of Value	1
Wilderness Character Summary Rating	**-10**

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

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, extremely large number of bait stations to deploy and re-fill regularly for several weeks.
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. Also, introduced predators for control (e.g., cats, snakes) would likely have greater impacts on the ecosystem than mice.
7) Mouse 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 the Farallon Islands' ecosystem.
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.
10) Aerial rodenticide application without the use of gull hazing: The potentially large non-target impacts to gulls outweighs the benefits of the eradication.
11) Combination of Above Methods: Of the methods above that are technologically feasible, even the use of all such methods together would not eliminate the adverse impacts of mice on the natural quality of the Farallon Wilderness and its special features of value. Mouse control through the use of bait stations, hand baiting and other efforts to limit their population (e.g., by relocating owls, trapping, use of biological control agents) would not result in the eradication of mice and the long-term degradation they cause to the biological health and integrity the Farallon Wilderness.

MRDG Step 2: Alternative Comparison

Alternative 1:	No Action
Alternative 2:	Brodifacoum 25-D Conservation, non-mechanical hazing methods
Alternative 3:	Brodifacoum 25-D Conservation with bait stations, mechanical hazing methods
Alternative 4:	Brodifacoum 25-D Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings

Wilderness Character[1]	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	+	-	+	-	+	-	+	-
Untrammeled	0	0	0	-3	0	-3	0	-3
Undeveloped	0	0	0	-2	0	-3	0	-3
Natural	0	-1	1	-3	1	-3	1	-3
Solitude/Primitive/Unconfined	0	0	0	-1	0	-2	0	-3
Other Features of Value	0	-1	1	0	1	0	1	0
Total Number of Effects	0	-2	2	-9	2	-11	2	-12
Wilderness Character Rating	**-2**		**-7**		**-9**		**-10**	

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

Alternative 5:	Diphacinone-50 Conservation, non-mechanical hazing methods
Alternative 6:	Diphacinone-50 Conservation with bait stations, mechanical hazing methods
Alternative 7:	Diphacinone-50 Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings

Wilderness Character[1]	Alternative 5		Alternative 6		Alternative 7		Alternative 8	
	+	-	+	-	+	-	+	-
Untrammeled	0	-3	0	-3	0	-3		
Undeveloped	0	-2	0	-3	0	-3		
Natural	1	-3	1	-3	1	-3		
Solitude/Primitive/Unconfined	0	-1	0	-2	0	-3		
Other Features of Value	1	0	1	0	1	0		
Total Number of Effects	2	-9	2	-11	2	-12		
Wilderness Character Rating[1]	**-7**		**-9**		**-10**			

[1] Note that impacts scores are an unweighted tabulation of the number of effects to wilderness character and thus do not reflect the overall differences in positive and negative impacts to wilderness character between alternatives. The relative importance of each impact is addressed in the narrative portions of the MRDG.

MRDG Step 2: Determination

Refer to the **MRDG Instructions** before identifying the selected alternative and explaining the rationale for the selection.

Selected Alternative

☐	Alternative 1:	No Action
☐	Alternative 2:	Brodifacoum 25-D Conservation, non-mechanical hazing methods
☐	Alternative 3:	Brodifacoum 25-D Conservation with bait stations, mechanical hazing methods
☒	Alternative 4:	Brodifacoum 25-D Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings
☐	Alternative 5:	Diphacinone-50 Conservation, non-mechanical hazing methods
☐	Alternative 6:	Diphacinone-50 Conservation with bait stations, mechanical hazing methods
☐	Alternative 7:	Diphacinone-50 Conservation with bait stations, mechanical and helicopter hazing methods, helicopter landings

Explain Rationale for Selection:

As documented in Step 1, some type of action is necessary to remove invasive house mice and their impacts on the natural character of wilderness and the Farallon Wilderness's special features of value and to further the conservation purpose for which the Farallon Wilderness was established. Actions that do not involve Section 4(c) prohibited activities in wilderness were evaluated in Step 2 and determined to be technologically infeasible, incapable of achieving wilderness management needs, or to pose unacceptable risks to personnel safety.

In determining which action is the minimum necessary, we were guided by the Wilderness Act and Fish & Wildlife Service policy. Service policy (610 FW 2; 601 FW 3) provides that native wildlife and plants are essential components of wilderness. This policy permits management of invasive species in wilderness when it has been demonstrated that they have degraded or will degrade the biological integrity, diversity, environmental health, or wilderness character; or when invasive species pose a significant threat to the health of fish, wildlife, plants, or their habitats. When natural ecosystem processes have been altered by invasive species, Service policy authorizes action to eradicate invasive species and restore biological integrity and wilderness character, provided that the action is the minimum required to administer the wilderness and achieve refuge purposes. For eradication actions involving chemical treatments, Service policy directs the Service to select the agent that will have the least impact on non-target species and the wilderness environment.

Alternative 1, No Action, was not selected because it does not satisfy the minimum action required to remove the impacts on house mice on the natural character of the Farallon Wilderness or preserve the conservation value of the refuge's wilderness areas as a preserve and breeding ground for birds and other native species. If mice were only eradicated from non-wilderness Southeast Farallon Island, native wildlife and plants in the wilderness portions of the Refuge would continue to experience the adverse impacts of mice as described for the No Action alternative. Mice would also easily repopulate Southeast Farallon from the wilderness.

All the feasible action alternatives (Alternatives 2 – 8 above) provide methods for the potential eradication of house mice. For the purposes of alternative descriptions and scoring of positive and negative impacts to wilderness, it was assumed that all action alternatives would result in the eradication of house mice from the South Farallon Islands. All of these alternatives would cause adverse impacts to certain aspects of wilderness character to varying degrees. The alternative selection process considered the degree to which an alternative would further the wilderness's conservation purpose, the nature and duration of each alternative's impacts to wilderness character, and the extent to which each alternative minimized adverse impacts while insuring that mice would be successfully eradicated from the South Farallon Islands.

Alternatives 5, 6 and 7 – These alternatives propose the use of the rodent bait Diphacinone-50 Conservation. While diphacinone has been used to successfully eradicate other rodents such as rats from islands, it is less potent than brodifacoum and must be consumed multiple times over several days to be effective. Thus, it must be available for a longer period of time than brodifacoum, requires one additional bait drop, and extends the operational period, thereby increasing the duration of adverse impacts to all aspects of wilderness character compared to brodifacoum alternatives. More importantly, studies have shown that diphacinone is unpalatable to mice; in other words, there is a high likelihood that mice will not consume the bait. Thus, the risk of project failure is considered high. Failure would not allow the Service to further the conservation purpose of the Farallon Wilderness, nor would it preserve or enhance the natural quality and special features of the Farallon Wilderness over the long-term. Although the risk to non-target wildlife is less with diphacinone than brodifacoum, because of the high risk of project failure, alternatives utilizing diphacinone are not considered the minimum tool required.

The remaining alternatives (Alternatives 2-4) involve the use of brodifacoum. Studies have shown that the rodenticide brodifacoum has a high success rate of eradicating house mice from islands and this product is regarded as the most effective available for this purpose. Because of its higher potency than diphacinone, brodificoum also requires fewer applications, resulting in a shorter operational period, fewer air drops of bait, and lower quantities of bait. However, brodifacoum poses greater risks to non-target wildlife, particularly certain species of birds. This MRDG evaluated different tools associated with the use brodifacoum in order to determine the minimum tool necessary to avoid or reduce non-target impacts.

As explained in the FEIS (Sections 2.10.5 and 2.10.7), a broad array of gull hazing techniques, including mechanical tools and helicopters, and possibly the use of bait stations, are necessary measures to mitigate otherwise potentially significant harm to gull populations, an impact to the natural character of wilderness. Studies have shown that gulls can habituate to hazing techniques, rendering them less effective. In order to continue successful hazing over extended periods of time and to ensure that there are no long-term population-level impacts to gulls, multiple techniques must be used. A gull hazing trial on the South Farallon Islands in 2012 showed that the use of a variety of hazing tools including gull effigies, human approach, biosonics, propane cannons, lasers, a variety of pyrotechnics, and a helicopter, successfully hazed the Farallon gull population over a period of nearly three weeks. In the hazing trial report, it was determined that a variety of tools would be necessary to successfully haze the gulls for the periods required in the mouse eradication project (FEIS Appendix E). Hazing tools that cause greater impacts to wilderness will only be used when found to be minimum necessary, such as when less adverse tools are found to be unsuccessful. The temporary installation of bait stations in wilderness would only be used if found to be necessary to prevent gull access to bait in certain areas at the time of project implementation.

Alternative 4 (which is identical to Alternative B in the FEIS) is the only brodifacoum alternative that entails the use of bait stations and a broad suite of hazing techniques to reduce non-target impacts to wildlife, including gulls. Brodifacoum would be applied in accordance with the EPA-approved label and a Pesticide Use Permit issued by the Service's National IPM Coordinator. As explained in the FEIS in Section 4.5.6.1, no population-level impacts to any species are expected to occur under this alternative. Moreover, impacts to the untrammeled, undeveloped, natural and special features values of wilderness character from mechanical hazing techniques and bait stations would be temporary. The use of these tools to reduce non-target impacts far outweighs their costs.

Alternative 4 also allows the landing of helicopters in wilderness. Although the use of helicopters to transport personnel and gear is an additional impact to certain wilderness qualities, the impacts to wildlife (pinnipeds) are substantially reduced compared to foot transport to and from the wilderness as proposed in Alternatives 2 and 3. Pinnipeds are protected by the Marine Mammal Protection Act, which prohibits disturbance. To disturb pinnipeds, an Incidental Harassment Authorization (IHA) will be needed from the National Marine Fisheries Service. The IHA will include the numbers of animals that may be disturbed. Available data showed that use of a small, relatively quiet helicopter reduced the numbers of pinnipeds disturbed accessing the wilderness by 94%. This benefit to the natural character of wilderness outweighs the impacts of helicopter landings in the wilderness.

Neither Alternative 2 nor 3 from this MRDG use the minimum tool required to best achieve the conservation purpose of the Farallon Wilderness or preserve and enhance its natural quality and special features of value.

As described above, gulls habituate to hazing techniques. Thus, a variety of tools are necessary to haze gulls successfully over extended periods. Deploying brodifacoum under Alternative 2 without the ability to use a full array of hazing techniques and bait stations could result in significant impacts to gull populations and substantially reduce the likelihood of project success. The inability to use helicopters would also result in increased, short-term impacts to pinnipeds from disturbance. These constraints compromise the ability of Alternative 2 to further the conservation purpose of the Farallon Wilderness and preserve its natural and special features of value. They also increase the likelihood of take of non-target wildlife, particularly gulls. This alternative could result in long-term population-level impacts on some gull species.

Alternative 3 would likely result in the eradication of mice, thereby furthering the conservation purpose of Wilderness and positively effecting its natural and special features of value over the long-term. However, this alternative does not allow for helicopters to be used for hazing or personnel transportation. This removes a potentially important hazing tool to reduce non-target impacts to birds and results in increased disturbance impacts to pinnipeds compared to Alternative 4.

The Service has determined that Alternative 4 (which is identical to Alternative B in the FEIS) is the minimum necessary to further the conservation purpose of the Farallon Wilderness and preserve its natural quality and special features of value. Under Alternative 4, operations are expected to be completed within about six weeks. The first significant rainfall following the second bait application will degrade bait to a point where is unavailable to non-target wildlife. Immediately upon the completion of operations, all equipment, temporary installations and the tent camp will be removed. Thus, all operational-related impacts to wilderness character will be temporary.

Mouse eradication would result in several significant benefits to the natural quality of the Farallon Wilderness, including benefits to populations of several native species including the ashy storm-petrel, Leach’s storm-petrel, Farallon arboreal salamander, Farallon camel cricket, other terrestrial invertebrates, and native plants such as the maritime goldfield. The long-term benefits of Alternative 4 to the natural quality of wilderness and the preservation of the area as a breeding ground for sea birds and other native species outweigh its temporary adverse impacts to wilderness character.

Describe Monitoring & Reporting Requirements:

- As required in the EPA label, rodent bait application will be monitored to assure that the amount of bait applied does not exceed the label rate.
- For the duration of the operational period, monitoring will be conducted to measure efficacy of gull hazing and to modify techniques as needed.
- For the duration of the operational period, monitoring will be conducted to quantify non-target exposure to rodenticide and other potential environmental impacts.
- For a period of about two years, monitoring will be conducted to confirm mouse eradication.
- A detailed report of operational monitoring will be provided within one year of completing the operational phase of the project.

Approvals

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
☐	Mechanical Transport:	
☒	Motorized Equipment:	Gull hazing tools including propane cannons, biosonics, and pyrotechnics (although not technically motorized).
☐	Motor Vehicles:	
☒	Motorboats:	Up to 20 trips in small, inflatable boats with outboard engines to drop off personnel on the edge of wilderness.
☒	Landing of Aircraft:	About 90 hours of flight time over wilderness for bait application and gull hazing over about six weeks. About 35 helicopter landings to transport personnel and gear.
☐	Temporary Roads:	
☐	Structures:	
☒	Installations:	Up to 500 bait stations may be temporarily installed for the duration of the operation. Up to 200 of combined rodent traps, chew blocks, track plates and cameras may be temporarily installed for the duration of the operation and periodically for monitoring over a two-year period.

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 signature authorities:

Prepared	Name	Position	
	Gerry McChesney	Wildlife Refuge Manager	
	Signature		Date
	Gerry McChesney		12/12/2018
Approved	Name	Position	
	Anne Morkill	Project Leader	
	Signature		Date
	Anne L. Morkill		12/12/2018

Appendix H:

Avian Species List

South Farallon Island NWR 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*

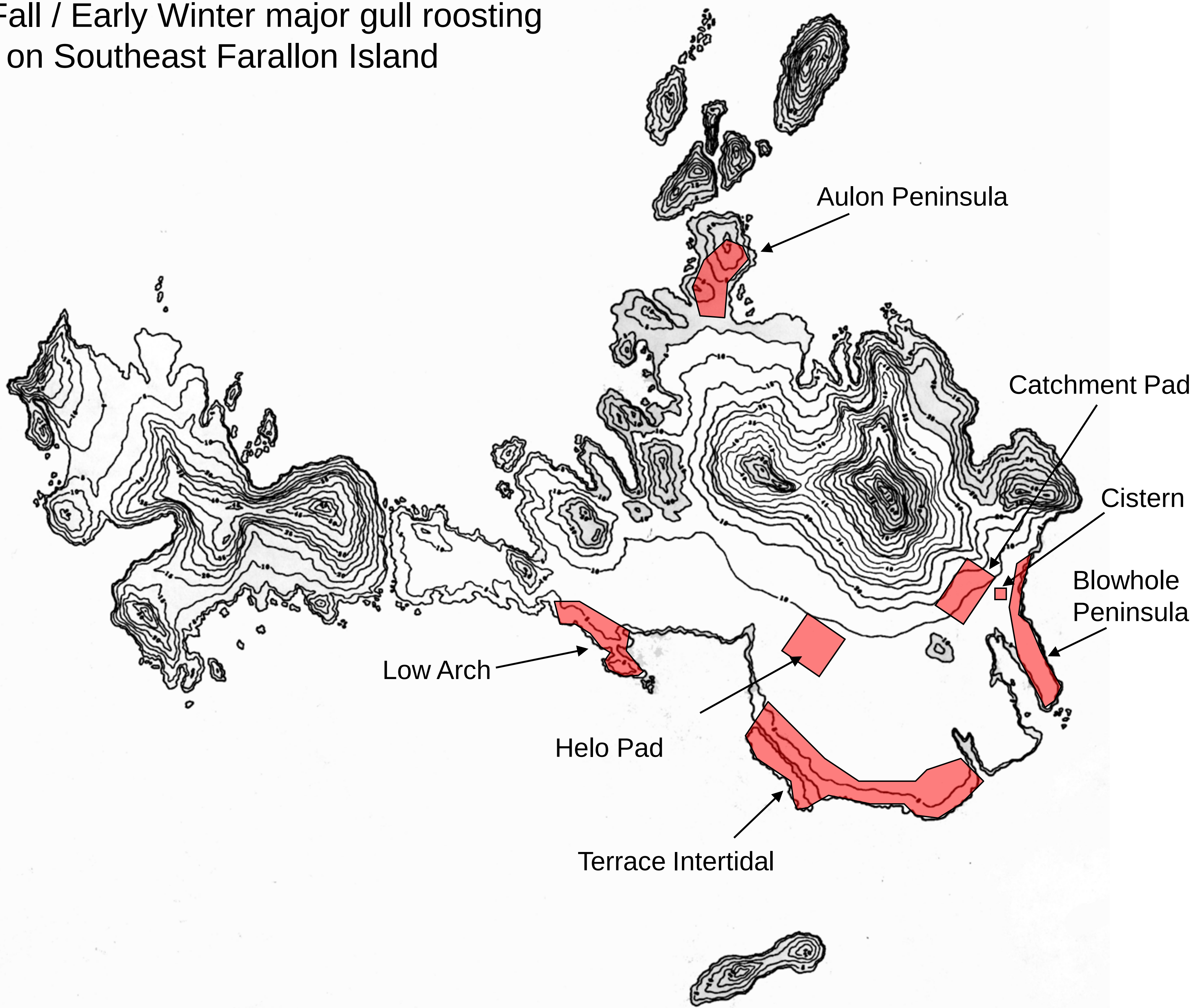
Fringillidae - Fringilline and Cardueline Finches and Allies
Common Rosefinch *Carpodacus erythrinus* - *P
Purple Finch *Haemorhous purpureus*
Cassin's Finch *Haemorhous cassinii*
House Finch *Haemorhous mexicanus*
Red Crossbill *Loxia curvirostra*
Common Redpoll *Acanthis flammea* - *
Pine Siskin *Spinus 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

Appendix I:

Map of Western Gull Roosting Sites

Late Fall / Early Winter major gull roosting areas on Southeast Farallon Island



Appendix J:

Intertidal Species List

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

Appendix K:

Maps of Pinniped Haul-Out Sites

Maps of Pinniped Haul-out Sites on the South Farallon Islands NWR

Figure 1: Elephant seal haulout locations on the South Farallon Islands

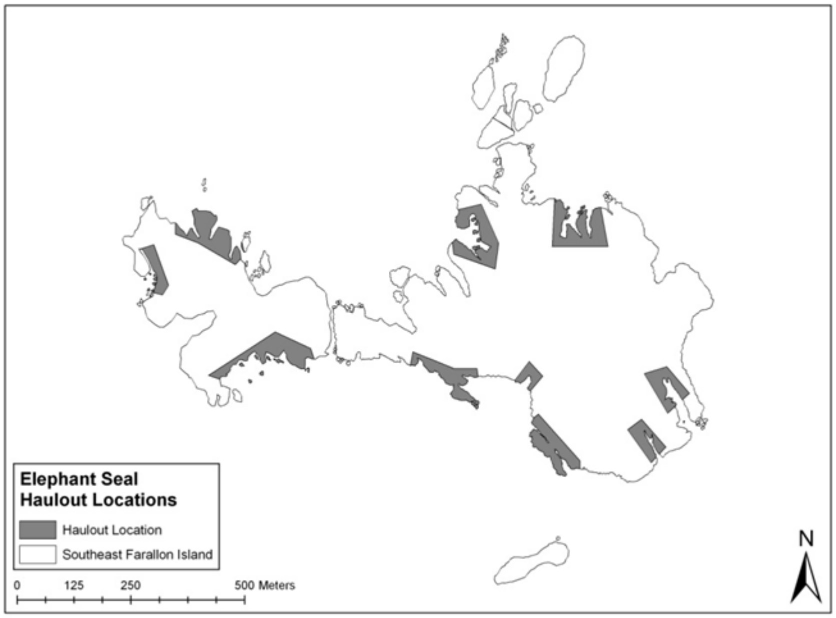


Figure 2: Harbor seal haulout locations on the South Farallon Islands.

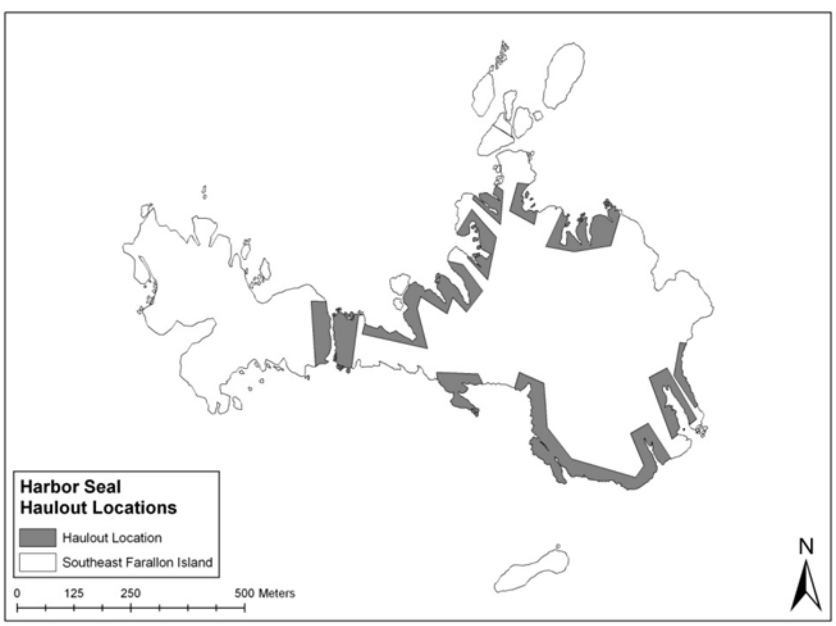


Figure 3: Steller sea lion haulout locations on the South Farallon Islands.

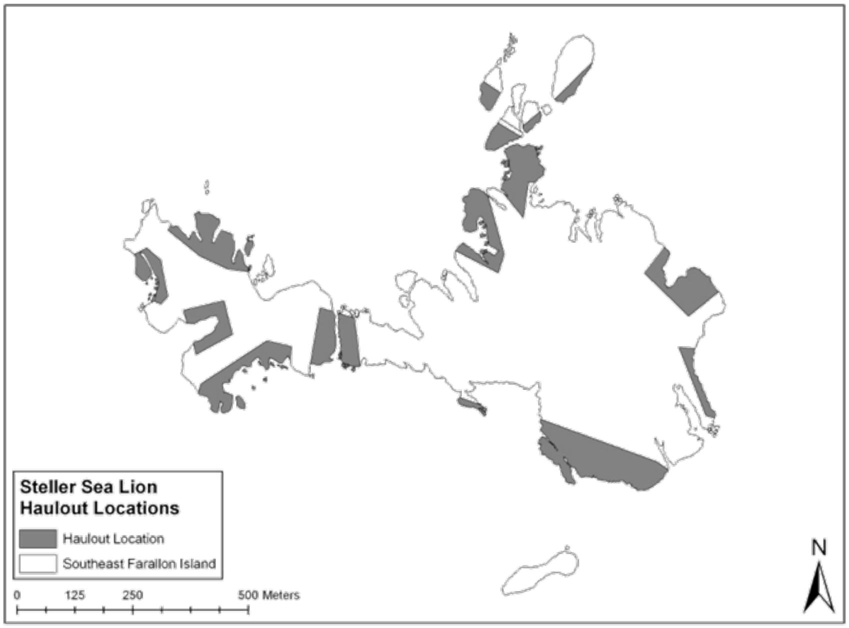


Figure 4: California sea lion haulout locations on the South Farallon Islands.

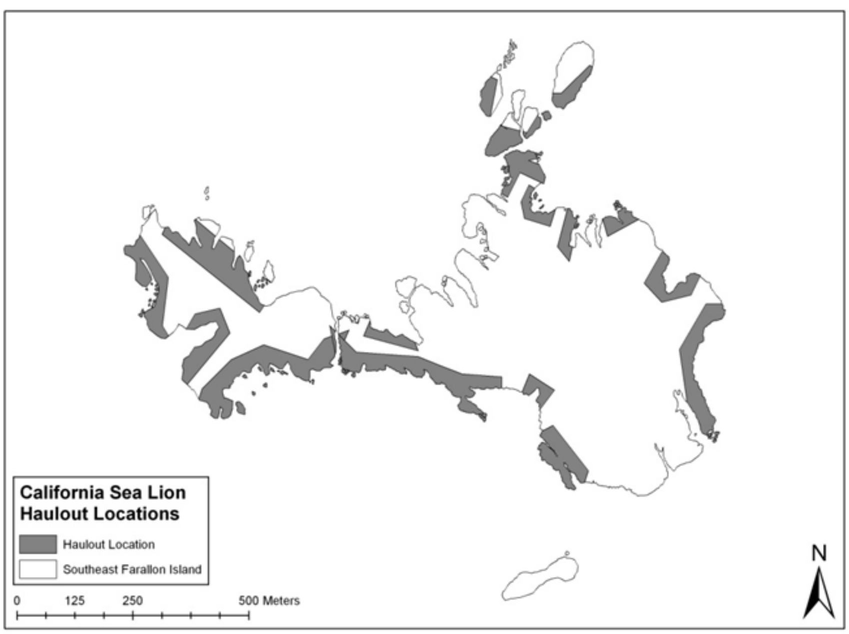
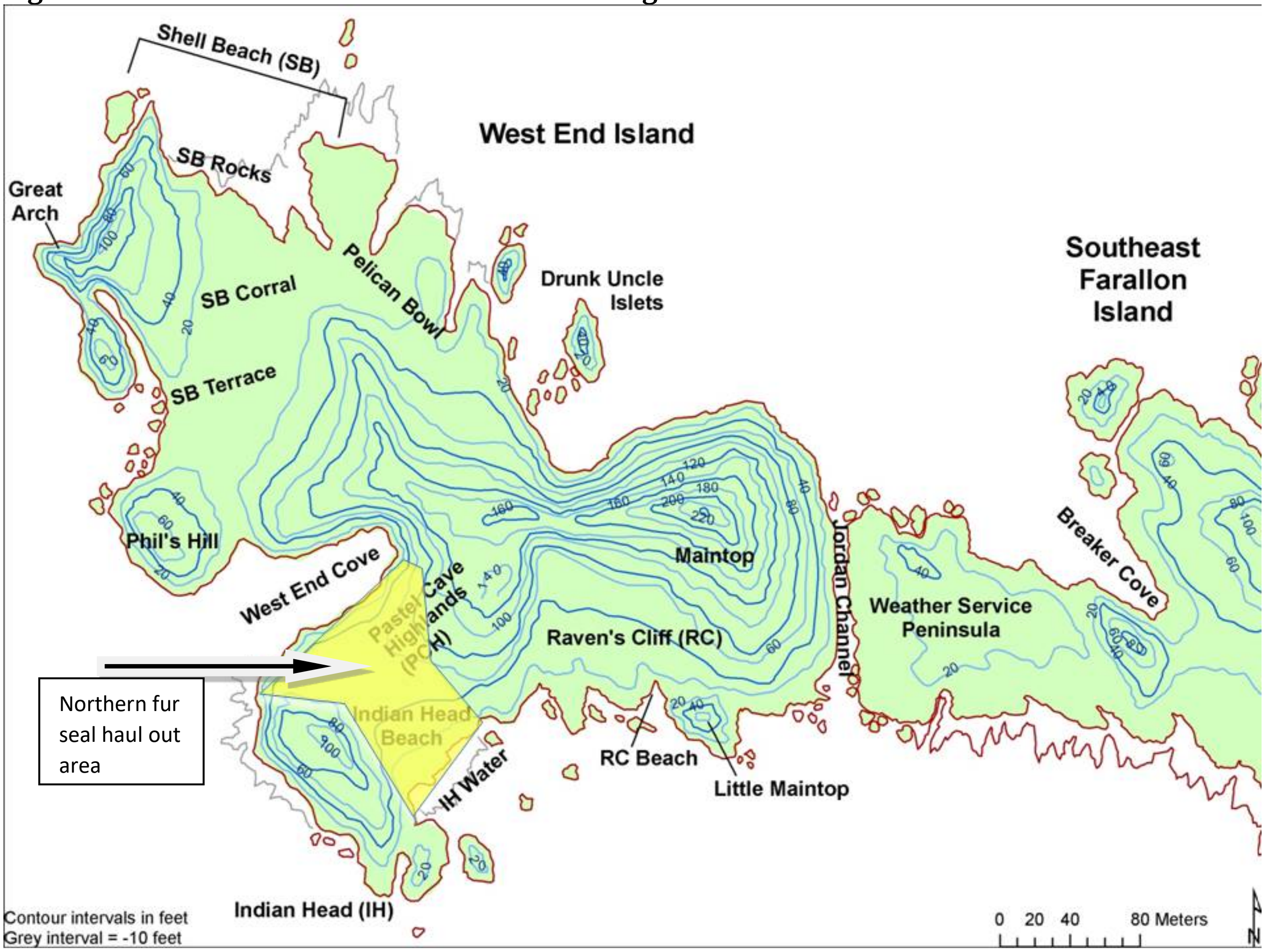


Figure 5: Northern fur seal haulout and breeding area on the South Farallon Islands.



Appendix L:

Plant Species List

South Farallon Islands Plant Species 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

Appendix M:

Modeling the Impacts of House Mouse Eradication on Ashy Storm-Petrels on Southeast Farallon Island

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.

<u>Ashy Storm-Petrel reproductive success</u>

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, $(\text{Day of Year})^2$, 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.

Analysis of Ashy Storm-Petrel Population Trends

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:

logit survival = ln[(survival probability)/(1-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.

Parameters of the "Current Population Dynamic Model"

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.

<u>Population model Leslie matrix: population size and calibration</u>

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.

<u>Population model: modeling impacts of Burrowing Owl predation</u>

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

Annual Trends in Burrowing Owl abundance and Ashy Storm-Petrel predation

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).

<u>Caveats and Limitations</u>

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 populations 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.
[4] - 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.

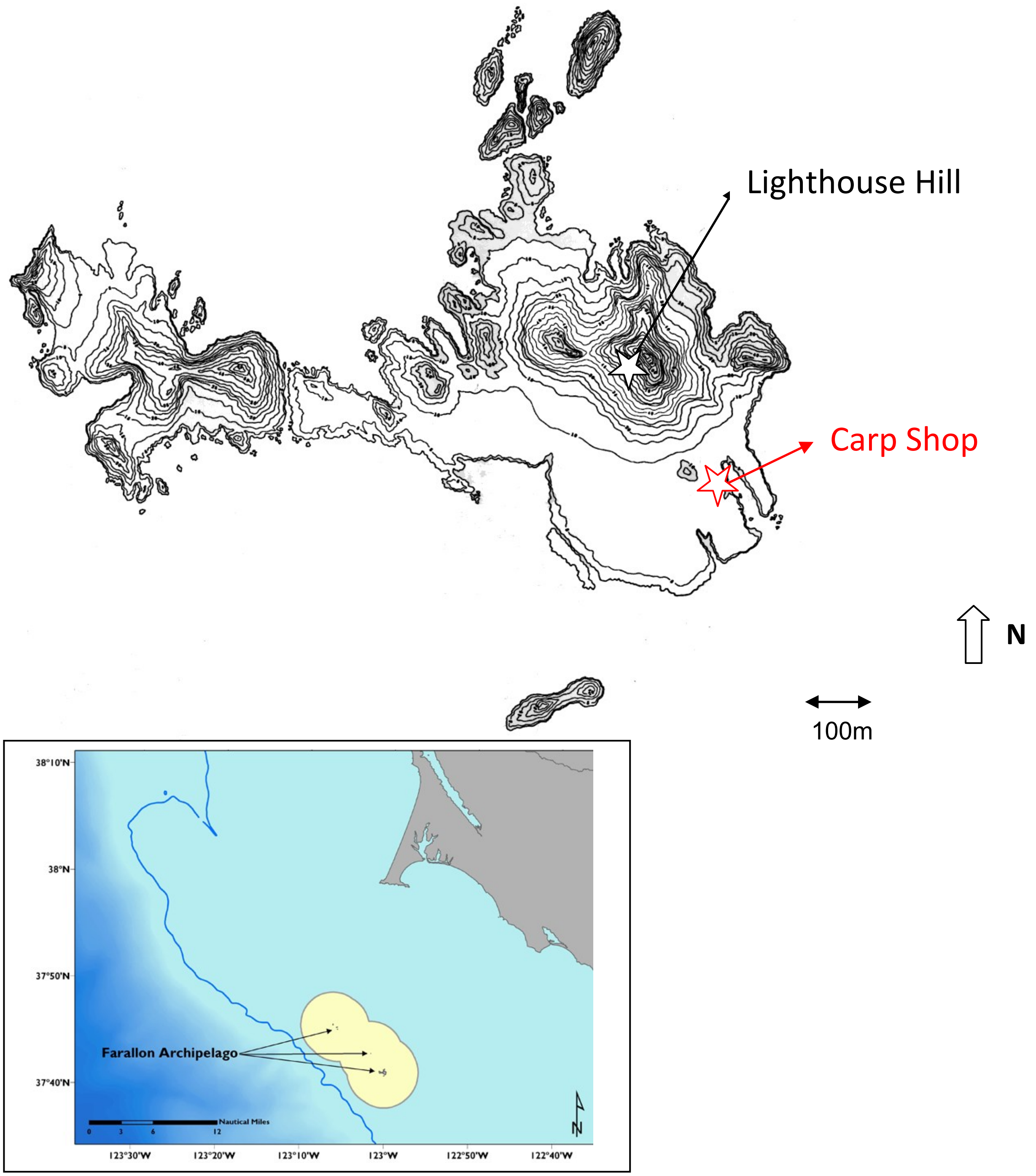


Figure 2. Seasonal Cycle of House Mouse Abundance Index (2001-2004, 2011-2012), Index of Ashy Storm-Petrel predation by Burrowing Owl (2008-2012), and Burrowing Owl abundance Index (2008-2012) at Southeast Farallon Island. Monthly mean values with standard deviation are shown.

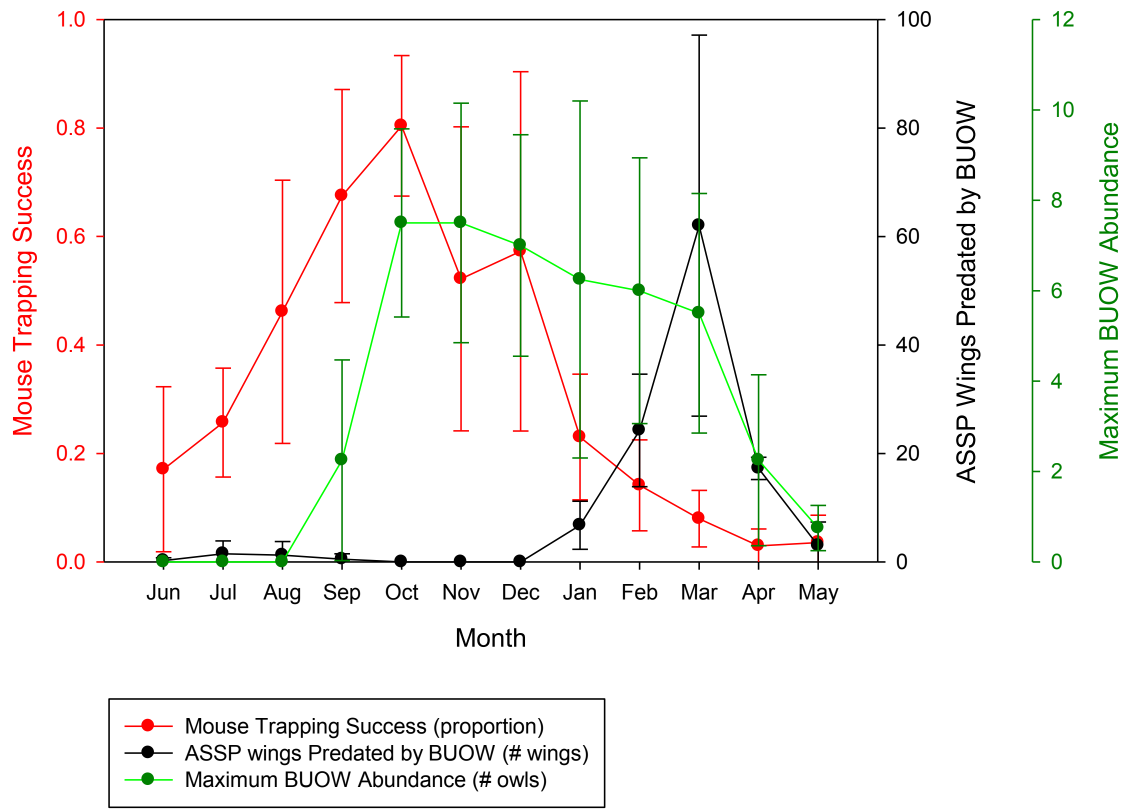


Figure 3. Variation in the annual Burrowing Owl abundance index (mean Sept-April abundance) for 2001 to 2012 on Southeast Farallon Island. The curve of best fit, as determined by AIC, is shown: a quadratic, accelerating trend. P = 0.001

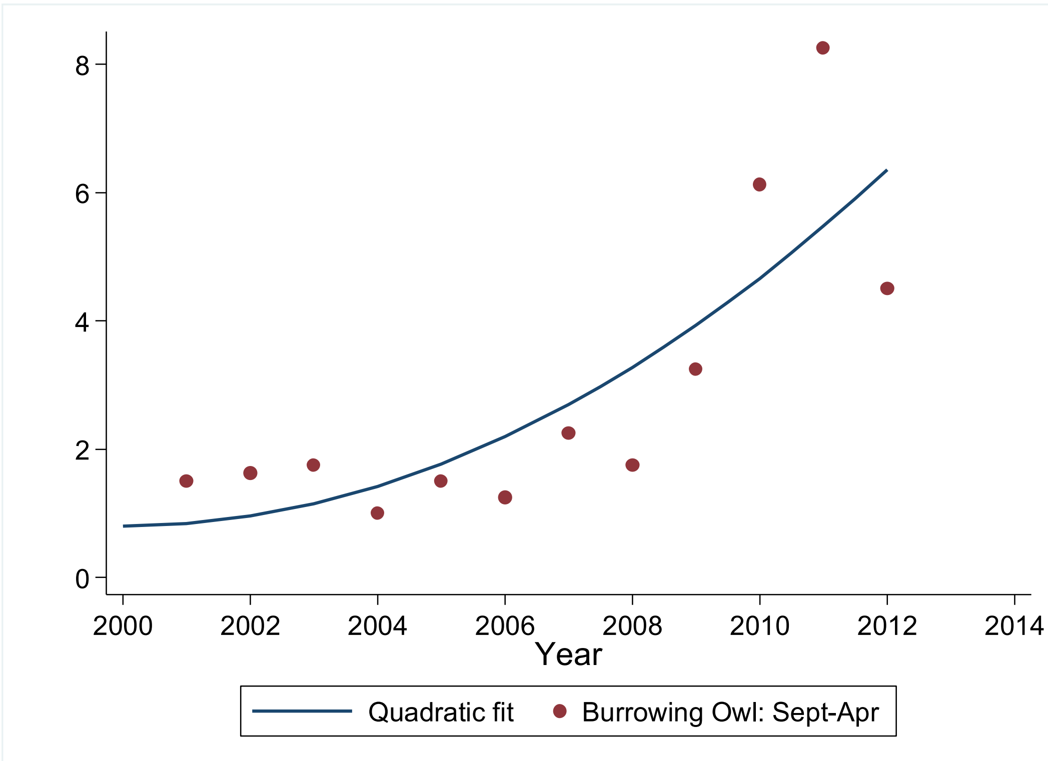


Figure 4. Annual (January-December) index of Burrowing Owl predation on Ashy Storm-Petrels from 2003 through 2011 on Southeast Farallon Island. 2012 data is not included in this figure, as only data through April was available at the time of analysis. The curve of best fit, as determined by AIC, is shown: a quadratic, accelerating trend. P=0.003

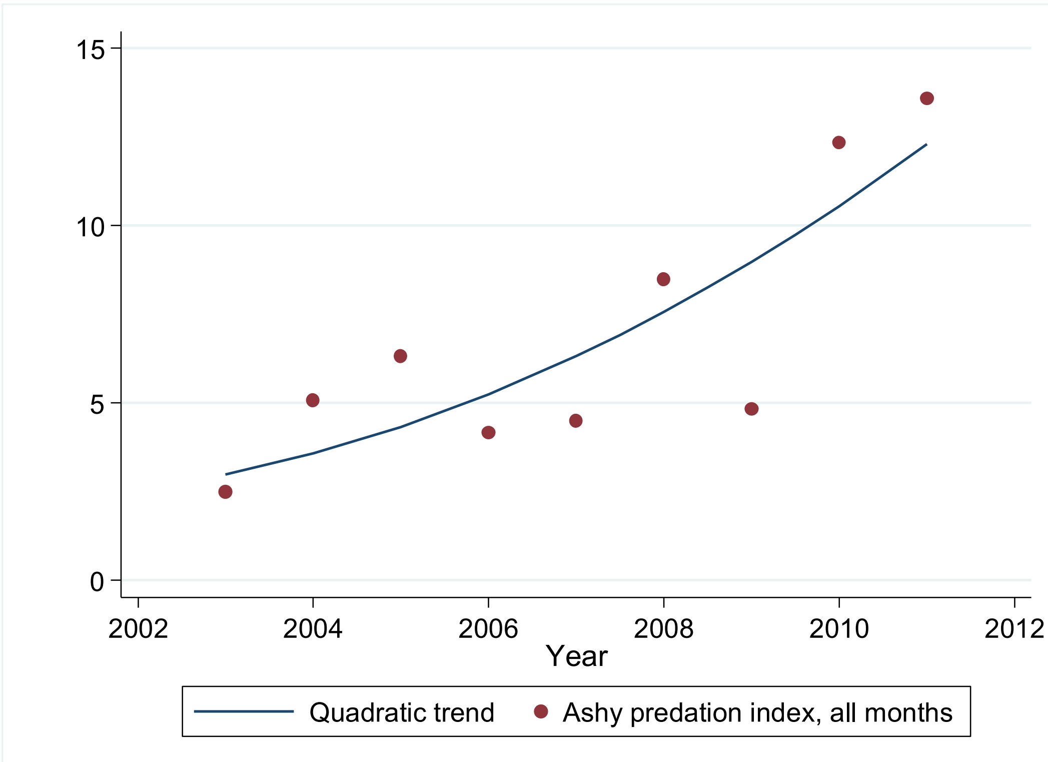


Figure 5. Population Index from Mist-netting Analyses for Ashy Storm-Petrels, 2000 to 2012 from Southeast Farallon Island. Values shown are natural log of the population index, plus one. The index is set at 1 for 2000 for illustrative purposes, though analyses were conducted with 2000 value set to 0 (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)

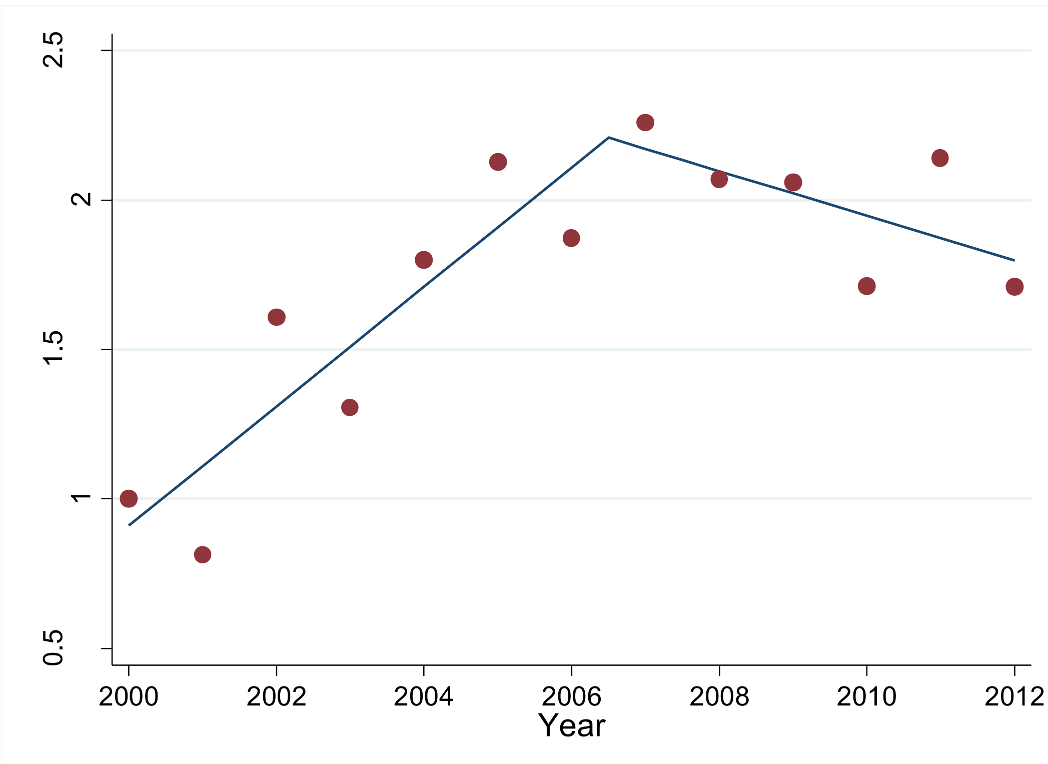
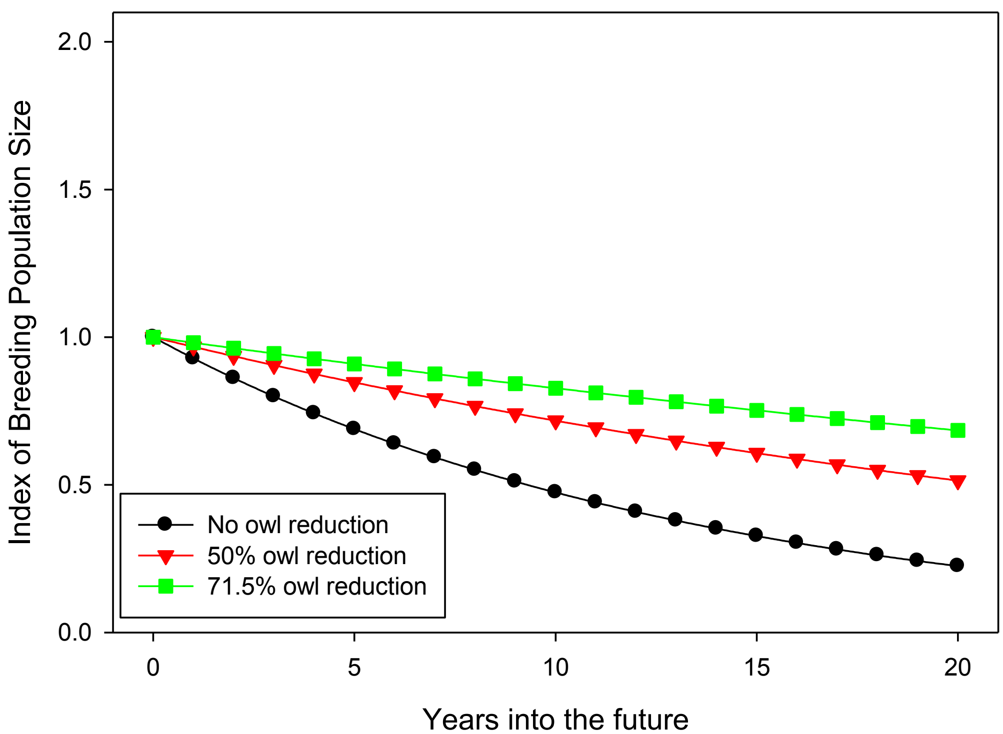
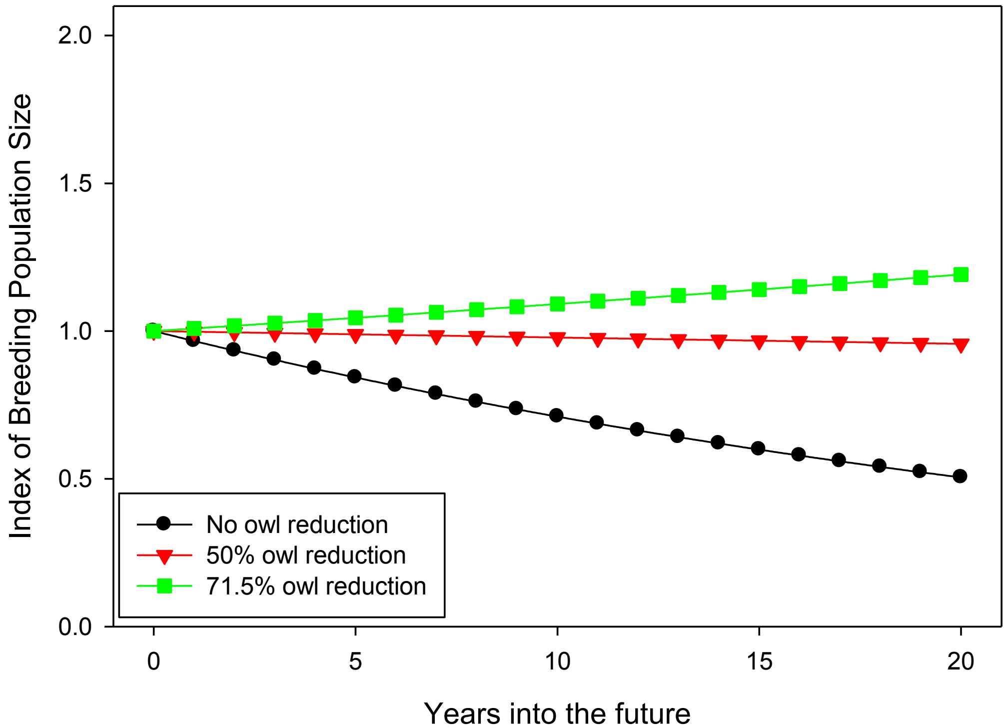


Figure 6. Farallon Ashy Storm-Petrel Population projections under the three levels of reduction in Burrowing Owl Abundance: 0% reduction, 50% reduction, and 71.5% reduction (see Methods). Levels of reduction are modeled for three separate scenarios: A) “Observed Steep Decline”; B) “Moderate Decline” ; 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.

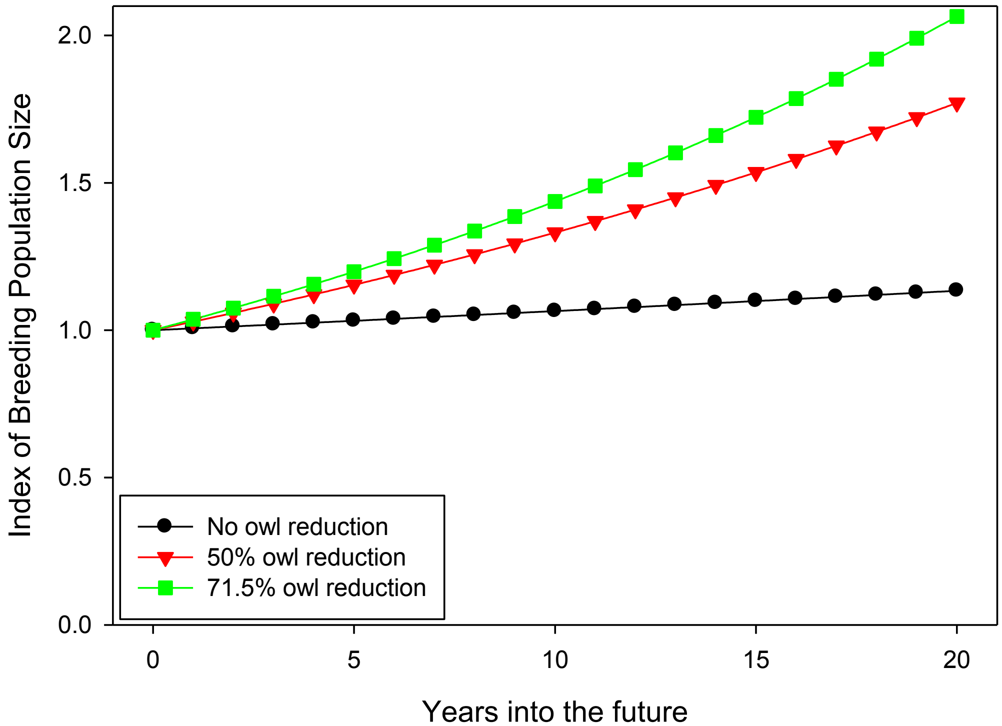
A) “Observed Steep Decline” Scenario



B) "Moderate Decline" Scenario



C) "Near Stable" Scenario



Appendix N:

Western Gull Population Viability Analysis

prbo

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.

Addendum to Appendix N. POPULATION VIABILITY ANALYSIS OF WESTERN GULLS ON THE FARALLON ISLANDS IN RELATION TO POTENTIAL MORTALITY DUE TO PROPOSED HOUSE MOUSE ERADICATION

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March 15 2018

Summary

This addendum to Appendix N of the draft EIS for proposed Farallon house mouse eradication was completed by the same authors of the original 2013 report. It serves to update the original report in two ways. Firstly, the addendum provides a more detailed introduction to the overview of the population modelling approach presented and provides an explanatory figure to describe the approach. Secondly, the addendum provides Methods, Results and Discussion on the calculation of *C*, the mortality level where there would be 95% overlap in modelled population size after 20 years comparing all three examined Environmental Scenario (Optimistic, Realistic, or Pessimistic) with no mortality models. The original report only assessed this for the “Realistic” environmental scenario.

Overview of Approach

Our approach was to first develop a population dynamic model for the South Farallon population of Western gulls using the best available information (published and unpublished) that captures current population trend and incorporates stochasticity in the demographic parameters (Figure 1). To develop the model we analyzed demographic data from the study population of Western Gulls as necessary to estimate demographic parameters. These analyses either used the full time series (1986-2009) or the more recent years (1999-2009), whichever was more appropriate as explained in the Methods. These analyses were used to determine age-specific variation in the parameters needed for the Leslie matrix. The analyses also quantified annual variation in demographic parameters and established the degree of stochasticity in those parameters for the model. We then simulated three different environmental scenarios, in which the frequency of years with high reproductive failure in the future did not re-occur ("Optimistic"), occurred at low, historic frequency ("Realistic"), or occurred at the more recent, elevated frequency ("Pessimistic"). We projected future population change under these three scenarios over 20 years. We then compared those simulation results, with no additional mortality, to a comparable set of simulations in which a one-time mortality event occurred in Year 0 in which *C* Western gulls died. We define the threshold "*C*" as the number of gulls killed at year 0 at which there is no ecologically distinguishable impact in modelled population size results with and without mortality after 20 years. We determined the magnitude of *C* such that there would be 95% overlap in population size in Year 20 comparing an Environmental Scenario (Optimistic, Realistic, or Pessimistic) with additional mortality to the same scenario without additional mortality. We compared the frequency distribution of outcomes, varying *C* in order to obtain 95% overlap. Our assumption was that if overlap was 95% or greater between two scenarios (with and without mortality of C gulls) then the two were ecologically indistinguishable. The following describes our approach in detail.

Methods: Starting Population Size, Mortality Scenarios, and Simulations

The Leslie matrix population model was implemented using a post-breeding census (Caswell 2001, Akçakaya 2005). Hence, the youngest age class in the simulations refers to juvenile individuals who have just fledged. The simulations were of the entire population, juveniles, sub-adults, and adults. There was no evidence that survival or reproductive rates vary in relation to population size or density for this population (Point Blue unpublished). Therefore we assumed population parameters to be independent of density (Nur & Sydeman 1999a).

The starting total population size for the simulations was 32,200 individuals, including all age classes, in the absence of any additional mortality. To obtain this value we started with the best estimate for initial breeding population size most relevant to the time series examined here, 17,400 observed in 2011 (P. Warzybok, R. Bradley unpublished); this value was similar to the 2009-2011 three-year average of 17,100. Assuming average breeding probability and the long-term age structure implied by the elements of the Leslie matrix (Caswell 2001), given 17,400 breeding individuals, we expect an additional 14,800 juveniles, sub-adults, and non-breeding adults in the population.

In scenarios with mortality, the starting population size in year 0 was 32,200 – *C*, where *C* represents the number of gulls removed from the population as a result of a mortality event. 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 the risk of mortality differs between age classes.

This value of *C* was determined from an assessment of whether the set of outcomes under a “no-additional-mortality” scenario (henceforth “no mortality”) was different from the set of outcomes under an “additional mortality” scenario. We did this for each of the three Environmental Scenarios (“Optimistic”, “Realistic” and “Pessimistic”) by assessing overlap of the modeled distributions of simulated total population size after 20 years. We defined two probability distributions to be different if the overlap of one with the other was less than 95%. Thus, 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 their medians may be statistically different. Evaluating the null hypothesis of no difference in median (or mean) was not very relevant, since we know that we removed *C* gulls from one scenario ("mortality") compared to the other ("no mortality"). Instead, we are assessing whether the population change "signal" resulting from removal of *C* gulls is still evident after 20 years of stochastic variability.

To operationalize this definition we first identified the median of the no mortality distribution, which we call m_{no}. We then analyzed the distribution of outcomes under the same conditions except that *C* gulls were removed at the outset. We determined *C* by varying it in increments of 100 and identifying the value at which, with *C* gulls removed, the distribution of outcomes had been shifted by 5% (i.e., 55% of outcomes were now below the original median) when compared with the "no mortality" scenario. A displacement in the distribution by 5%, specifically 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 have the same shape and spread, and acknowledging that the tails of these distributions are subject to random error. Note that a displacement of 0% implies an overlap of 100%, whereas a displacement of 50% necessarily entails an overlap of 50%. In the latter case, 50% of the original distribution lies above the maximum value observed for the new distribution.

We repeated this exercise for each of the three Environmental Scenarios, "Optimistic", "Realistic", and "Pessimistic." All scenarios depict results based on 10,000 simulations, the maximum for the RAMAS program. For the calculations of overlap of distributions, however, we used 30,000 simulations, combining results of three different runs of 10,000 simulations each in order to more precisely characterize the degree of overlap.

In summary, the value of *C* obtained in these modeling exercises represents the maximum level of mortality that produced ecologically indistinguishable differences in the probability distributions of Western gull population size 20 years into the future when compared to the no-additional-mortality distribution.

Results: Determination of Mortality Threshold, *C*

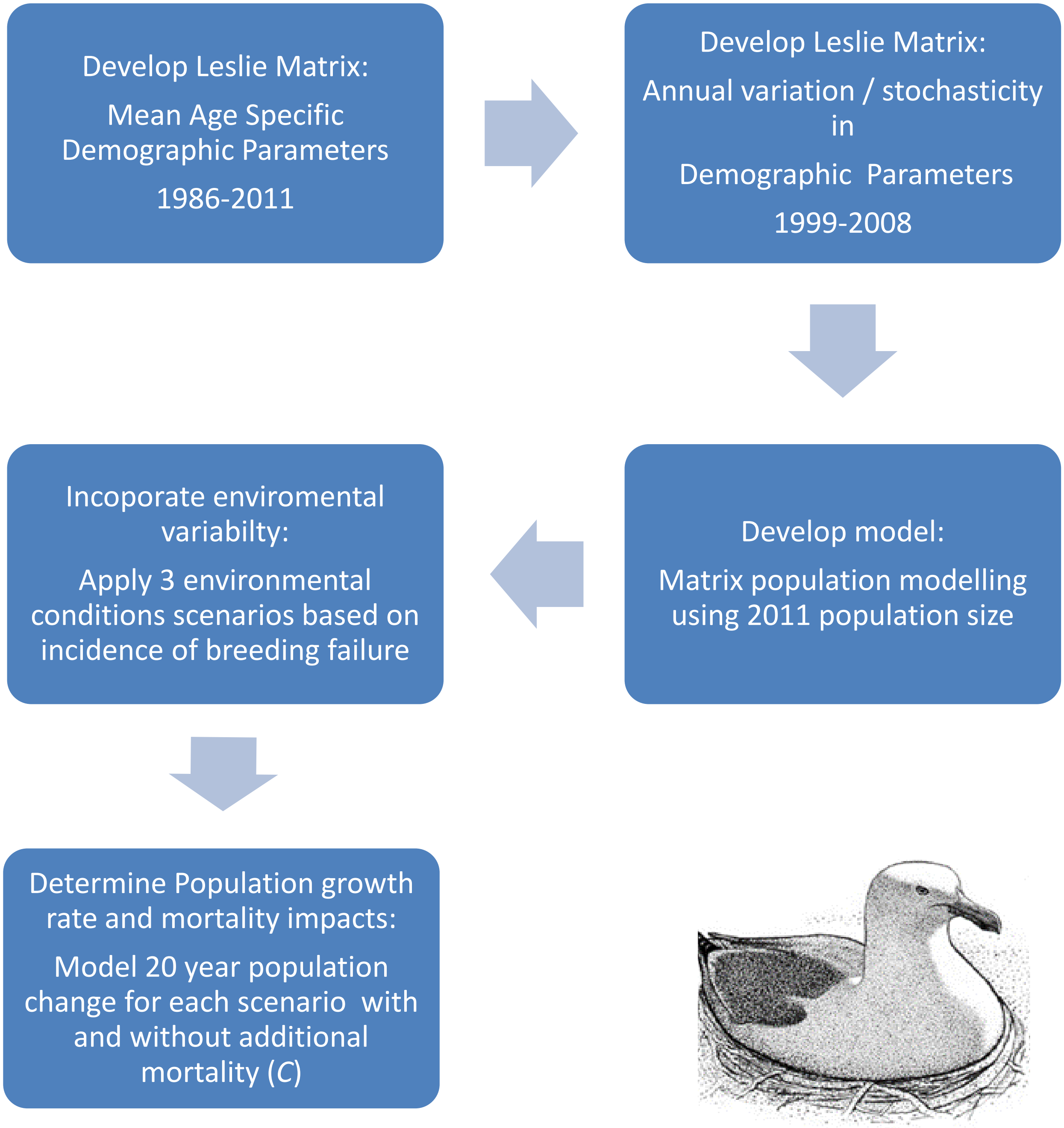
By simulating results with different mortality levels, we determined that, for the “Realistic” Scenario, removal of 1700 gulls results in a shifting of the probability distribution of population size after 20 years by 5% and thus represents 95% overlap between the “mortality” and “no additional mortality” scenarios. What had been the 50th percentile under “No additional mortality” (8.7% decline) becomes the 55th percentile under assumption of “Mortality of 1700 gulls” at year 0 of the simulation. Using the same methods, we determined that *C* for the “Optimistic” Scenario was 1100, and for the “Pessimistic” Scenario was 1900. The 95% CI for the calculations of *C* in all scenarios was approximately ± 300 individuals. Thus, *C* increased as the proportion of “bad” breeding years increased in the simulations.

Discussion of Long-term Mortality Impacts and the Mortality Threshold, *C*

We determined the level of mortality, *C*, 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 of 32,200 birds in 2011, the value of *C* was 1700 gulls. These results are independent of any assessment of actual risk to this Western gull population from rodenticide exposure in a proposed eradication effort; instead, results obtained apply to any mortality event of relatively short duration.

This value is substantial and reflects the high degree of stochasticity associated with the three demographic parameters, especially for reproductive success. We also found that *C* varied with environmental scenario; *C* was 1100 under the "Optimistic" scenario and was 1900 under the "Pessimistic" scenario. While it might seem counterintuitive that a lower level of mortality is sufficient to shift the outcome distribution by 5% under "Optimistic" conditions, compared to the "Realistic" and "Pessimistic" scenarios, these results are consistent with our finding that the coefficient of variation (CV) of population outcome was greatest for the "Pessimistic" scenario (0.41) and lowest for the "Optimistic" scenario (0.36). In other words, the greater the variability in population outcome, the greater *C* must be to result in a long-term effect of the mortality event that can be discriminated against the backdrop of environmental variability. The relative similarity of *C* values between the "Realistic" and "Pessimistic" scenarios (1700 vs 1900) is notable; the two mortality thresholds were not statistically distinguishable. This results suggests that it is occurrence of near breeding failure events, or absence of such events, that is most important to future population numbers in 20 years, rather than the precise frequency of near breeding failure events.

Figure 1. Overview of model development and application. Two sets of input parameters were used: those for age-specific values needed for the Leslie matrix (upper left) and those for determining annual variation in demographic parameters to capture stochasticity (upper right). The population model was used to consider three environmental scenarios ("Optimistic", "Realistic", and "Pessimistic"), which differed with respect to frequency of "bad years" for gull reproduction. These same scenarios were also used to compare results with and without the additional mortality event, i.e., death of *C* gulls in year 0. The magnitude of *C* was determined for each environmental scenario separately.


Develop Leslie Matrix:
Mean Age Specific Demographic Parameters
1986-2011
Develop Leslie Matrix:
Annual variation / stochasticity in
Demographic Parameters
1999-2008
Develop model:
Matrix population modelling using 2011 population size
Incoporate enviromental variabilty:
Apply 3 environmental conditions scenarios based on incidence of breeding failure
Determine Population growth rate and mortality impacts:
Model 20 year population change for each scenario with and without additional mortality (C)

Original Report

A 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.

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.

i) **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.

ii) **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).

iii) **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.

iv) **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).

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.

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).

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.

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.

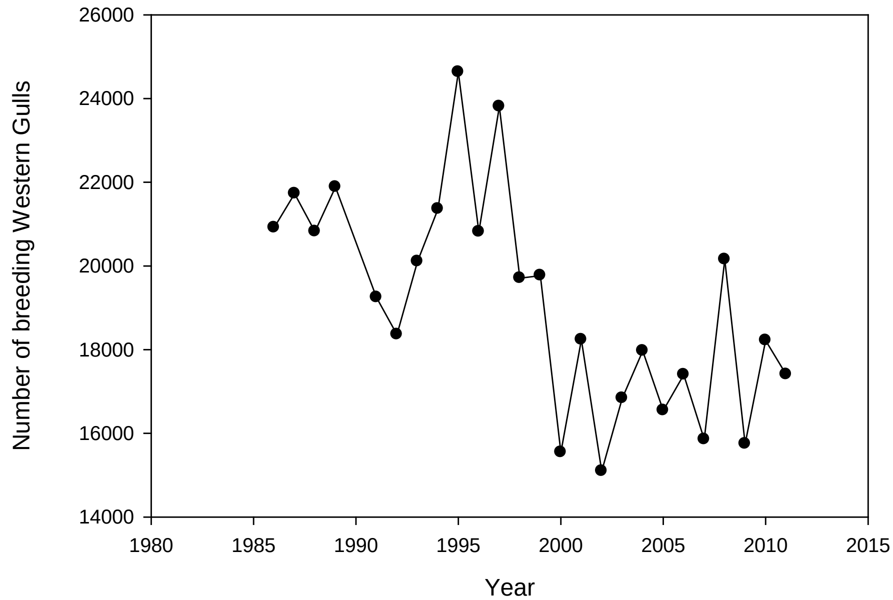


Figure 2. Annual variation in recapture probability and survival (± SE) for Farallon Western Gulls from long term study plots, 1986 to 2009 for both females and males. Missing vales for female recapture probability could not be estimated in program Mark.

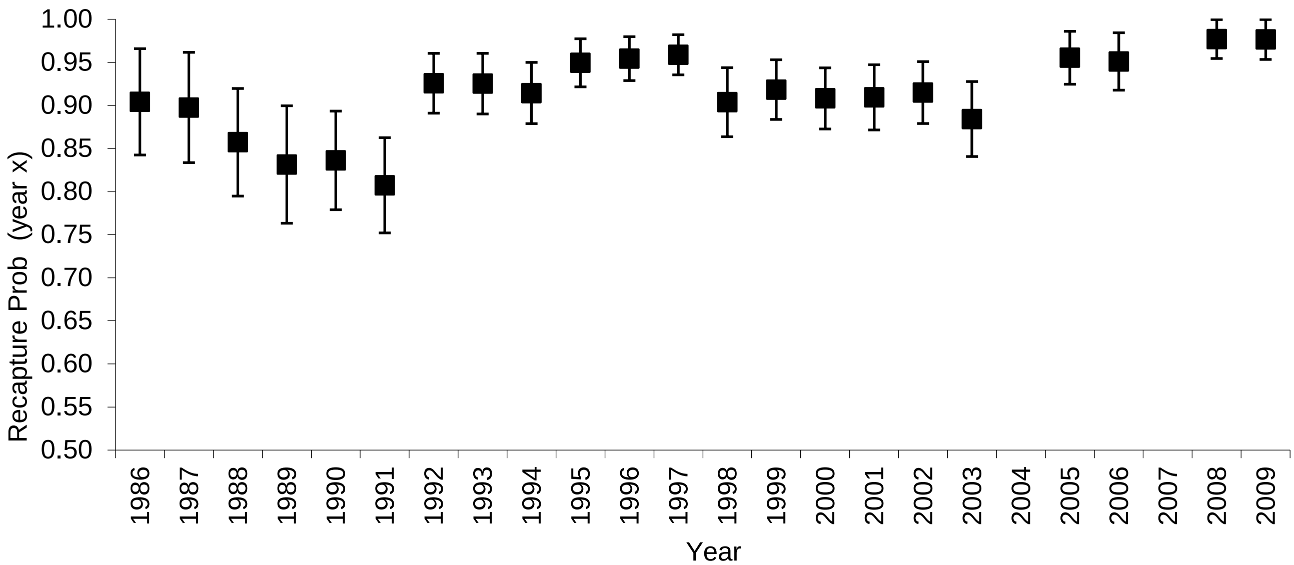


Figure 2a. Female recapture probability

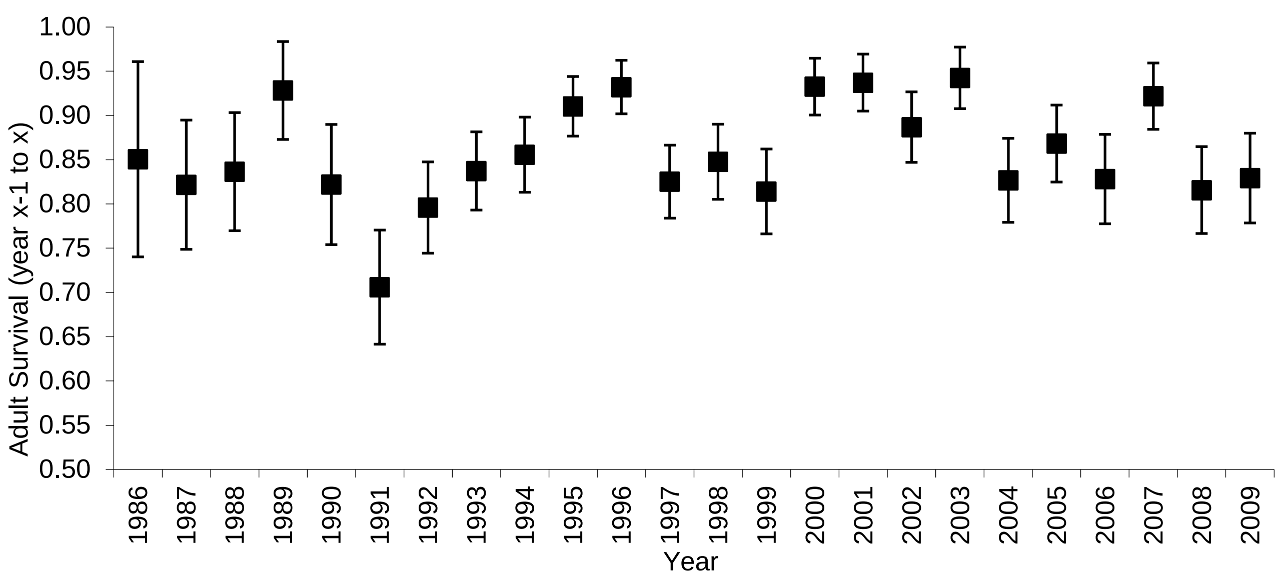


Figure 2b. Female Survival

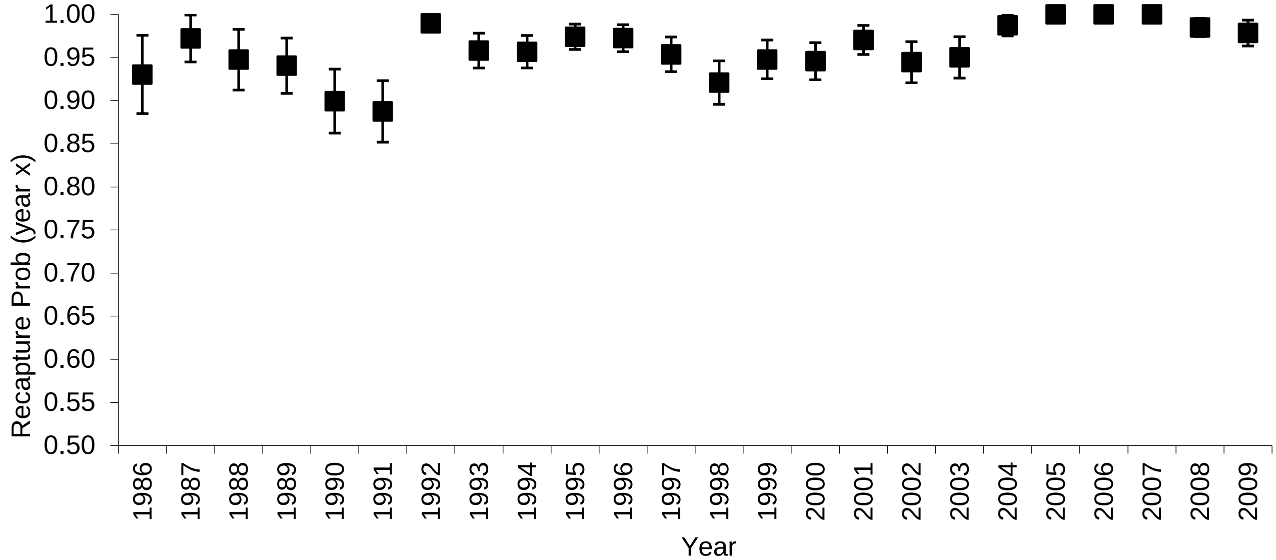


Figure 2c. Male recapture probability

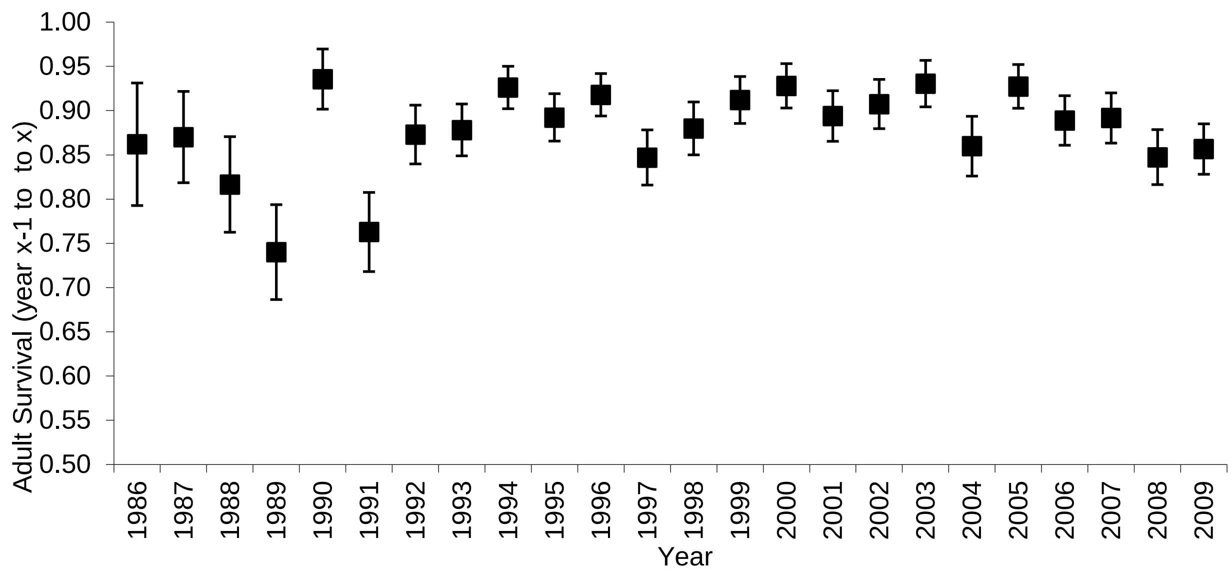


Figure 2d. Male survival

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.

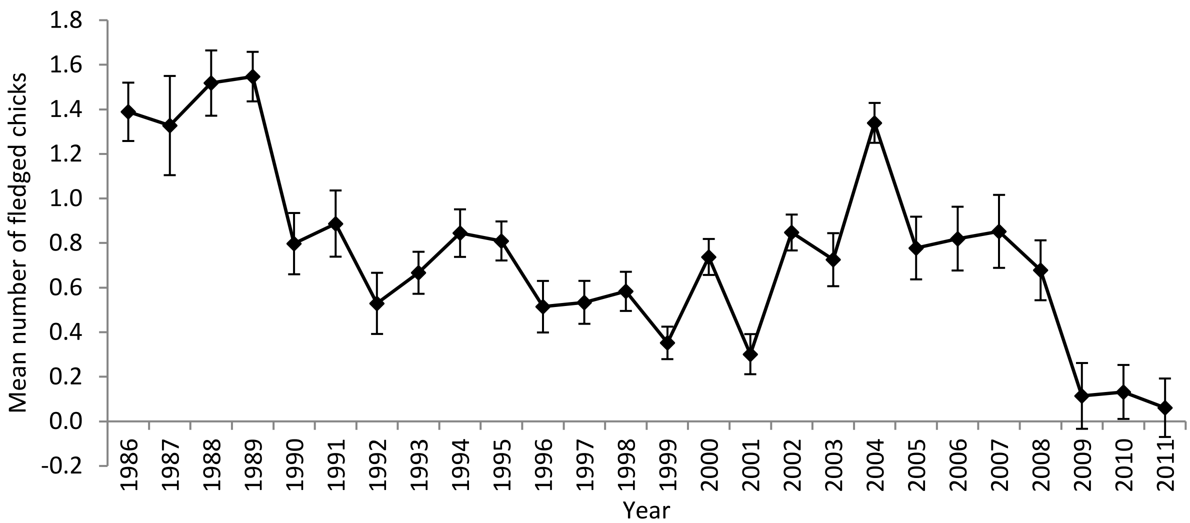


Figure 4. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Optimistic" conditions (no re-occurrence of near-failure years), with (red) and without (black) eradication-associated mortality. Shown are the 25th percentile, 50th percentile (solid regression line and circles), and 75th percentile outcomes. Mortality scenario removes 1700 birds in year 0. Assumes a starting population of 32,200 birds.

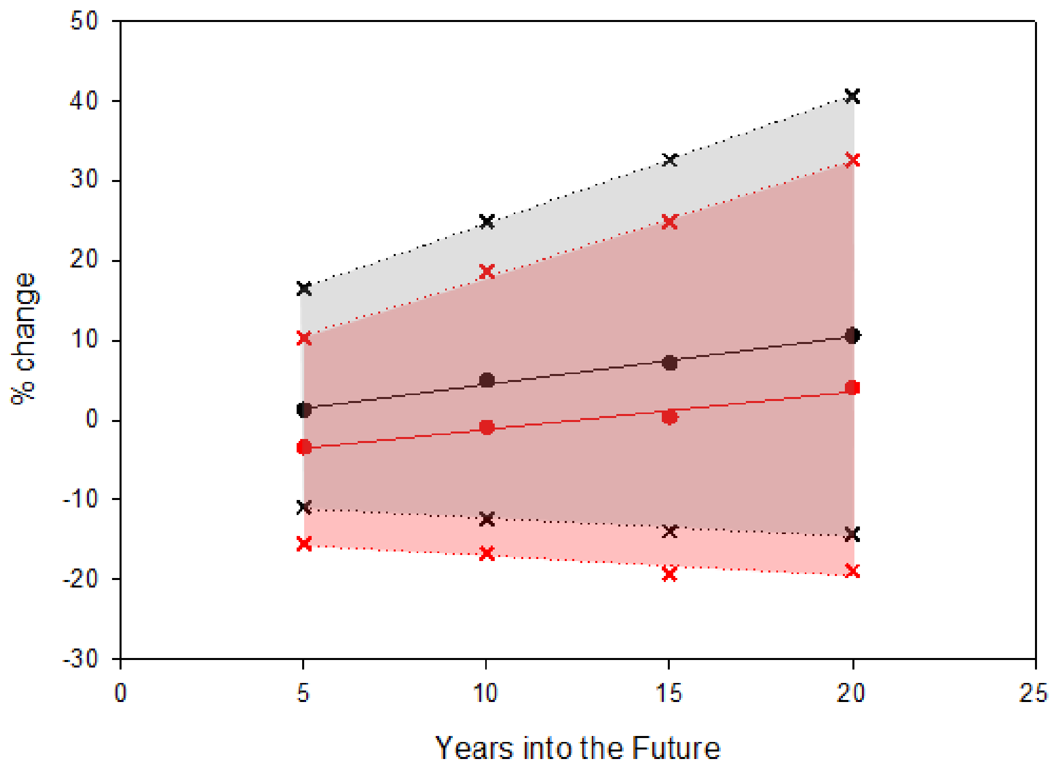


Figure 5. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Realistic" conditions (re-occurrence of near-failure years at historic frequency of, on average, 3 times per 26 years), with (red) and without eradication-associated mortality (black). Shown are the 25th 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.

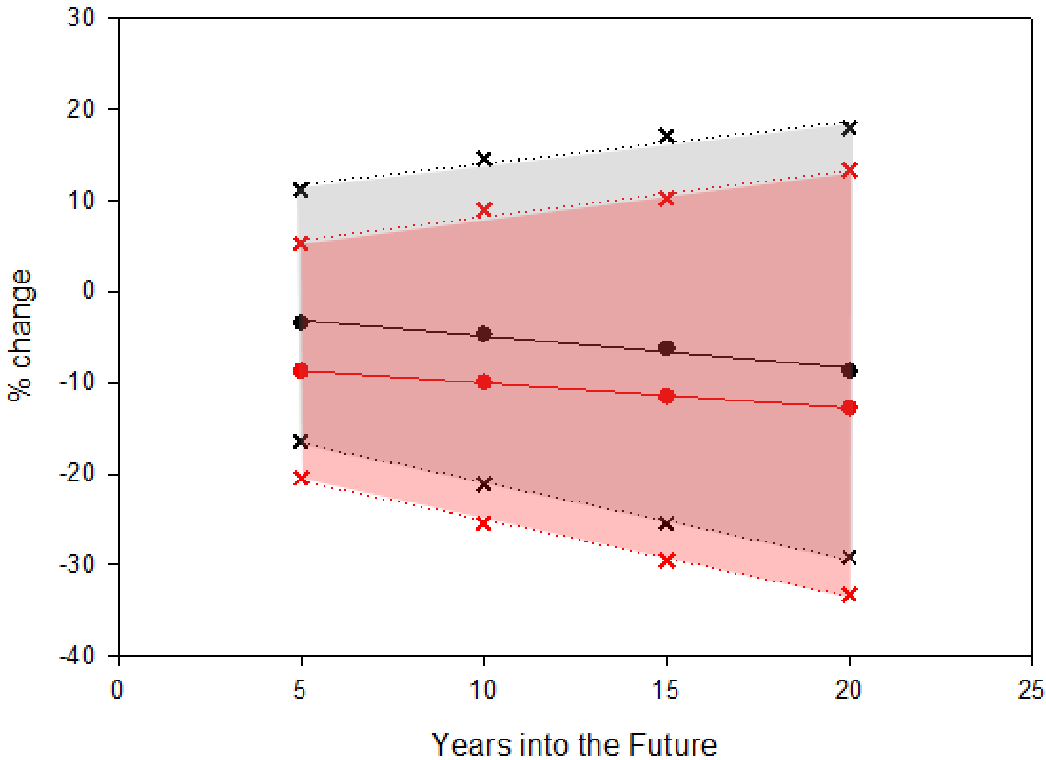


Figure 6. Estimated percent change in the Farallon Western Gull population over 20 years, assuming "Pessimistic" conditions: re-occurrence of near-failure years at recent frequency (on average, 3 times per 12 years), with (red) and without (black) eradication-associated mortality. Shown are the 25th 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.

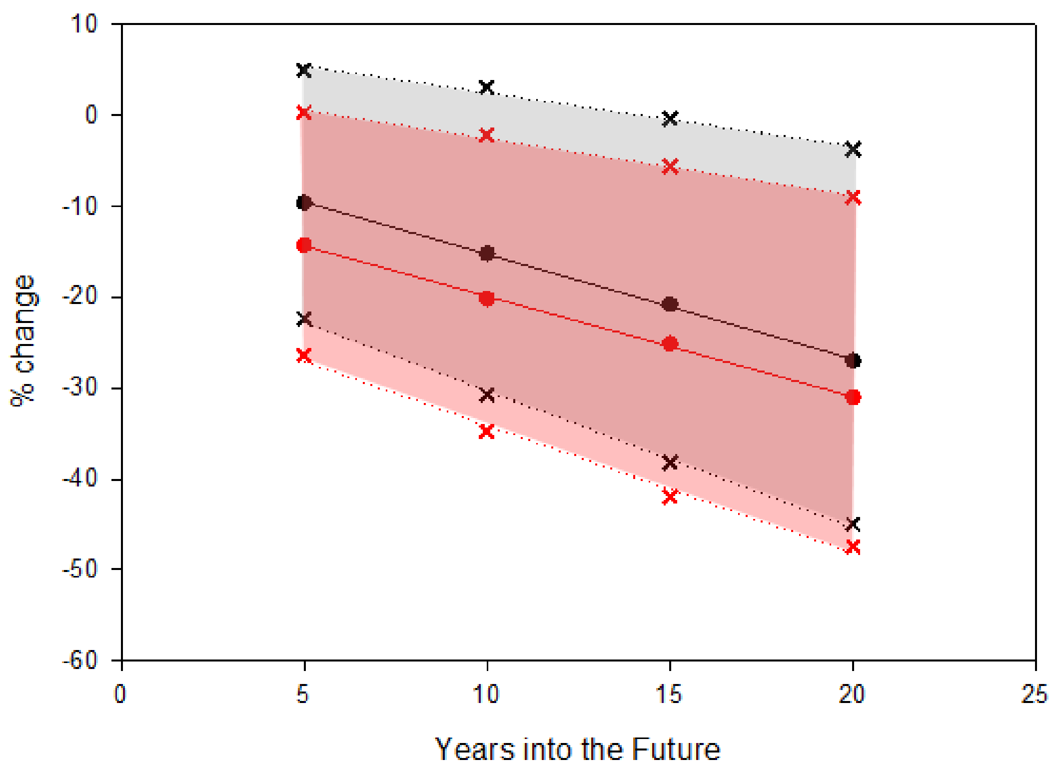
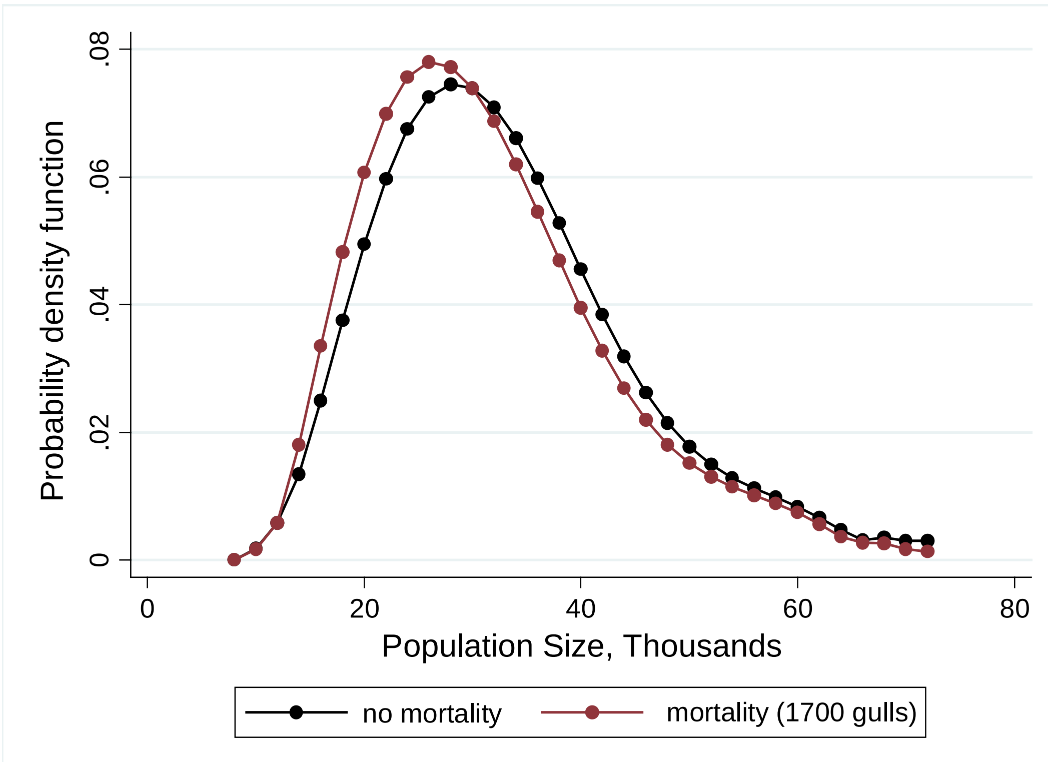


Figure 7. Probability distribution for "no mortality" and "mortality of 1700 gulls" scenarios, after 20 years, under "Realistic" Conditions: "historic" frequency of near-failure (results of 10,000 simulations for no mortality and 30,000 simulations for mortality of 1700 gulls). Note initial population 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%.



Appendix O:

Scoping Report

U.S. Fish & Wildlife Service

Farallon National Wildlife Refuge

South Farallon Islands Invasive House Mouse Eradication Project: Scoping Report

Photos Courtesy of Island Conservation

UPDATED SCOPING REPORT

South Farallon Islands Invasive House Mouse Eradication Project:

Prepared by Environmental Policy Solutions, LLC in collaboration with the U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex

1.0 INTRODUCTION

The U.S. Fish and Wildlife Service (Service) is the lead federal agency for the proposed house mouse eradication project on the South Farallon Islands, part of the Farallon Islands National Wildlife Refuge, California.

In April 2006, the Service initiated the National Environmental Policy Act (NEPA) process and subsequently held a public scoping meeting on May 17, 2006 to define the range of issues to be addressed and to identify whether there were any significant issues related to the proposed eradication project. At that time, the Service was proposing to prepare an environmental assessment (EA) for the project. Based on information gathered and initial analysis during preparation of the EA, the Service decided to prepare an environmental impact statement (EIS) for the project. The Service published a Notice of Intent (NOI) to prepare an EIS in the Federal Register on April 13, 2011 (76 FR 20706) and held a public scoping meeting on May 12, 2011. The public scoping process closed on June 10, 2011. Subsequently, an interagency scoping meeting was held on July 29, 2011.

A draft Scoping Report was provided in the South Farallon Islands house mouse eradication project Revised Draft Environmental Impact Statement (RDEIS), Appendix O. This Updated Scoping Report summarizes the results of the 2006 and 2011 scoping processes and replaces Appendix O of the RDEIS.

1.1 EIS Scoping Process

Based on the initial analyses for the draft EA scoping process and further internal discussion about the appropriate NEPA pathway, the Service decided to prepare an EIS for the project. The Service published a Notice of Intent on April 13, 2011 announcing its decision to prepare an EIS. The Service invited written comments from interested parties to ensure identification of the full range of alternatives, issues and concerns.

The Notice of Intent identified three preliminary alternatives for public consideration, based on information gathered for the initial EA. Both action alternatives proposed the use of the same rodenticide, Brodifacoum-25 Conservation, but differed in application approaches:

1. *Alternative A: No action;*
2. *Alternative B: Aerial broadcast of the rodenticide “Brodifacoum-25 Conservation” as the primary technique; and*
3. *Alternative C: Phased aerial broadcast of "Brodifacoum-25 Conservation" as the primary technique. In this alternative, different islands would be treated at different times ranging from days to weeks apart.*

Information gathered through the scoping process was then used to assist the Service in development of a range of alternatives.

1.2 Coordinating/Cooperating Agencies and Organizations

Coordinating agencies and organizations involved in the South Farallon Islands Invasive House Mouse Eradication Project have included:

- United States Environmental Protection Agency (EPA)
- United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS)
- National Oceanic and Atmospheric Administration (NOAA), Greater Farallones National Marine Sanctuary (formerly Gulf of the Farallones National Marine Sanctuary
- California Department of Fish and Wildlife (CDFW; formerly California Department of Fish and Game)
- Point Blue Conservation Science (formerly PRBO Conservation Science)
- Island Conservation

2.0 SCOPING PROCESSES FOR THE EA AND EIS

The Service used the NEPA scoping process (40 CFR 1501.7) to solicit input on the scope of issues and alternatives to be addressed in the NEPA analysis for the project. The Scoping process for the project included internal and external scoping efforts. Internal scoping involved studying literature regarding the biological, physical, and social issues associated with rodent eradication, as well as identifying a reasonable range of feasible mouse eradication methods for the islands. External scoping included the public scoping process, in addition to consultation with experts in invasive species eradication initiatives, experts on the Farallon Islands ecosystem, and representatives of federal and state agencies.

2.1 EA and EIS Scoping Processes

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

As noted in Section 1.1, a Notice of Intent (NOI) to prepare an EIS was published in the Federal Register on April 13, 2011. In addition, a scoping notice was sent to a variety of interested parties, including those who attended or submitted comments at the initial scoping meeting on May 17, 2006 for the EA, as well as to various federal and state environmental agencies. The notice was also posted on the website of the Farallon Islands National Wildlife Refuge, and to a website established by former project partner Island Conservation (www.restorethefarallones.org).

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

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

2.2 Project Websites

Announcements and general information about the project were posted on the Refuge website. Another website, www.restorethefarallones.org, was established by former project partner Island Conservation to provide information about the proposed project, the scoping announcement, and the Farallon Islands ecosystem.

2.3 Public Comment Periods & Scoping Meetings

The 45-day comment period for EA scoping was from April 14, 2006 through May 29, 2006. The Service consulted agency experts during the scoping process, and used this information to help define the issues to be addressed. For EIS scoping, an initial 30-day comment period from April 26, 2011 to May 27, 2011 was extended to June 10, 2011 with notifications sent out to interested parties. A public scoping meeting was held on May 12, 2011 in San Francisco, California. An agency scoping meeting was held on July 29, 2011 with interested federal and state environmental agencies. Representatives from the following agencies participated in the Agency Scoping Meeting held at the Service's San Francisco Bay National Wildlife Refuge Complex headquarters:

- USDA-APHIS, National Wildlife Research Center
- U.S. Environmental Protection Agency (EPA)
- NOAA, National Marine Fisheries Service (NMFS)
- NOAA, Greater Farallones National Marine Sanctuary (GFNMS)
- California Department of Fish and Wildlife (CDFW)

During the 2006 scoping period for the EA, the Service received substantive comments from 15 individuals or organizations. During the scoping period for the EIS, the Service received comments from 56 individuals as well as two petitions signed by 2,750 individuals, from which 497 signatures included additional comments. Another 41 individuals signed other petitions relating to the project.

The meeting locations, attendees, dates, and corresponding comment periods are highlighted in the table below:

Table 1: Public Meeting Locations, Comment Periods, Public Meeting Dates, and Numbers of Attendees at Public Meetings for the EA Scoping (Upper) and EIS Scoping (Lower).

Location	**Comment Period**	**Date**	**Attendees**
Building A, Fort Mason Center, San Francisco, CA	4/14/2006-5/29/2006	5/17/2006	10
Building 201, Fort Mason, San Francisco, CA	4/26/2011-6/10/2011	5/12/2011	20

2.4 Summary of EA Public Scoping Comments

Major concerns and suggestions expressed during the external scoping process for the EA are listed below, as well as the frequency with which they occurred in comments.
During the public scoping process for the EA in 2006, the public asked the Service to fully evaluate the environmental effects of the proposal answering questions such as:

1. Bait pellet toxicity
    a. How long are the pellets toxic and are they removed after application?
    b. How much bait must be ingested to be toxic and could there be accidental ingestion by seabirds and young pinnipeds?
    c. How much secondary and/or non-target poisoning from seabirds and raptors scavenging poisoned mice would occur?
    d. Have there been studies of the effects of these bait pellets on marine invertebrates or benthic invertebrates?
    e. Would bait residue be left in tidepools that are rarely flushed?
    f. Would sediment be contaminated and be re-suspended in the water column?
2. Implementation
    a. Where do the mice end up?
    b. Can a helicopter be used in a wilderness area?
    c. If the area is closed to fishing is there a perceived degradation of the fishing grounds?
3. Monitoring
    a. How would reintroduction of mice be prevented?
    b. What are the long-term monitoring plans?

In addition, many members of the public asked to be kept informed of the progress of the project, and in particular, of results after the project is completed. Six members of the public voiced strong support for the project and one member of the public stated that animal rights activists might consider the extermination cruel and questioned whether humans have the right to interfere with a dominant species or nature.

2.5 Summary of EIS Public Scoping Comments

Major concerns and suggestions expressed during the public scoping process for the EIS are listed below, as well as the frequency with which they occurred in comments. Because some comments expressed interest in multiple themes, the number of comments in the "Frequency Occurred" column does not directly correspond with the exact number of individual comments received.

Table 2 presents the comment themes from individuals, organizations, and public agencies regarding issues to be considered in the EIS for the proposed South Farallon Islands Invasive House Mouse Eradication Project.

Table 2: Themes from Substantive Comments from the EIS Scoping Process.

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

Specific delineations of comments and concerns from individuals, organizations, and government agencies regarding the methods and alternatives proposed for the project are defined in Table 3, in percentages.

Table 3: Substantive Comment Response Percentages from the EIS Scoping Process.

Stance on Preliminary Alternatives	**Individuals**	**Organizations**	**Government Agencies**	**% total responses**	**% (incl. petitions)**
Fully support listed alternatives	10	3	0	23%	2.4%
Support listed alternatives with exceptions	4	1	3	16%	1.7%
Against listed alternatives: rodenticide use	22	2	0	54%	5.6%
Against listed alternatives: mouse eradication	3	1	3	7%	0.7%
Against listed alternatives: Brodifacoum-25 use	2,750	1	0	N/A	92% incl. petitions ONLY

Table 4 contains an in-depth summary of substantive scoping comments. Numbers correspond with a stance on listed alternatives, and letters correspond with substantive comment categories: A- Purpose and Need, B- Alternatives, and C- Nontarget Impacts; (i.e.) 2 B, C is a comment that supports the alternatives with exception and commented on the alternatives and non-target impacts.

Table 4: Summary of substantive comments and their corresponding comment categories from the EIS Scoping Process.

No.	Comment	Freq.	Category
1	<u>Environmental Protection Agency (EPA):</u> • 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 <u>range</u> 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 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	1	2 A,B,C

No.	Comment	Freq.	Category
	▪ 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, i.e., 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 eradications 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 sufficient documentation to support assumptions ▪ Analyze impacts from the No Action Alternative ▪ 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:		

No.	Comment	Freq.	Category
	▪ 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 Department of Fish and Wildlife – 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 projects ▪ Describe how this project will apply lessons learned and decrease impacts to non-targets i.e.) 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	1	2 A,B,C
3	<u>USDA-APHIS – 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.	1	2 A,B,C

<table>
<tr><th>No.</th><th>Comment</th><th>Freq.</th><th>Category</th></tr>
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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.

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

Need for Action:

Provide a detailed discussion of the need for the project and the need to implement now to help identify the environmental issues that should be evaluated.
The use of the toxicant should be a last resort

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

Alternatives:

Explore other action alternatives that minimize harmful environmental effects
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

Monitoring:

Strong monitoring effort for eradication efficacy, ecosystem response, and ecological impacts should be integral of the eradication planning
Monitoring must be adequately funded

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.

</td><td></td><td></td></tr>
<tr><td>4</td><td>
<u>California 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.

</td><td>1</td><td>2 B,C</td></tr>
</table>

No.	Comment	Freq.	Category
	• 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.		
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 scientist's 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
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 raptors 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

No.	Comment	Freq.	Category
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
28	Broadcasting brodifacoum will also poison raptors such as red-tailed hawks and 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

No.	Comment	Freq.	Category
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 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.	1	5 B,C
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

2.6 Relationship of EIS Scoping Process to Alternatives Analysis

A number of scoping comments suggested that the Service explore additional alternatives to accomplish project objectives. In response to these concerns, the Service decided to employ a Structured Decision-Making Model to develop a reasonable range of alternatives for the draft EIS. After reviewing comments from both the 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 DEIS. The Alternatives Assessment Process, which was the report associated with the Structured Decision-Making Model, was subsequently developed and a report was submitted to interested agencies for review. The Service evaluated 49 toxic and non-toxic alternatives to determine the extent to which each would fulfill the goals and objectives for the project.

As a result of this process, the Service identified a new alternative involving the use of Diphacinone 50 Conservation for full analysis in the DEIS. The Service also eliminated from further consideration one of the preliminary alternatives identified in the NOI, the phased use of Brodifacoum 25D, because of the high risk that mice could easily move between islands which would dramatically increase the risk of failure. The range of alternatives carried forward for full consideration in the DEIS included three alternatives:

- Alternative A: No Action,
- Alternative B: Aerial broadcast of Brodifacoum 25D Conservation, and
- Alternative C: Aerial broadcast of Diphacinone 50 Conservation

2.7 Impact Topics Identified for EIS

The Service identified impact topics for the EIS that would provide the basis for evaluating the impacts from the three alternatives. Impact topics were generated from comments made during the internal and external scoping processes. The Service identified key impact topics, listed below, based on the most important concerns stakeholders had identified:

- **Impact Topic: Physical Resources**
  - Sub-topic: Impacts to water resources
  - Sub-topic: Impacts to geology and soils
  - Sub-topic: Impacts to wilderness
- **Impact Topic: Biological Resources**
  - Sub-topic: Non-target impacts from toxicant use
  - Sub-topic: Disturbance to sensitive species
- **Impact Topic: Social and Economic Environment**
  - Sub-topic: Impacts to Personnel Safety
  - Sub-topic: Impacts to Refuge visitors and recreation
  - Sub-topic: Impacts to fishing resources
  - Sub-topic: Impacts to social and economic resources

These Impact Topics were coded into categories for the DEIS, which helped simplify the process of locating individual comments relating to a certain Impact Topic in the document and appendices.

The DEIS also included sections that analyzed the following topics as they related to the above impact topics:

- Unavoidable adverse impacts
- Cumulative impacts
- Irreversible or irretrievable commitments of resources
- Relationship of short-term uses to long-term ecological productivity

3.0 CONTACTS

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Appendix P:

Draft EIS Comment Response Report

Farallon Mouse Eradication DEIS/RDEIS Comment Response Report

Introduction

Public review of the Draft EIS (DEIS) began on August 16, 2013 (78 FR 50082 and 78 FR52524), with a request for comments by September 30, 2013. The Service held a public meeting on August 29, 2013, during which Service staff and partners were available to provide information and answer questions in person. On October 25, 2013 the Service issued a Federal Register notice informing the public that a Revised Draft EIS (RDEIS) was available for review and requested comments by December 9, 2013 (78 FR 64002 and 78 FR 63977). The Service issued the RDEIS in order to clarify language on the population status of the ashy storm-petrel (*Oceanodroma homochroa*) and to revise the assessment of impacts to the ash storm-petrel under the no action alternative. Both the DEIS and RDEIS were available to the public electronically at http://www.regulations.gov; docket number FWS-R8-NWRS-2013-0036. A paper copy of the DEIS and RDEIS were also available to the public at the San Francisco Public Library in San Francisco, California and at the San Francisco Bay National Wildlife Refuge Complex headquarters in Fremont, California. In addition to the Federal Register notice, the Service mailed notices to all parties who had requested information and submitted a press release to local media informing them of the availability of both the DEIS and RDEIS.

Following the comment period, the Service addressed all substantive comments received, conducted additional studies and analyses, and made changes to the RDEIS as necessary. The Final EIS includes an Appendix that summarizes the substantive comments received along with the Service's responses to these public and agency comments.

The public submitted a total of 553 correspondences on the DEIS and RDEIS. Each correspondence was reviewed for substantive comments. Substantive comments were classified by a comment theme with a specific comment concern. Representative quotes for each comment concern were then identified by a specific correspondence number. The concerns identified include the following:

1. Objectivity of the Revised Draft EIS.
2. DEIS didn't explain lessons learned.
3. Rodenticides could persist in the island's ecosystem for the long-term.
4. The risk to the marine environment is not properly evaluated.
5. The need for this project is not clear.
6. There is no guarantee that a successful mouse eradication will minimize the indirect impacts of mice on petrels.
7. Sublethal effects not evaluated properly.
8. How many gulls will die?
9. Gull Hazing is unclear.
10. Economic impacts were not properly evaluated.
11. Does FWS have the money or the means to get the money necessary to mitigate for the duration of risk?
12. The bait application plan is not appropriate.

13. The EIS needs a detailed monitoring plan.
14. The EIS needs a detailed mitigation plan.
15. The Gull Risk Assessment should be reparametrized.
16. Swift 1998 was incorrectly cited.
17. Choose the diphacinone alternative or the No Action alternative.
18. Forgo the use of rodenticide on the Farallon Islands.
19. Not a good range of alternatives considered.
20. This project is unlikely to be successful.
21. Supporting reports are insufficient.
22. Cumulative Impacts are not properly evaluated.
23. Toxicant impacts are not properly evaluated.
24. How many individuals will die?
25. Animal Capture, how will it be done?
26. Operational Impacts not properly evaluated.
27. Tradeoffs not assessed properly.
28. Diphacinone is not evaluated properly.
29. Mice below ground values are questionable.
30. Table 2.5 does not reflect the language in the DEIS.
31. The Service should invest in innovative eradication tools.
32. The Service should get the States permission to use rodenticides.
33. EPA's pesticide comments.
34. Bird Capture is unclear.
35. Best Management Practices should be incorporated.
36. Significance needs to be reevaluated.
37. Salamander impacts are not properly evaluated.
38. Do gulls or other species consume mice?
39. The premise of the project and the accurate assessment of impacts relies on predictions of how the ecosystem will respond.

Comment Concerns and Response

Concern 1.1: Island Conservation (IC) has a conflict of interest.

Representative Quotes:

1. Environmental Protection Agency #551, EPA raised concerns regarding potential conflict of interest with IC preparing the impact assessment and most likely also carrying out the eradication project… We assume the necessary disclosure statement has been filed per 40 CFR 1506.5(c).

2. James Moskito #550, If it is true that IC has been paid over $481,000 by FWS to write the DEIS. Is that a huge conflict of interest and unethical? Since it is also IC that will perform the project, I recommend an independent third-party review of ... the project be completed prior to commencing.

Response: The Service entered into Cooperative Agreement number 81640AJ123 with Island Conservation in September 2010. The specific tasks of that agreement were for Island

Conservation to assist the Service with development of an Environmental Assessment, additional environmental compliance, and research and development for the South Farallon Islands house mouse eradication project. After the initiation of this agreement, it was brought to our attention that language included in the agreement gave the impression that project implementation was also included. With this realization, the Service cancelled Cooperative Agreement 81640AJ123.

A new Cooperative Agreement, number 81640BJ054, with Island Conservation was entered into in August 2011. The new agreement clearly limited Island Conservation's assistance with the project to development of an EIS, including drafting portions of the document for FWS final review and approval, conducting research trials, and assisting with the development of a communications plan. As required under NEPA [40 CFR 1506.5(c)], Island Conservation also provided the Service a disclosure statement stating that they had no financial or other interest in the outcome of the project. Island Conservation remained a partner for the duration of the Draft EIS preparation.

In early July 2014, Island Conservation gave verbal notice to the Service that they were withdrawing as a partner on the project. Written notice of Island Conservation's withdrawal was received on November 20, 2014. Island Conservation has not participated in the drafting of the Final EIS.

FEIS Revisions Made: None.

Concern 1.2: The Service should evaluate more non-toxic/less toxic alternatives.

Representative Quotes: 1. Wildcare #552, Wildcare 's position is that more research into non-toxic alternatives needs to be done by the USFWS and that the urgency of implementation has been overstated;…,one of our primary concerns is how few proposed methods of eradication were considered. 49 options were listed and 42 of those involved poison - 14 different types dispersed 3 different ways.

2. American Bird Conservancy - #485 The RDEIS fails to thoroughly evaluate the alternatives for possible rodenticide bait delivery, instead focusing primarily on aerial applications of brodifacoum or diphacinone. Bait stations are readily ruled out (pp. 44-45) because of areas of steep and rugged terrain, labor intensiveness, and potential disruptions to nesting birds and marine mammals. However, the bait stations would significantly reduce the risk of nontarget exposure.

Response: We did an extensive evaluation of 49 alternatives using a Structured Decision-Making Model approach to identify a range of reasonable and feasible action alternatives that were responsive to the purpose of the project, which is to eradicate invasive house mice from the South Farallon Islands in order to eliminate their negative impacts on the islands' native ecosystem. The Alternatives Assessment Report (Appendix C) is a comprehensive assessment of the alternatives that were reviewed for inclusion in the range of alternatives. Among those reviewed were seven non-pesticide alternatives. In addition, the use of bait stations as the primary bait delivery method was considered. That option was dismissed from further consideration in Section 2.7 due to issues with efficacy, health and safety. Research into non-toxic methods is beyond the scope of this project; however, as discussed in response to Concern 5.5, such research by others is ongoing.

FEIS Revisions Made: Revisions and updates made to throughout Section 2.7: Alternatives considered and dismissed from further consideration.

Concern 1:3*:* Why not just remove burrowing owls from the Farallon Islands rather than eradicating invasive mice?

Representative Quotes: 1. American Bird Conservancy #485, However, it does not seem that such an alternative (owl translocation) has actually been given full consideration, or if it has, the analysis that was undertaken to rule it out is not explained. We believe that a full explanation of what would be involved and why it is not being considered should be included in the RDEIS.

2. American Bird Conservancy #485, Obtaining a depredation permit under the MBTA to translocate Burrowing Owls "would not be possible at this time" because "…USFWS Office of Migratory Birds is not issuing permits to take or translocate native wildlife except in certain cases to protect endangered or threatened wildlife ...[and] ashy storm-petrels are not listed on the ESA." In light of the putative willingness of FWS to issues an incidental take permit for this project for more than 1,000 Western Gulls, the suggestion that obtaining a depredation permit under the very same statute to translocate fewer than 12 burrowing owls each year is "not possible" is incomprehensible...provide adequate information about what efforts have been made to work with CDFW to obtain {Special Purpose Permit} this permit, and what insurmountable obstacle arose. Taken together, the statements in the RDEIS page 46 provide a vague and unsatisfactory justification for not pursuing translocation or other control of Burrowing Owls as a way to address directly the problem of owl predation on Farallon wildlife.

Response: Translocating burrowing owls away from the South Farallon Islands does not address the purpose of this project; that is, "...to meet the Service's management goal of eradicating invasive house mice from the Farallon Islands National Wildlife Refuge in order to eliminate their negative impacts on the native ecosystem of the South Farallon Islands." Thus, translocation of burrowing owls was not considered as an alternative.

FEIS Revisions Made: Revisions and updates made to Section 2.7.9: Burrowing owl translocation.

Concern 1:4: The comparison of action alternatives is not meaningful because diphacinone is less toxic to birds; therefore, the application rate, applied bait, concentration of rodenticide, and bait availability are not comparable (Table 2.5)

Representative Quotes: 1. Environmental Protection Agency #551, The CEQ Regulations emphasize the importance of the alternatives analysis, stating it is the heart of the EIS (40 CFR 1502.14). The RDEIS provides a comparison of the two alternative actions in Table 2.5; however, the comparison is not meaningful because it does not consider the differences in toxicity of the two rodenticides, which is the main difference between alternatives. Therefore, application rates, total applied bait and the amount of rodenticides applied, concentration of rodenticide within the bait, and even bait availability, are not comparable."

Response: Both of the action alternatives provide a means to supporting the purpose and need (i.e., eradicating house mice from the South Farallon Islands). The alternatives analysis considers the difference in toxicity between the two rodenticides. Toxicity to biological resources, among numerous other factors, of the two rodenticides is discussed in Chapter 4, including sections about the toxicity of brodifacoum and diphacinone to water, geology and soils, birds, mammals, amphibians, fish, and invertebrates. Impacts of the two rodenticides, including consideration of duration of toxicant risk, toxicant sensitivity, and other factors, are summarized for brodifacoum in Table 4.4 and for diphacinone in Table 4.5. A detailed analysis of the potential exposure and effects of Farallon Islands' western gulls, which was identified as a high-risk species, is described in Chapter 4 and specific details about the analyses are provided in Appendix F. Operational details, such as bait application rate and time between applications, are different between the two products as a result of the difference in toxicity (shown in Table 2.5, Section 2.13). Operation details, such as application rate, rodenticide concentration, and related variables associated with the proposed alternatives are provided in Chapter 2.

FEIS Revisions Made: Revisions and updates made to Section 2.13: Comparative summary of actions by alternative.

Concern 1.5: The DEIS is not objective.

Representative Quotes: 1. Sonce Devries #468, The reviewer is prompted to ask what is truly driving the need to conduct this action at this time. The answer is that monies from the Natural Resource Damage Assessment settlement for a shipwreck near the SF Bay have been allocated to pay for this as a "restoration" project. If the monies are not spent on this project they must be spent on another restoration project. Thus, regardless of whether or not there is a true need to accomplish the mouse eradication now to preserve other species and that a procedure is available to implement a successful eradication without significant risk to nontarget species, the refuge desires to proceed with this project to fulfill the goals presented in their CCP. Since the EIS is required to be neutral and transparent in its discussion of the proposal. I find the lack of objectivity about this issue to be a serious deficiency.

Response: As explained in Chapter 1 of the FEIS, the proposed project is consistent with the laws, policies, and goals of the refuge. The Service objectively evaluated a wide range of options to accomplish the purposes of the project and provided several opportunities for public and agency comment. The Service did not identify a preferred alternative until the FEIS stage of the NEPA process in order to foster robust public and agency comment on the alternatives proposed in the RDEIS.

FEIS Revisions Made: No revisions were made to the FEIS.

Concern 1.6: FWS is biased in favor of Alternative B: aerial broadcast of brodifacoum.

Representative Quotes: 1. Sonce Devries #468, While the DEIS states that no choice of alternatives has been made, the text clearly indicates that the reader is being strongly encouraged to select Alternative B, the use of brodifacoum, as the preferred alternative. Well-written EISs go to great lengths to present a completely neutral discussion of the facts and allow the reviewer to reach their own conclusions. The DEIS does not meet that standard.

Response: The RDEIS presented two action alternatives, each using a different type of rodenticide product. A No Action alternative was also considered and evaluated. Because the Service wanted the public to carefully consider all three alternatives, and because the Service itself had not identified a preference among the alternatives, the RDEIS did not identify a preferred alternative. The RDEIS and FEIS analyze each alternative in a thorough and objective manner. We disagree that the NEPA process has been biased in favor of any alternative.

The FEIS presents the best available factual information for each alternative. A greater amount of information is available on rodent eradications using brodifacoum, the product proposed for use in Alternative B. This is mainly because brodifacoum has been used more widely in mouse and other rodent eradications than diphacinone (Alternative C). For example, as shown in Table 2.2 of the FEIS, of 87 house mouse eradication attempts, 70 utilized brodifacoum and none used diphacinone.

FEIS Revisions Made: None.

Concern 1.7: FWS relies on contractors too much and not on FWS personnel or other federal employees.

Representative Quotes: 1. Sonce Devries #468 2nd submission, A second major concern is the regulation at 40 CFR 1506.5c which requires the lead federal agency independently evaluate the information submitted to it by others and be responsible for its accuracy. During the scoping meetings, the FWS indicated they would be relying on the expertise of IC, rather than personnel within the FWS. This is very troubling since you and I are well aware that there are personnel within FWS who are experts in the field of rodent eradications and are available for consultation. The refuge should have relied heavily on these personnel to advise and assist in the preparation of the EIS and consultation on how best to perform the physical work.

Response: The Department of Interior NEPA regulations (43 CFR 46.105) state that a Responsible Official may use a contractor to prepare any environmental document in accordance with the standards of 40 CFR 1506.5(b) and (c). If a Responsible Official uses a contractor, the Responsible Official remains responsible for: (a) Preparation and adequacy of the environmental documents; and (b) Independent evaluation of the environmental documents after their completion. The Service prepared the Draft EIS (and Final EIS) in accordance with these regulations. We also consulted with rodent eradication experts within the Service, USDA, and the US EPA. The Service oversaw all aspects of the Farallon mouse eradication planning process, reviewed and was responsible for all content of the Draft EIS and Final EIS.

FEIS Revisions Made: None.

Concern 2.1: The DEIS did not discuss lessons learned from islands that had unexpected non-target mortality, like Rat Island and Palmyra Atoll, or recommendations from the Rat Island Review.

Representative Quote*:* 1. Pacific Islands Fish Wildlife Service, Following the Rat Island rat eradication project a detailed review was conducted by the Ornithological Union (Salmon and Paul 2010). The review of this project included four specific recommendations for changing the Services procedures for planning and conducting and eradiation project... We suggest a section in the EIS that identifies the four recommendations and discusses them with respect to this project.

2. Environmental Protection Agency #551, Additional planning should occur to address possible needs to apply bait other than as originally intended but within limits set by labeling. Procedures should be developed to avoid the type of on-the-fly decisions regarding bait application that resulted in pesticide label violations in the Rat Island eradication and may have increased nontarget mortality.

3. American Bird Conservancy #485, The RDEIS mentions Rat Island in only one paragraph and in a bullet point on the penultimate page of the document. This bullet is from the 2011 scoping meeting in which the attendees asked FWS to incorporate lessons learned from Rat Island. Clearly this was not done. That the Avian Risk Assessment leaves out a review of Rat Island raises broader concerns about the integrity of this document.

Response: In Section 1.1.2 of the FEIS, the Service has added an explanation of how lessons learned from Rat Island and other rodent eradication projects have influenced the development of the alternatives proposed in the EIS. Sections 1.5, 4.5.1, and 1.5.2 also discussed the four recommendations from the 2010 Ornithological Union report on the Rat Island project in relation to this project. The Service has begun drafting contingency plans for this project that will address the potential for a bait spill or unexpected non-target impacts.

FEIS Revisions Made: Lessons learned were added to chapters 1, 2, and 4 of the FEIS. Information on lessons learned added to Section 1.1.2 briefly discusses lessons learned and how they were addressed in the document. Sections 1.5, 1.5.1, and 1.5.2 detail how the Service addressed lessons in the planning of this project, outlined the recommendations from the Rat Island Review, and the best management practices for mouse eradication developed by the Department of Conservation in New Zealand. Furthermore, Section 2.6.5 outlines how the Service incorporated lessons learned into the operational planning of the proposed mouse eradication on the Farallon Islands, while Section 4.5.1 outlines how the Service has incorporated lessons learned into the assessment of impacts and the level of mitigation and monitoring that would be required should this project move forward. An example of how information from past projects influenced the development of this project is the addition of gull hazing to mitigate non-target risk to gulls, which has been incorporated into both Alternatives B and C.

Concern 2.2: The DEIS did not discuss lessons learned from islands with recent eradication failures: Desecheo Island, Wake Island, Henderson Island.

Representative Quote*:* 1. Marin Audubon #410, If there were problems with other eradications, particularly in areas that are a concern here, how were they overcome? Is this project learning from those earlier experiences?

2. Environmental Protection Agency #551, Much information can be obtained from previous rodent eradication attempts and it is not clear that lessons learned from these projects have been integrated into the planning for the proposed project. We are aware that 3 recent rodent eradication attempts - Wake Atoll, Henderson Island, and Desecheo Island- have failed.

Response: The alternatives development process (Section 2.2) for this project included consideration of ways to avoid operational issues that were identified as problems in previous rodent eradication projects. The RDEIS did not include a section explicitly outlining how the operational elements of the alternatives related to lessons learned from past projects. To address this, we have added Sections 1.5, 2.6.5, and 4.5.1 to the FEIS, which explains how relevant lessons learned from past projects, including the failed rat eradication efforts on Desecheo Island, Henderson Island, and Wake Atoll, influenced the development of the alternatives in the FEIS, as well as their potential impacts to the islands resources.

FEIS Revisions Made: Lessons learned were added to chapters 1, 2, and 4 of the FEIS. Information on lessons learned added to Section 1.1.2 briefly discusses lessons learned and how they were addressed in the document. Sections 1.5 and 1.5.1 and 1.5.2 detail how the Service addressed lessons in the planning of this project, outlined the recommendations from the Rat Island Review, and the best management practices for mouse eradication developed by the Department of Conservation in New Zealand. Furthermore, Section 2.6.5 outlines how the Service incorporated lessons learned into the operational planning of the proposed mouse eradication on the Farallon Islands, while Section 4.5.1 outlines how the Service has incorporated lessons learned into the assessment of impacts and the level of mitigation and monitoring that would be required should this project move forward.

Concern 2.3: Provide lessons learned from past projects where salamanders of this type were held in captivity for 90+ days.

Representative Quote*:* 1. Environmental Protection Agency #551, The RDEIS does not sate whether this type of salamander ever has been successfully held in captivity for up to 90 days.

Response: The U.S. Fish and Wildlife Service consulted with a herpetologist at San Francisco State University who has successfully captured and maintained wild-caught salamanders of the genus *Ensatina*, *Aneides*, and *Batrachosep*s for longer than 90 days (V. Vredenburg, personal communication). The Service intends to follow an existing standard operating procedure for maintaining endemic South Farallon Islands salamanders in captivity. Standard procedures will be followed for caring for and maintaining salamanders on Southeast Farallon Island during the operational period until risk of impact is determined to be acceptable by the Service.

FEIS Revisions Made: Salamander captive hold was updated in Section 2.10.7.5: Captive Management of Salamanders.

Concern 2.4: Discuss the risk to crabs from brodifacoum exposure based on the lessons learned from Palmyra Atoll.

Representative Quote*:* 1. Environmental Protection Agency #551, The USDA Palmyra Atoll Rodent Eradication Monitoring Report, September 2012, found dead land crabs containing brodifacoum residue. These findings should be discussed and impacts to any crab species clarified.

Response: Six species of land crabs are reported to occur on Palmyra Atoll with a total mean density of 460 crabs per hectare (Howald et al. 2004). These crab species range in size from the 100 g hermit crab to the 5 kg coconut crab (Wegmann et al. 2012). There are no land crabs occurring on the South Farallon Islands. Crab species that occur near the South Farallon Islands include intertidal crabs, such as *Hemigrapsus nudus*, and bottom-dwelling crabs, such as dungeness crab (*Metacarcinus magister*).

Additional information about Palmyra Atoll and its land crabs has been incorporated into the Final EIS in Section 4.5.4. Additional information about the toxicity or occurrence of rodenticides in crabs can be found in Section 4.5.4 of the Final EIS.

FEIS Revisions Made: Section 4.5.4: Impacts of Action Alternatives on Biological Resources discusses the expected impacts to crabs on or near the South Farallon Islands from brodifacoum exposure.

Concern 3.1: Risks to birds, marine mammals, other species, and the environment are underestimated.

Representative Quote*:* 1. Sonce Devries #468, The DEIS does not discuss the extreme sensitivity of the gulls to brodifacoum ingestion, whether in pellets or in mice contaminated with brodifacoum. Therefore, if any gulls ingest brodifacoum it may be assumed the gull will die either immediately or in the space of several days.

2. Brooke McDonald #464, I am concerned that the emphasis in the DEIS on global populations does not fully take into consideration the potential damage to the delicate ecology and unique research opportunities that are present on the Farallon Islands. Some of the population estimates that are given in the DEIS, such as the estimate that there will be between 25 and 30 individual peregrine falcons on the islands during the project, seem to me to be suspiciously high. I'm concerned that if overly large estimates are given for the number of animals on the island and potential take is not assessed in terms of local populations, mortality of a few individuals may not be taken seriously, and the recovery of the island ecosystem may be set back. I respectfully request that the FEIS consider the potential risks that and environmental consequences of the extirpation of species from the islands...

Response: The Final EIS acknowledges that the species most at risk of non-target impacts from brodifacoum is the western gull (Section 4.5.4.4.1). The Final EIS provides analysis of risk to western gulls in Sections 4.5.4.4 (Appendix A), Project Feasibility and Risk Trial Report (Section 4.8 of Appendix A), and Appendix F (Western Gull Risk Assessment). The Service has developed mitigation measures to minimize these risks such as hazing gulls and other non-target bird species, carcass removal, time limits for project implementation, and collecting residual bait after the operation period. Mitigation measures are described in Sections 2.10.7. The EIS provided numeric ranges for the number of individual birds from different species likely to occur on the islands during project implementation. During that time of year, most of the birds present on the islands are migratory and non-resident. These figures were derived mainly from 10 years of monitoring data collected on the refuge and are not overly large estimates. Potential numbers of bird species listed in the EIS are not for any one time but represent numbers that may visit the islands over the course of the entire expected operational period. Our assessments of potential impacts to non-target species focused on population level impacts, not impacts to individual animals in Section 4.5 (See table 4.3 and 4.4). This approach is consistent with Service policy (601 FW 3), which focuses on maintaining native wildlife populations by developing management strategies to accomplish refuge purposes.

FEIS Revisions Made: Revisions were made throughout Section 4.5: Consequences to Biological Resources based on the above response.

Concern 3.2: Since rodenticides will persist in the environment as long as carcasses laden with rodenticide are available on the island, how will carcasses be disposed of?

Representative Quote*:* 1. Marin Audubon Society #410, The discussion of measures to mitigate impacts includes removing carcasses to reduce the potential for gulls to eat them. We recommend that mice be gathered up before they are actually carcasses. This would better assure that they would not be eaten by gulls thereby causing other incidental deaths.

2. Friends of the Gull #221, The EIS states that carcass removal will be implemented after the start of the eradication efforts to reduce the threats of secondary exposure to gulls, owls, and other scavengers. It is expected that a large number of carcasses will be generated by this project. The FEIS should include specific information regarding carcass removal activities and should state where and how carcasses will be disposed.

Response: Carcass removal is outlined in Section 2.10.7.2. That section has been updated to include a map of the area where bait and carcasses will be removed, how they will be disposed of, and the extent of the removal program. This mitigation measure will be limited to areas of the island that are easily accessible and would not pose a risk to human health and safety. The Service will dispose of all carcasses and bait pellets in accordance with The Resource Conservation and Recovery Act regulatory requirements.

FEIS Revisions Made: Revisions made in Section 2.10.7.2: Carcass removal.

Concern 3.3: Carcasses laden with toxicant will attract raptors, putting them at risk of exposure and other species.

Representative Quote*:* 1. Sonce Devries #468 2nd submission, The documents completely ignore the fact that the largest concentration of raptors on the West Coast will be located on Hawk Hill, located some 25 miles from the island, during the proposed eradication time in November. This is a very important stopover...Raptors have very keen eyesight and sense of smell and routinely forage over many square miles on a daily basis. They will inevitably locate dead and moribund mice on the Farallones and come to feed on them.

2. No Name Given #517, Eliminating nontarget effects is particularly important considering that Hawk Hill is 25 miles away and will be teeming with raptors, vultures, and owls at the time of

the proposed eradication... No hazing program could possibly prevent all the birds from eating carcasses.

Response: The likelihood that the Farallon mouse eradication would attract raptors to the islands is negligible for several reasons: 1) The distance between Hawk Hill and the South Farallon Islands is about 29 miles. Despite this relatively close distance for raptors to fly, long-term monitoring has shown that very few migrant raptors (outside of burrowing owls and peregrine falcons) occur at the Farallon Islands. In recent years, less than 10 individuals per year of species besides the burrowing owl and peregrine falcon have been recorded on the Farallones during the month of November, and none of these species are known as scavengers; 2) previous studies described in the FEIS have shown that the majority of rodents killed in eradication projects die underground and thus are not available to surface predators; 3) while raptors are known for their keen vision, it is not keen enough to spot a dead rodent at distances like those between the islands and the mainland; and 4) most birds have a poor sense of smell. While scavenging Turkey Vultures are common along the central California coast and have a more refined sense of smell, they very rarely have flown across the water to the islands and it is highly unlikely that they could detect the odors of rodent or other carcasses over the distances required.

For those raptors that would be present during the eradication project, a plan would be implemented to capture as many of those birds as possible and either translocate them away from the island or hold them in captivity until the risk of rodenticide exposure is considered to be acceptable.

FEIS Revisions Made: None.

Concern 3.4: How will sick or injured non-target animals be treated?

***Representative Quote**:* 1. Environmental Protection Agency #551, Specifically how or whether sick or injured wildlife that may be found by the public or during monitoring would be treated under the action alternatives and who would be responsible for this treatment?

Response: Supplies of anticoagulant antidote, Vitamin K, will be on hand during the implementation phase of the eradication until it is determined that the risk from rodenticide exposure has declined to negligible. A veterinarian will be on the island or on call to respond as necessary to apply antidote, care or euthanasia of captured wildlife that were exposed to rodenticide. In outreach materials, the public will be provided instructions on what they should do if they find any wildlife potentially exposed to rodenticides on the mainland.

FEIS Revisions Made: Additional information provided in Section 2.10.7: Mitigation measures to protect biological resources.

Concern 3.5: Risks to bats need to be assessed.

***Representative Quote**:* 1. Environmental Protection Agency #551, Impacts to bats are not assessed. The RDEIS states that a number of bat species visit the Farallones… It notes that island invertebrates play an important ecological role as prey items for migrant bat species on the Farallones (p. 100), and that toxic residues have been found in the tissues of various invertebrate species (p. 137).

Response: Only small numbers of bats occur on the Farallones as fall migrants. Cryan and Brown (2007) summarized records of bats recorded on the Farallon Islands from 1968 to 2005. They found that the hoary bat is the only species occurring regularly. Of 296 records of hoary bats, all occurred between August 10th and November 11th. However, only in 1998 were there records of bats present during November. In more recent years, bats have become even less common on the islands. For example, in 2014-2016), less than 10 bats total were observed on the Farallones, all during fall migration and all prior to the planned implementation period, making the risk to their populations from potential Farallon mouse eradication as negligible. For these reasons, bats have been added to Section 4.3 Aspects excluded from detailed analysis.

FEIS Revisions Made: Revisions were made to Section 4.3: Aspects excluded from detailed analysis.

Concern 3.6: The DEIS does not state the half-life or anticipated lethal dose level for bait on land and in water after application.

***Representative Quote**:* 1. Ocean Foundation #484, The RDEIS is inadequate since it fails to disclose the half-life or anticipated lethal dose level for bait on land and in water after application, or for bait in various weather conditions, nor does the DEIS disclose the time from first exposure...

2. American Bird Conservancy #485, Greater transparency is needed as well as a full justification of the choices of LD-50s, half-lives, dose rates, above-ground death rates, and other assumptions.

Response: Section 4.5 provides a significance determination for individual non-target species that have the potential to be exposed to rodenticides. 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 period. The significance determination takes into consideration numerous factors that are categorized as influencing toxicant or disturbance risk. The factors include the amount of time rodenticide would be available through primary or secondary pathways; susceptibility of different species to rodenticide based on LD50 data for analogous species; and potential exposure pathways, among several other factors. Species that are not included in Section 4.5 are not considered to be at risk of rodenticide exposure based on existing monitoring data for different populations.

Chemical properties of diphacinone and brodifacoum are listed in Section 2.6 of the Final EIS. LD50s of the two rodenticides in mice and birds are briefly mentioned in these sections, with more detail provided in Section 4.5.4.3. LD50 values for birds range from 0.26 mg/kg (mallard) to 10 mg/kg (ring-necked pheasant) (EPA 2004).

Information about the toxicity of the two rodenticides in fish is provided in Section 4.5.4. Information about above/below ground death rates was provided in the response to Concern 35.1.

FEIS Revisions Made: Revisions were added to Section 2.6: Anticoagulant rodenticides, Section 4.4: Consequences to Physical Resources, and 4.5: Consequences to Biological Resources.

Concern 3.7: What is the bait destruction plan, and how do you plan on collecting bait all over the island?

Representative Quote*:* 1. Friends of the Gull #221, The DEIS states that retrieving, moving, or crushing rodent bait so that it is inaccessible to gulls may be conducted to reduce the 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. The final EIS should include specific information about the bait destruction plan, including a timeline... Gull hazing should efforts should continue until all of the uneaten pellets have degraded and field documentation to this effect has been collected.

Response: Section 2.10.7.3 of the Revised DEIS made the following statement about 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 of the Revised DEIS). 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."

More specific information about rodenticide bait destruction and/or removal may be identified in an operational plan that will be developed following completion of the Final EIS and Record of Decision.

FEIS Revisions Made: Revisions were added to Section 2.10.7: Mitigation Measures to Protect Biological Resources.

Concern 3.8: California Department of Pesticide Regulations (Cal DPR) has stated that second generation anticoagulants persist in tissue for extended periods of time and can impact biological resources.

***Representative Quote**:* 1. No Name Given #499, Excerpts from attached document from the Cal DPR, herby submitted for the record… DPR finds that use of two of the four second generation anticoagulant rodenticides -brodifacoum and bromadiolone- present a hazard related to persistent residues in target animals resulting in impacts to nontarget wildlife.

Response: Second generation anticoagulant rodenticides can persist in biological tissues of target organisms for an extended period of time, anywhere from several weeks to many months. Potential impacts associated with predator or scavenger consumption of rodenticide-containing mice is provided in Sections 4.5.4 and 4.5.6., with brodifacoum risks to raptors specifically being discussed in Section 4.5.6.1.1.1 and risks to seabirds in Section 4.5.6.1.1.7. We have developed mitigation measures, described in Section 2.10.7, meant to reduce exposure of non-target organisms to rodenticides, including mice killed by exposure to rodenticides.

FEIS Revisions Made: Revisions were added to Sections 2.10.7: Mitigation measures to protect biological species, 4.5.4: Impacts of Action Alternatives on Biological Resources, and 4.5.6: Impact Indices.

Concern 4.1: Bait drift is going to happen and the EIS does not satisfactorily describe this fact or describe exactly how bait drift will be minimized.

***Representative Quote**:* 1. Environmental Protection Agency #551, The RDEIS identifies some mitigation to minimize the risk of incidental bait drift into the marine ecosystem (p. 71) but refers to them as adaptive management measures and states that more careful consideration would be required prior to implementing such measures during the eradication because they add complexity and risk to the proposed action. Courts have ruled that agencies should discuss mitigation measures, along with an assessment of whether they can be effective, in the EIS. In addition, CEQ makes clear in its guidance that mitigation commitments should be carefully specified in terms of measurable performance standards or expected results, so as to establish clear performance expectations. energy.gov/sites/prod/files/NEPA-CEQ_Mitigation_Monitoring_Guidance_14Jan2011.pdf

Response: The referenced text in Section 2.10.7.7 (Preventing bait drift into the marine environment) has been clarified. Both Alternatives B and C include a set of bait application protocols that would minimize the possibility of bait drift into the marine environment. These include mapping the island coastline prior to bait application, using established flight lines for bait application, setting bucket swath parameters, and establishing wind conditions in which to fly. In addition to these protocols, Section 2.10.7.7 discusses two additional measures that might be deployed depending on feasibility. These include reducing the bucket swath width even further and reducing helicopter flight speeds. Because the feasibility of these two measures is uncertain, they were not factored into the analysis of bait drift in the Environmental Consequences section. The set of required bait application measures were factored into the environmental consequences section in chapter 4, which concluded that there is a low risk of bait drift into the marine environment.

FEIS Revisions Made: Revisions were added to Sections 2.10.7.7: Preventing bait drift into the marine environment.

Concern 4.2: Rodenticides will contaminate the entire GFNMS including the fish, whales, pinnipeds, and sharks.

Representative Quote*:* 1. Tom Yarish #544/549, The repeated aerial broadcast or other application of the rodenticides poses a definite and quantifiable risk to many species of the protected marine sanctuary ecosystem public trust resources.

2. Skyler Thomas #476, The poison will remain on the island in one form or other for an extended period of time. Seeping into soil, ingestion from animals, etc. will affect the wildlife in ways and over a time period that are not properly addressed in this proposal. Stating that cetaceans, sharks, or any other water-based animal will not be affected because they will most likely be offshore is a speculative statement, not a scientific one.

3. No Name Given #517, The proposed plans are aerial dropping 1.3 metric tons of rodenticides on these rocky islands during the rainy season. Not only would this plan have adverse effects on nontarget species some of this poison will be washed into the ocean to be consumed by the food chain.

Response: Revisions to Chapter 4 of the Final EIS have been made to address the potential for exposure and effects in marine biota, including fish, crabs, intertidal species, and their habitats, in the vicinity of the South Farallon Islands.

FEIS Revisions Made: Revisions added in Section 4.4: Consequences to physical resources and 4.5: Consequences to Biological Resources.

Concern 4.3: Fisheries will be contaminated for a year, which could affect humans.

Representative Quote*:* 1. No Name Given #504, Not only do I believe that carpet bombing an island as sensitive biologically as this one with a potent animal killing poison is wrong, but I'm also extremely concerned about the runoff of this poison into the Greater Farallon National Marine Sanctuary. What about the damage known and unknown at this time to the intertidal organisms that get it first, then the fish and crabs that eventually make it to our plates.

Response: Impacts to the marine environment are described in Sections 4.4.1 (water), 4.5.6.1.4 (fish), 4.5.6.1.5 (invertebrates), and 4.5.6.1.2 (marine mammals). In addition, we have updated many sections of the FEIS regarding potential impacts of rodenticide exposure to intertidal species, fish, crabs, and other marine species. The majority of the literature suggests that contamination of the marine environment is not likely, especially considering the very low amounts of bait that may inadvertently end up in the marine environment and propensity of the bait to quickly break down in the marine environment. The weight of evidence suggests that human exposure to potentially harmful concentrations of rodenticide through consumption of marine biota collected in the vicinity of the South Farallon Islands following the operational period are not likely. Brodifacoum is not likely to accumulate to potentially harmful concentrations in edible portions of seafood; this chemical tends to accumulate primarily in liver tissue.

As stated in the response to comment theme code 4.2, we will consult with the National Marine Fisheries Service on potential impacts of the proposed action to species and/or Habitat Areas of Particular Concern.

FEIS Revisions Made: Revisions added to section 4.6.3: Fishing Resources and 4.5: Consequences to Biological Resources.

Concern 4.4: Bottom dwellers like crabs and halibut are at an increased risk of consuming rodenticide as sediment in the marine environment.

Representative Quote*:* 1. No Name Given #517, I am told by Wildlife Refuge Specialist, Jonathan Shore, that the toxic chemicals in the dissolving pellets drop to the ocean floor. This is where the bottom creatures like halibut and crabs. We eat these creatures.

2. Environmental Protection Agency #551, Impacts to crabs are unclear. The RDEIS states that impacts to intertidal invertebrates would be negligible (P. 176). It also discusses toxicity to land crabs, citing investigations that found that crabs readily consumed brodifacoum bait with no lethal effects, with other studies demonstrating that land crabs are not negatively affected by anticoagulant rodenticides, although crabs could be sources of secondary exposure (p137).

Response: Risks to the marine environment are described in Chapter 4, including water resources, fish, marine invertebrates, and other relevant biota. As described in the Operational Specifics (Section 2.10.5), all reasonable actions will be used during bait application operations to mitigate bait drift into the marine environment. Aerial broadcast of brodifacoum to Anacapa Island, which has similar topography in certain areas as the South Farallon Islands, in 2001 – 2002 did not result in any detectable contamination of the marine environment (Howald et al. 2009). Brodifacoum detection rates among marine fish and invertebrates, including crabs, have been low following rat eradication operations among other locations (Masuda et al. 2015). There are no land crabs occurring on the South Farallon Islands; crab species that occur on the South Farallon Islands include intertidal crabs, such as *Hemigrapsus nudus*, and bottom-dwelling crabs, such as dungeness crab (*Metacarcinus magister*). Due to the very low quantity of bait inadvertently reaching the marine environment and the propensity of the bait to quickly break down in the marine environment, it is unlikely that bottom-dwelling predators and scavengers, such as fish and crabs, will directly consume bait; therefore, accumulation of rodenticide residues could only occur through food-chain transfer. Given that the majority of the literature suggest that contamination of the nearshore and benthic marine environment is not likely (with the exception of findings at Palmyra Atoll, where application rates were approximately six times higher than proposed for the South Farallon Islands because land crabs readily ate bait on Palmyra), supporting data suggest risks to predatory fish and scavengers from consuming prey in the vicinity of the South Farallon Islands are negligible. In addition, second generation rodenticides are unlikely to be detected in edible portions of seafood because these chemicals tend to accumulate primarily in liver tissue.

FEIS Revisions Made: Revisions added to Sections 2.10.5: Operational Specifics and 4.5: Consequences to Biological Resources.

Concern 4.5: FWS and its contractors should put up a surety bond for any potential damages to the Greater Farallones National Marine Sanctuary.

Representative Quote*:* 1. Ocean Foundation #484, The RDEIS is inadequate since it fails to provide a failsafe mechanism for full financial reimbursement of local and regional public agencies, the State of California, and the Greater Farallon National Marine Sanctuary for any and all damages incurred in the conduct of the project. The FEIS must provide an analysis of how the FWS and any and all subcontractors to the agency would post a surety bond extending to the maximum credible cost of full damage recovery that could be anticipated in the event of a worst-case event during the project.

Response: Federal law, 31 U.S.C. Section 9302, prohibits federal agencies like the Service from purchasing surety bonds. Agencies of the federal government are self-insured for losses. If the Service engages a contractor to conduct the mouse eradication project, the Service will require the contractor to carry appropriate amounts and types of insurance coverage.

FEIS Revisions Made: None.

Concern 4.6: The bait deflector is proposed to be used, but evidence from the Palmyra Atoll Review suggests that the bait deflector should not be considered the ultimate mitigation tool.

Representative Quote*:* 1. Environmental Protection Agency #551, The RDEIS states several times that the bait deflector will minimize, and in several places, prevent bait drift into the marine environment (p. 120, 170, 171, 172, 200, 202). On Page 214 it states "bait drift into the marine environment - if it occurs..." The EIS should be clear that bait drift would occur. The RDEIS states that the use of the bait deflector and the trickle buckets have been shown to be effective at reducing the extent of bait drift into the marine environment during aerial broadcast (p. 71); however, the USDA Palmyra Report warned that "evidence on Palmyra Atoll suggest that use of the deflector during directional baiting should not be considered the ultimate mitigation tool for reducing the amount of bait directly entering into aquatic environments. for future operations, the potential for bait to enter the marine environment must be a factor in the aquatic risk assessment and further methods to minimize the amount of bait entering the marine environment should be fully explored.

Response The text of the FEIS has been clarified in all relevant places to indicate that drift of small amounts of bait-into the marine environment is likely. The risk of bait drift is considered to be low because both Alternatives B and C include a number of measures, in addition to a bait deflector, designed to minimize the chance and amount of bait entering the marine environment. See Section 2.10.5: Operational Specifics.

Regarding Palmyra Atoll, it should be noted that the atoll consists of an extensive reef, two shallow lagoons, and about 50 islets that are covered with vegetation, mostly coconut palms, Scaevola, and tall Pisonia trees. The coastline at Palmyra Atoll is highly obscured from the air by large coconut trees that line the coast around much of the atoll. Additionally, Palmyra has a highly irregular coastline, making it extremely difficult to aerially bait with complete accuracy. Furthermore, during the Palmyra operation, the satellite data was obscured which minimized the effectiveness of the mitigation measures and resulted in an excessive amount of bait entering the lagoons and surrounding marine environment.

In contrast, the Farallon Islands have a coastline with no visual obstructions that could impact the pilot's ability to successfully apply bait along the coastline while minimizing bait drift into the marine environment. In addition, hand baiting may be considered for limited, accessible portions of the shoreline with resources of particular concern and where the risk of using this alternative technique would not be considered a threat to the success of the eradication.

FEIS Revisions Made: None.

Concern 4.7: Water sample results for diphacinone should be added from Mokapu and Lehua.

Representative Quote*:* 1. Environmental Protection Agency #551, The discussion of water sampling results for diphacinone (Section 4.4.1.3 p. 121) cite the Mokapu and Lehua Islands as examples where no residues were found. It should be noted that the Mokapu example is more appropriate than the Lehua one because coastal treatments were greatly curtailed on Lehua."

Response: Information was added to Section 4.4.1.4 summarizing the toxicological results of water samples taken from Lehua and Mokapu Islands in Hawaii.

FEIS Revisions Made: Revisions were added to Section 4.4.1.4: Water Resources, Alternative C: broadcast of diphacinone.

Concern 4.8: The DEIS fails to address the emerging scientific data that indicates that climate change may affect the movement and levels of organochlorine pesticides and other chemicals, as well as the island species.

Representative Quote*:* 1. Sonce Devries #468, The climate change justification for doing the eradication at this time is very weak given that sea level rise is projected to cover all of the primary habitat for mice and the seabird burrows. If this is indeed the case, then no justification can be made for doing this eradication since the population at risk and the predators will be subsequently eliminated.

2. Ocean Foundation #484, The RDEIS is inadequate because it makes the specious claim that one of the primary rationalizations for pursuing the project is to create stronger resiliency in one certain wildlife population in the face of climate warming and climate-related changes to the ocean environment. But the DEIS fails completely in addressing the emerging scientific data indicating that a changing climate may affect the movement and levels of organochlorine pesticides and other chemicals in the environment and may weaken the ability of animals and humans to tolerate such pollutants.

Response: In Section 4.8.3 (page 220) of the Draft EIS, it was stated that "...projected sea level rise off northern and central California has the potential to significantly alter 37 island habitats and cause a redistribution of wildlife populations. Digital elevation models have demonstrated that a rise of 0.5 m would result in permanent flooding of 23,000 m^2 of habitat at the South Farallon Islands (Point Blue unpubl. data). This represents approximately five percent of the islands' surface area..."

Environmental variables altered by global climate change, such as temperature, pH, or salinity, can influence the disposition of chemicals in the environment, as well as interactions between chemicals and cellular targets. We also acknowledge that climate change has the potential to challenge how species cope with their external environment, affecting their movement patterns or even leaving them sensitive to particular variables, potentially including environmental contaminants. We state in our project goals that removing house mice will help "improve species and ecosystem adaptability and resilience in light of projected future climate change." We believe improved adaptability can be a product of removing house mice, believed to be a significant stressor, from the South Farallon Islands. Contaminants are just one of many persistent stressors of marine ecosystems. Like many marine pollutants, climate change-associated stressors have been persistent and will continue to persist into the foreseeable future. Considering these persistent stressors, we believe the proposed action presents an opportunity to alleviate a significant stressor (house mice) on the island ecosystem, potentially enhancing island flora and fauna resiliency to the impacts of other environmental threats.

FEIS Revisions Made: Revisions were added to Section 4.8.3 Cumulative Impacts: Current and ongoing actions.

Concern 4.9: Black abalone are not evaluated.

Representative Quote*:* 1. Ocean Foundation #484, The RDEIS is inadequate because it fails to consider the ESA-listing of the black abalone, and the fact that a Section 7 consultation will need to be conducted for the black abalone relative to the proposed project.

Response: The need for Section 7 consultations, including for the endangered black abalone, were discussed in Section 4.5.2.1 of the RDEIS. Other sections of the RDEIS, primarily Section 3.4.4.1 and Section 4.5, discuss the status of black abalone at the islands and potential impacts to black abalone from each alternative. Section 7 consultation would be completed for black abalone prior to implementation of an action alternative.

FEIS Revisions Made: Revisions were made to Sections 3.4.4.1, 4.5.2.1, and 4.5 to provide updated information on the status of black abalone at the islands, additional information on the species overall status and potential impacts to black abalone from action alternatives.

Concern 4.10: A robust and comprehensive incident response plan/contingency plan for any pesticide spills should be included prior to the issuance of any permit.

Representative Quote*:* 1. Ocean Foundation #484, Prior to consideration or issuance of any permit or approval for any part of this project, the FEIS must disclose a robust and comprehensive Incident Response Plan that addresses all emergency response contingencies, including incident chain of command, the regional USCG response capabilities for coping with and responding to three-dimensional maritime spills of toxic materials throughout the water column and including an inventory of spill response equipment available for sea-states that may occur during the project timeframe in the event of a worst case accident or a spill involving poisoned bait and/or fuel or other substance.

2. Environmental Protection Agency #551, Because of the complexity of this project and the difficulty in predicting ecosystem response, the project partners should develop requirements during planning and project implementation to anticipate and handle unexpected future events. This contingency planning should be part of the adaptive management plan and included in the FEIS.

Response: Developing full contingency plans was beyond the scope of this EIS. In Section 2.10.11 of the Final EIS, it is described the need for contingency plans and that the Service had begun preparing partial contingency plans to address the unlikely event of a bait spill or unexpected non-target impacts. Detailed contingency plans would be developed prior to an eradication as part of of a operational plan. Other contingency plans, such as to respond to a helicopter accident or fuel spill, would be developed as well.

FEIS Revisions Made: Section 2.10.11: Contingency plans, was added discussing contingency plans.

Concern 5.1: Why is this project necessary, particularly in light of the FWS decision not to list the ashy storm-petrel?

Representative Quote*:* 1. Wildcare #552, Wildcare also questions the necessity of such an extreme eradication plan. The USFWS declined to list the ashy storm-petrel as endangered. Their documents state there is no long-term decline in the species. This fact negates one of the primary reasons given by the USFWS for eradicating mice.

2. Pacific Islands Fish and Wildlife Service, The RDEIS also should reconcile with the Service's 12 Month Petition Finding for the ashy storm-petrel, which states: "We conclude that the population is currently experiencing fluctuations due to various factors, including avian predation. After assessing the best available scientific data, we have concluded that there is no consistent long-term trend in the species population nesting on SE Farallon Islands." Again, we suggest not focusing on petrel population decline, but on an expected improvement in petrel productivity from mouse eradication and reduction in owl predation.

Response: The purpose of this project is not tied solely to restoring storm-petrel populations. The purpose of the project, as set forth in Section 1.1.2, as described in the RDEIS, is to eradicate invasive house mice from the Farallon Islands National Wildlife Refuge in order to eliminate their negative impacts on the Farallon ecosystem. Increasing storm-petrel populations is but one goal of the project. Other project goals include increasing the productivity and abundance of salamanders, crickets and other invertebrates; increasing the abundance and recruitment of native vegetation; improving wilderness character; and restoring ecosystem processes altered by non-native mice.

Even though the Service declined to list ashy storm-petrels under the Endangered Species Act, actions to benefit this native species are still warranted. The Service recognizes that the ashy storm-petrel population on the Farallones does appear to have increased since the early 1990s. However, as discussed in Section 1.3.1 and in the accompanying report by Nur et al. (2013), elevated burrowing owl predation can result in reduced ashy storm-petrel population size. In the Service’s finding on the petition to list the ashy storm-petrel under the Endangered Species Act

(USFWS 2013a), the Service examined all available information on the species' population status and threats throughout its range. The Service concluded that there was insufficient information to indicate that the species was headed for extinction, and thus listing was not warranted at that time. However, in the petition finding and accompanying Species Report (USFWS 2013b), the Service reported that "Results from Nur et al. (2013, p. 18) show that reducing the burrowing owl population will likely benefit the ashy storm-petrel population on the island." Given the ashy storm-petrel is still a Service Bird Species of Conservation Concern and the South Farallon Islands hold about 50% of its population, actions that benefit the species are an appropriate management goal.

FEIS Revisions Made: Sections 1.1.3 Need Statement, 1.1.4 Purpose Statement, and 1.3 Benefits of house mouse eradication were revised to clarify that the purpose, need and benefits of the project are to eliminate the negative impacts of mice to the entire ecosystem of the South Farallon Islands.

Concern 5.2: Why does this project need to be implemented now? Why not wait until a non-toxic method is available? Use the Precautionary Principal.

***Representative Quote**:* 1. Jim Geraghty (Change.org signer), The unintended consequences of applying poison will have a disastrous effect on all other wildlife on the islands. Please do not let this happen. Institute the Precautionary Principle in this case and err on the side a safety and protection.

2. San Francisco Environment, The high uncertainty of success in protecting bird species of concern, the ashy storm-petrel, even if the mice were successfully removed. Predicting the success of rodent eradication projects is historically difficult. The fact that house mice on the Farallones have only an indirect impact on bird populations further clouds our ability to predict success, and casts doubt on the EIS assessment.

Response: As described in Chapter 1, Purpose of and Need for the Proposed Action, and Chapter 3, Affected Environment, the Farallon Islands host a unique and nationally important marine island ecosystem. From scientific information gathered at the Farallones and many islands globally, invasive rodents, including house mice, have many ecosystem impacts that alter those ecosystems. Best available scientific information tells us that house mice on the Farallon Islands are impacting native seabirds (especially the rare ashy storm-petrel), salamanders, invertebrates (including the endemic Farallon camel cricket), plants, and wilderness character. If the Service selected the No Action alternative, these impacts will remain and the Farallon ecosystem will continue to be degraded as long as house mice occur on the islands.

The Service does not believe that there is a high uncertainty of success associated with the project. As described in the RDEIS and FEIS, invasive rodents, including rats and mice, have been eradicated from over 500 islands worldwide. During that time, techniques have been refined to increase the likelihood of success while minimizing non-target risk. Such techniques and lessons-learned have guided the development of the action alternatives in the EIS.

The majority of rodent eradication projects conducted in recent years have been successful, with limited non-target impacts. Post-implementation studies and data from these projects have documented rapid recovery of many native island species following rodent eradications (See Section 2.5). The Service therefore believes that implementation of the project will result in beneficial, not adverse, long term impacts to island resources.

FEIS Revisions Made: Revisions were made in Sections 2.5: History of rodent eradications.

Concern 5.3: Shuford et al. 2008 discusses alternative methods to reduce the hazards that ashy storm-petrels are facing. Why not address these rather than mouse eradication?

Representative Quote*:* 1. Sonce Devries #468 2nd submission, You [Gerard McChesney] were third author on an article published in the Cal. Birds of Special Concern in 2008 (Shuford et al 2008). The article discusses the hazards affecting ashy storm-petrels and identified a list of projects that could be performed to benefit the entire population. No one of those potential alternative protection measures were ever discussed during the scoping phase.

Response: The goals of the mouse eradication are for ecosystem benefits, not just for ashy storm-petrels. The paper mentioned listed as one of its recommendations to "reduce Burrowing Owl predation on storm-petrels at the South Farallon Islands by eradicating non-native House Mice, as loss of the owl's primary prey should result in reduced owl populations on the island." As long-lived birds, threats to ashy storm-petrel adult survival is among the greatest threats to the species. Some of the other recommendations for ashy storm-petrels discussed in the reference cited are being implemented by the Service or others. These include installing artificial nesting habitat in the Channel Islands and using education campaigns and new regulations to reduce human disturbance at sea cave colonies. However, these actions have little or no benefit to the Farallon Islands population.

FEIS Revisions Made: Revisions were made in Sections 1.2.1: Background: introduced species on islands and 1.3: Benefits of house mouse eradication.

Concern 5.4: Nur et al. 2013 overstates the need for mouse eradication. Reconcile this paper with the FWS's 2013 Report on Ashy Storm-petrels.

Representative Quote*:* 1. Pacific Islands Fish and Wildlife Service, Reconcile the Report's discussion of petrel trends (Figure 1) with those in the RDEIS (Figure 2), including the Nur et al 2013 study's limitations and value of Figure 1.6 in the RDEIS. We suggest emphasizing the even if the petrel population is stable, there is an anticipated increase in petrel population. We also suggest including the Report's 20-year population trend graph (Figure 1) in the EIS.

Response: Newly updated work on the impact of Burrowing Owls on storm-petrel populations built on and strengthened the results of Nur et al (2013), showing clear links between increased burrowing owl abundance and impacts to ashy storm-petrel populations. The Service ESA petition finding assessed long-term linear trends only. The new ashy storm-petrel conservation plan highlights the need for Farallon mouse eradication as a key conservation action for the species. Regardless of current population status, reducing winter populations of burrowing owl on the Farallones will have positive impacts for the Farallon storm-petrel population.

FEIS Revisions Made: Revisions were made in Sections 1.1.4: Need statement and 1.3: Benefits of house mouse eradication.

Concern 5.5: There is no evidence that mice on the Farallones carry any potential harmful diseases and should not be considered a need for action.

Representative Quote*:* 1. Sonce Devries #468, No site-specific evidence is presented to support the threat of mouse-borne diseases to pinnipeds. If this is truly a concern, please provide a detailed explanation why testing for possible pinniped diseases was not performed at the same time as the testing for pesticide resistance.

Response: Since the likelihood of disease transfer from mice to pinnipeds is minimal and the mice on the Farallones aren't known to harbor any diseases at this time that are likely to negatively impact pinnipeds, the Service decided to remove that section from the FEIS.

FEIS Revisions Made: Revisions were made in Sections 1.1.4: Need statement, 1.2: Need for Action, and 1.3: Benefits of house mouse eradication.

Concern 5.6: What is the urgency? Mice have been on the Farallones for over 100 years.

Representative Quote*:* 1. Wildcare #552, Wildcare 's position is that more research into non-toxic alternatives needs to be done by the USFWS and that the urgency of implementation has been overstated; the mice have been on the islands for more than 100 years.

Response: Presidential Executive Order 13112 on Invasive Species (February 3, 1999), Section 2(a)(2), directs federal agencies, to the extent practicable and as permitted by law and budgetary constraints, to detect and respond rapidly to and control populations of invasive species in a cost-effective and environmentally sound manner and to provide for restoration of native species and habitat conditions in ecosystems that have been invaded. Similarly, Service policy supports efforts to restore degraded elements of integrity, diversity, and environmental health where feasible and consistent with refuge purposes, including management actions that restore ecosystem processes and functions (601 FW 3). Service policy further allows the use of chemical methods to remove invasive species as part of its Integrated Pest Management policy (569 FW 1). The eradication of non-native house mice from the Farallones is consistent with these policies. The Service has carefully and methodically developed the alternatives presented in the FEIS by taking into consideration applicable laws and policies, the best available science, lessons learned from other projects, and information gathered from public comments. Research into other rodent eradication methods is beyond the scope of this project. As described in Section 2.7 Alternatives Considered and Dismissed from Further Consideration, research into other methods is being explored, but their utility and ultimate approval for conservation purposes are as yet unknown.

FEIS Revisions Made: Revisions were made in Sections 1.2: Need for action and 1.3: Benefits of house mouse eradication.

Concern 6.1: How does the Service know that owls won't continue to consume storm-petrels and invertebrates? How do we know that salamanders, crickets, storm-petrels, and other species will benefit from mouse eradication?

***Representative Quote**:* 1. Eco Sign on Letter #546, The project's DEIS makes unsupported hypothetical assumptions that chemical eradication of the invasive mice on the Farallon Islands will discourage the relatively few migratory burrowing owls from returning, and in turn that will diminish predation by the owls on storm-petrels.

2. Ocean Foundation #484, ...the document instead attempts to rationalize the unnecessary killing of a lot of innocuous wildlife in the process of eradication of one species -the mice- but the document provides no conclusive evidence that the ashy storm-petrel will benefit over the long term from all of this collateral damage throughout the ecosystem.

Response: The ecology of burrowing owls visiting the Farallon Islands has been well studied and described in Section 1.2, Need for Action, of the FEIS. Those studies clearly showed a reliance on house mice from the time the owls arrive at the islands in the fall until the mouse population crashes in the winter, then a reliance on storm-petrels afterward until the owls' departure from the islands in the spring. Statistical modelling demonstrated that reductions in owl abundance of even 50% would benefit the ashy storm-petrel population (See Section 1.2.2.1 Impacts of mice of storm-petrels). Based on this information, the Service's professional judgement is that by eradicating house mice, both burrowing owl wintering populations and burrowing owl impacts on storm-petrels on the Farallon Islands will be dramatically reduced.

FEIS Revisions Made: Revisions were made in Sections 1.2: Need for action, 1.2.2.1: Impacts of mice on storm-petrels, and 1.3: Benefits of house mouse eradication.

Concerns 7.1: Sublethal effects need to be evaluated in more detail. NEPA uncertainty regulations are not satisfied. Including epigenetic impact assessment.

Representative Quote*:* 1. Sonce Devries #468, The DEIS states in the discussion on sublethal effects that the information is lacking, no assessment can be made, and directs the reviewer to 40 CFR 1502.22…This is a significant omission and renders this DEIS incomplete on this very important topic. As the literature makes clear, significant sublethal effects may be expected from the use of rodenticides and they may be serious enough to terminate proceeding with the proposal.

2. Maggie Sergio DEIS Public Meeting Comment, Epigenetics have not been evaluated in the DEIS which is a significant omission in determining the impacts associated with the project."

3. Pacific Islands Fish and Wildlife Service, Section 4.5.4.3.3 on Sublethal exposure (p. 139) is inadequate. The RDEIS cites Weldoln et al 2011 that sublethal adverse effects are unknown for brodifacoum and diphacinone. Our subject matter experts disagree with this assessment. In other Service documents (FWS 2012a, b) the Service has used a range of literature to assess sublethal effects. Please see the attached list of papers"

4. Oceans Foundation #484, the DEIS fails to consider the epigenetic effects of the poison in causing multigenerational mutagenic damage to species poisoned but not killed by the toxic materials used in the project.

5. Environmental Protection Agency #551, Review of this section of the CFR indicates that the following is required if the information is unobtainable: "(1) a statement that the information is incomplete or unavailable, (2) a reasonably foreseeable significant adverse impacts on the human environment, (3) summary of existing credible scientific evidence which is relevant to evaluating reasonably foreseeable significant adverse impacts on the human environment and (4) research methods generally accepted in the scientific community... It is evident that statement (1) has been complied with but the balance of the requirements have not been addressed despite the fact that a body of literature exists addressing the issues of sublethal effects from the use of rodenticides.

Response: The Council on Environmental Quality's regulation on Incomplete or Unavailable Information (40 CFR Section 1502.22), relates to situations where an agency has identified incomplete or unavailable information regarding a reasonably foreseeable significant adverse effect on the human environment. Based on the information and analysis in the FEIS, none of the described sublethal effects would rise to the level of significance under either action alternative. Nevertheless, the Service researched the topic of sublethal effects further and updated the section (4.5.4.3.5) on sublethal effects by providing an outline of the information that was missing from the literature, a statement of relevance, a summary of the existing data, and the Service's evaluation of the potential impacts based on the available data.

The Service was unable to locate any published literature or scientific evidence regarding adverse epigenetic impacts on wildlife from brodifacoum or diphacinone. The comment presents no evidence supporting the existence of such impacts, or reason to consider such impacts foreseeable, significant, or non-speculative. Furthermore, the proposed mitigation measures in the action alternatives, such as gull hazing, are designed to minimize non-target consumption of bait. The Service does not consider the risk of significant adverse epigenetic impacts from the proposed action to be reasonably foreseeable (see 40 CFR 1502.22 and 43 CFR 46.125).

FEIS Revisions Made: Revisions were made in Sections 4.5.4.3.5: Sublethal effects.

Concern 8.1: Provide an estimate of the number of gulls expected to die from eradication operations.

Representative Quote*:* 1. Pacific Islands Fish and Wildlife Service, The RDEIS should try to be more precise in its discussion of potential impacts to western gulls. While the Appendices do provide information on expected gull mortality, the RDEIS text itself does not include that key information. We suggest placing a numeric estimate of gull mortality into the RDEIS that uses the methodology in the alternatives.

2. Environmental Protection Agency #551, In the assessment of impacts to gulls, identify the differences in gull mortality expected under the two action alternatives under various conditions. Include this information in the body of the FEIS.

Response: Section 4.5.4.4.1 provides an impact assessment for gulls, including estimates of the numbers of gulls that would be at risk and the numbers that could be taken before having a population level impact. One primary goal of the Service's mitigation plan for this project is to minimize non-target impacts. Mitigation measures for gulls are designed to keep mortality of western gulls below 1,700 birds, the upper level identified that would not cause a significant population level impact.

An assessment of the risks to both brodifacoum and diphacinone exposure to western gulls is provided in Appendix F of the RDEIS and FEIS. A summary of the gull risk assessment is provided in Section 4.5.4.4.1 both the RDEIS and FEIS, and impacts assessments to gulls from each action alternative were provided in Sections 4.5.6.1 and 4.5.6.2 of the RDEIS and FEIS. As described, gulls are sensitive to both toxicants. Because of its greater potency, exposure to brodifacoum (Alternative B) poses a greater risk of toxicant exposure to gulls than diphacinone (Alternative C). However, Alternative C poses a greater risk of disturbance impacts because of the potential of Diphacinone-50 bait to degrade more slowly, increasing the period of time that gulls would need to be hazed from the islands. By utilizing appropriate mitigation measures, risks to western gulls can be dramatically reduced in both alternatives.

FEIS Revisions Made: None.

Concern 8.2: How will the Service keep gulls from dying in public tourist locations like Fisherman's Wharf. Prepare a communications plan and mainland monitoring plan to deal with events such as these.

***Representative Quote**:* 1. Pacific Islands Fish and Wildlife Service, We emphasize that it will be important to ensure that the project has an effective communications plan in place to prepare for off-site gull mortality. While the project is planning for extensive mitigation to reduce gull deaths, there is still the potential for several hundred gull deaths. Some of these would be likely to occur at mainland roosts or feeding areas. It would be prudent to have in place to deal with gull mortality at sites with high public visibility.

2. Environmental Protection Agency #551, ...we reiterate our previous recommendation to FWS that monitoring for nontarget carcasses be extended to mainland beaches, especially if brodifacoum is used.

3. San Francisco Environment, This project raises the specter of dead gulls (or other birds) washed up on City beaches or at tourist destinations such as Fisherman's Wharf. Such a scenario would not only create significant economic and aesthetic impacts; it is also very much contrary to SF's policies on natural resource protection and pesticide reduction, as manifested in legislation such as the Integrated Pest Management Ordinance (SF Environment Code, Ch 3).

Response: An intensive hazing program targeting gulls would be conducted on the islands during project implementation. It is expected that this hazing program will reduce the number of gulls exposed to rodenticide to low levels. However, we realize that some gulls will still be exposed to rodenticide bait and that sickened or dead birds could show up on mainland beaches or other areas. Because the eradication would take place on federal land, the project would be conducted following the Service's strict Integrated Pest Management policy (569 FW 1).

During project implementation, beached bird monitoring would be conducted utilizing the Greater Farallones National Marine Sanctuary's Beach Watch program (see Section 2.10.10.3 of the EIS). This monitoring would help identify if gulls sickened or killed by bait exposure are showing up on mainland beaches. As many gull carcasses as is feasible would be collected from survey beaches to reduce biological and social impacts as well as analyses of potential rodenticide exposure. Also, public notices will be posted about the eradication project and what the public should or should not do if they find sickened or dead birds or other wildlife.

It is highly unlikely that the number of sickened or dead gulls appearing on the mainland would cause significant economic or social impacts (see Sections 4.6.2 and 4.6.3 of the EIS). But, if an unusually large number of sickened or dead gulls were found to be occurring on the mainland during the eradication, a contingency plan would be followed to determine appropriate response action(s) to minimize social and economic impacts (see Section 2.10.11).

FEIS Revisions Made: Section 2.10.11: Contingency plans was added to the FEIS.

Concern 8.3: Where do the gulls go when they leave the Farallones?

Representative Quote*:* 1. Environmental Protection Agency #551, The RDEIS does not discuss where the gulls would likely go after they have been hazed from the islands for several weeks. Because of the close proximity of the Farallones to SF and open space coastal habitat in San Mateo and Marin Counties, we are concerned that the gulls could ingest a fatal dose of brodifacoum, die on the mainland and be a source of secondary wildlife poisoning to wildlife there.

Response: Sections 2.8.11: Bird mitigation trial and 3.4.2: Birds of the Farallon Islands of the FEIS has been updated to provide additional information about where gulls would most likely go after being hazed from the islands.

FEIS Revisions Made: Revisions have been added to Sections 2.8.11: Bird mitigation trial and 3.4.2: Birds of the Farallon Islands.

Concern 8.4: 1,700 gull deaths would be too many and would be considered significant.

Representative Quote*:* 1. San Francisco Environment, The REIS 'worst case' scenario predicts 1,700 dead Western gulls, a number that we consider unacceptably high - especially considering the low likelihood of success.

2. American Bird Conservancy #485, We are deeply concerned about the extent of potential incidental mortality of Western Gulls, both the level projected in the RDEIS and unanticipated levels that could even be higher. The optimistic 'worst case' of 75% hazing effectiveness could result in the cull of 1,700 gulls (Appendix F). How much incidental mortality of nontarget species is acceptable?

Response: The 1,700-gull mortality referred to in the RDEIS is not a predicted level of mortality in this project. However, modelling efforts described in the RDEIS and FEIS showed that it would take removing 1,700 western gulls from the Farallon population to have a a biologically significant impact. It is the Service's intention that hazing efforts will reduce western gull exposure to bait so that actual mortality is below the 1,700-significance threshold.

FEIS Revisions Made: Revisions have been added to Sections 4.2.3: Significance thresholds for the Farallon Islands, and 4.5: Consequences to Biological Resources.

Concern 8.5: Since gulls could potentially die on the mainland the public should be notified, signs should be placed at beaches, and beach surveys should be conducted.

***Representative Quote**:* 1. Environmental Protection Agency #551, Identify the potential locations and range where gulls could travel and provide notification to all segments of the public that could encounter dead gulls. Public notification should include information on the toxicity of rodenticides to dogs, which are more sensitive to rodenticides than many other species, and whom to contact if dead gulls are found during the project window. Detail how gull carcasses would be monitored on mainland beaches. Commit to active monitoring of mainland beaches during the entire implementation period when bait or mouse carcasses are available. Develop a plan for disposal of gull carcasses collected and assess impacts from this disposal, as appropriate.

Response: As described in the response to Comment Theme 8.2, a beached bird monitoring program would be conducted during project implementation utilizing the Greater Farallones National Marine Sanctuary's Beach Watch program (see Section 2.10.10.3 of the EIS). This monitoring will help identify if greater than baseline numbers of gulls (such as because they have been sickened or killed by bait exposure) appear on the mainland. Gulls found dead would be collected and disposed of following regulations for disposal of hazardous materials. A sample of gulls would be collected and available for testing for exposure to rodenticide, if the need arises. A detailed monitoring plan will be developed as part of the operational plan.

Public notices would be posted about the eradication project and what the public should or should not do if they find sickened or dead birds or other wildlife. These notices would include information about the risks to both humans and pets.

Additionally, Section 2.8.11 (Bird mitigation trials) of the FEIS has been updated to provide additional information about where gulls would most likely go after being hazed from the islands.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7: Mitigation measures to protect biological resources, 2.10.8: Minimizing impacts to wilderness, and 2.10.11: Contingency plans.

Concern 9.1: What will be the likely impact of hazing on mice?

***Representative Quote**:* 1. Environmental Protection Agency #551, "More importantly, the Gull Hazing Report, included in Appendix E in the RDEIS, does not address the possible effects of hazing on mice. The report does note, however, that bait remained in plots at close to the original application rate for the duration of the trial, suggesting that mice did not feed on it as might have been expected. More study appears to be needed on hazing effects.

Response: House mice are primarily nocturnal animals and due to their high metabolism, mice cannot survive more than a few days without eating. To impact their foraging behavior, a substantial amount disturbance from hazing would have to occur during their nocturnal foraging period. During the gull hazing trial, only minimal hazing was required at night because most gulls had already been hazed from the islands and no evidence was found that more gulls arrived during the night. Thus, hazing at night is expected to be minimal, and therefore impacts to mice from hazing is expected to be minimal. Further details on hazing efforts can be found in the hazing trial report, Appendix E.

FEIS Revisions Made: Revisions have been added to Section 4.5.5.3: Gull hazing.

Concern 9.2: How can the Service be certain that hazing will be effective for 2 or more months?

Representative Quote*:* 1. Environmental Protection Agency #551, We also are concerned with the potential impacts to gulls and the potential effectiveness of the proposed gull hazing operation, which appears rather optimistic. Failing to haze gulls effectively could lead to substantial gull mortalities, as occurred with glaucous-winged gulls in the 2008 Rat Island project, and the RDEIS acknowledges the potential for significant population level effects to occur for Western gulls.

2. Tom Yarish #544/549, Other mitigation measures such as harassing species to limit their exposure to the poisons and/or poisoned prey challenge the imagination and credibility to the point of appearing as absurd self-parodies and comic relief.

3. Sonce Devries #468, The projections of hazing success appear to be significantly overestimated given the well-documented literature and my own personal experience with how persistent most birds are in pursuit of food. Gulls in particular are extremely good at finding and quickly eating anything they can swell. This fact, coupled with the length of time required to complete the project, could rapidly result in a significantly reduced hazing efficacy.

Response: There are important differences between this project and the Rat Island project, and between hazing efforts for this project and hazing efforts conducted at sites like landfills. Hazing is difficult at locations like refuse management sites where there is a consistent, highly-visual, and recognizable long-term food resource available to gulls. Many gulls become habituated to food sources like garbage and meat scraps. Once habituated, hazing them from these sites is difficult. Gulls are not habituated to the type of cereal bait proposed for use under Alternatives B and C. Nor do gulls land on the Farallon Islands to feed; any feeding on the islands is opportunistic. Most previous studies of hazing have been conducted at sites like landfills and are therefore not predictive of hazing success for this project.

The results of the Farallon hazing trial demonstrated that relatively low-intensity hazing methods were effective throughout the trial period. While project implementation would require hazing for a longer period of time, the hazing program includes a number of different hazing methods and a fully staffed team to implement hazing operations. In addition, rodenticide bait application would not begin until all gulls have been effectively hazed from the islands. This will help to ensure that gulls do not have enough time to learn that they can eat bait before being hazed. This continuous hazing vigilance with robust staffing and supplies would continue on-site throughout the entire period bait is available on the ground and palatable to gulls. None of these efforts occurred during the 2008 Rat Island project and its associated gull mortality.

FEIS Revisions Made: Revisions have been added to Section 2.10.7: Mitigation measures to protect biological species, Gull hazing.

Concern 9.3: What is the likelihood that gulls will feed on bait under a full moon?

Representative Quote*:* None

Response: Gulls do not typically feed at night. Based on the hazing trial, effective daytime hazing results in an absence of gulls on the colony overnight. However, if gulls were to be found feeding on the islands at night, hazing efforts would be implemented.

FEIS Revisions Made: Revisions have been added to Section 2.10.7: Mitigation measures to protect biological species, Gull hazing.

Concern 9.4: What hazing strategies will be employed if weather conditions prevent planned activities?

Representative Quote*:* None

Response: Even in poor weather conditions during the gull hazing trial, hazing techniques were found to be successful. In particular, most bioacoustics and pyrotechnics were shown to be effective during poor weather. Although poor visibility, such as heavy fog conditions, would necessitate shoreline patrols to locate and haze groups of gulls, the Service will ensure that sufficient resources are on hand to address issues such as poor weather. Poor weather in the form of significant rainfall events would quickly degrade bait so that it is unavailable to gulls as a food source, thereby reducing the need for hazing activities.

FEIS Revisions Made: Revisions have been added to Section 2.10.7: Mitigation measures to protect biological species, Gull hazing.

Concern 9.5: What is the contingency plan if hazing is not working effectively? More study appears necessary to fully evaluate hazing effectiveness.

Representative Quote*:* 1. Environmental Protection Agency #551, More study appears to be needed on hazing effects. Proceeding with the hazing operations without additional information on this aspect of the project could jeopardize the eradication.

2. American Bird Conservancy #485, The possibility of higher than predicted mortality appears very real to us, opening up the potential for the Project to cause long-term harm to the most important breeding population of this species. How will the eradication operation respond to the possibility that hazing is not working, especially after pellets are on the ground?

3. Skyler Thomas #476, What if the flushing is unsuccessful and the gulls persist? Will the poisoning move forward regardless or be stopped? Unsuccessful flushing isn't even brought up into consideration.

Response: A robust hazing plan was developed and included in the FEIS, based on the results of an intensive gull hazing trial conducted on the South Farallon Islands (see Section 2.10.7.1 of the FEIS). Based on the gull hazing trial, the Service is confident that the hazing plan will be effective. In the event that the hazing is not as effective as planned, a contingency plan will be developed describing potential options and procedures for action (see Section 2.10.11 of the FEIS). One element that would be included in the contingency plan is that baiting would not commence until initial hazing had been shown to be effective.

FEIS Revisions Made: Revisions have been added to Section 2.10.7: Mitigation measures to protect biological species, Gull hazing and Section 2.10.11: Contingency plans was added.

Concern 9.6: The risks to pinnipeds from hazing are underestimated and should be minimized.

Representative Quote*:* 1. Bruce Watkins #543, The RDEIS has a lot of wishful thinking concerning the impacts of the hazing operations to the island's marine mammals. Do you really believe that an aggressive hazing operation that deters a large fraction of the island's birds will not have a significant impact on the islands' marine mammals?

2. Sonce Devries #468, The DEIS should provide a reference supporting the statement that helicopters and hazing activities will not constitute a Level A Harassment under the Marine Mammal Protection Act.

Response: Gull hazing operations have the potential for high levels of short-term disturbance to pinnipeds. No long-term impacts are anticipated. During the hazing trial, the overall impact of gull hazing activities on pinnipeds was low and short-term (see section 2.8.11 and Appendix E of FEIS). Numbers of pinnipeds present before and after the trial were similar to long-term average numbers for the same time period. Short-term impacts mainly resulted from the use of pyrotechnics, but effects varied by species. For harbor seals, about 25% of those in the hazing target area flushed. For California sea lions in target areas, about 15% moved more than one meter and 15% flushed. Other species showed less to no reaction from pyrotechnics. Other methods such as lasers and biosonics showed no real impact on pinnipeds. Given these results, the Service believes that pinniped disturbance from hazing activities can be kept to a relatively low level and that the chances of Level A harassment are highly unlikely.

As described in the EIS, pinnipeds will also be flushed during bait application. This potentially could result in nearly all pinnipeds being intentionally flushed from the island in preparation for bait application, in a slow and controlled fashion. This may be safer for these sensitive animals than less controlled disturbance that could occur during bait application. However, prior to finalizing an operational plan for an eradication, methods to minimize disturbance to pinnipeds would be worked out in consultation with the National Marine Fisheries as part of the application for a marine mammal incidental harassment authorization. The Service's intention is to avoid the possibility of Level A harassment.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.1: Mitigation measures to protect biological species, Gull hazing, 2.10.7.6: Reducing disturbance, 2.10.11: Contingency plans, and 4.5: Consequences to Biological Resources.

Concern 9.7: Funding for hazing must be available prior to implementation for an indefinite period.

Representative Quote: 1. Friends of the Gull #221, The recommendations of these reports {2012 Western Gull Risk Assessment} should be followed and the FEIS should include a description of a robust, well-planned, adaptively managed, adequately staffed and funded gull hazing program that will be implemented to ensure that all efforts will be taken to keep gulls from accessing bait during the eradication.

Response: As outlined in Section 2.10.7.1: Gull hazing, an intensive hazing program to reduce non-target risk to gulls would be part of the implementation plan. The Service would provide funds for a gull hazing program that would be adequately staffed to last the duration of time that bait could reasonably be expected to be available to gulls.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.1: Mitigation measures to protect biological species, and Gull hazing, 2.10.7.6: Reducing disturbance.

Concern 9.8: Ecosystem impacts to Farallon wildlife from hazing are not evaluated properly

Representative Quote: 1. Skylar Thomas #476, There is also a good chance that this operation will take longer than expected, thus displacing the animals for even longer time. Exactly how long can these animals be displaced without causing a significant impact? This is not provided in the document and shows a lack of planning or scientific research to support claims of low impact.

2. Oceans Foundation #484, The RDEIS is inadequate because it primarily relies on unproven reassurances by project proponents that hazing of nontarget species on the island …will be able

to reliably deter harmless species from consuming toxic bait, poisoned dead mice, or dead gulls that have consumed toxic mice. Recent scientific findings indicate that such hazing can, in itself, induce levels of stress in animals subjected to such activities sufficient to compromise their health and survival prospects over the long term. To ignore the downside of ecosystem impacts of hazing introduces an undue bias into the DEIS analysis in a skewed way that compromises many of the preparers' glib reassurances about 'harmlessly' mitigating the poison exposure of nontarget species through hazing.

Response: Results of the successful gull hazing trial and resultant gull hazing plan are described in Section 2.10.7.1 (Gull hazing) of the FEIS. Expected impacts to biological resources from action alternatives, including gull hazing, are described in Section 4.5 (Consequences to biological resources). No significant population impacts are expected from gull hazing. Project timing, during the fall when most wildlife populations are near annual minimums, as well as the relatively low levels of hazing expected to be needed for success contribute to keeping expected impacts low.

If in the highly unlikely chance that hazing were to continue into the seabird breeding season, which begins in late April, significant impacts to breeding birds would occur. For this to occur, palatable bait would still have to be available in quantities sufficient for uptake by a substantial number of birds, in addition to an extreme drought where no major rain event occurred between the time of implementation and the breeding season. In nearly 50 years of weather monitoring data for the Farallon Islands, this has never happened.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.1: Mitigation measures to protect biological species, Gull hazing and 2.10.11: Contingency plans.

Concern 9.9: How will you prevent gulls from feeding on steep slopes?

Representative Quote*:* 1. Sonce Devries #468, It will be impossible to prevent some number of gulls from foraging on the steep slopes where the intent is to deposit large quantities of bait to insure any mice in the area will be exposed.

Response: Long distance hazing methods like lasers, helicopters with bioacoustics, bioacoustics, and pyrotechnics can haze gulls in steep slope areas which may not be directly accessible. The amount of bait on the ground will have no effect on hazing techniques that will be used.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7: Mitigation measures to protect biological species, Gull hazing and 2.10.11: Contingency plans.

Concern 9.10: The hazing trial does not prove that hazing will work for an extended period of time. Extended hazing has not been substantiated in the literature.

Representative Quote*:* 1. American Bird Conservancy #485, It seems unlikely that the hazing will protect the gulls over that long period of time, especially given that each of the action alternatives call for hazing for merely two hours per day (p. 82). The risk assessment predications of 75 to 98% hazing success are not realistic.

2. Wildcare #552, The insufficient duration of the hazing trials on SEFI specifically cannot be considered an accurate portrayal of the success of the hazing program.

Response: To mitigate non-target mortality of gulls this project will employ robust hazing efforts. The hazing success values presented in the trial are based on published, peer reviewed results. These results showed that once birds had been successfully hazed, only approximately 2 hours per day were required to maintain high levels of hazing success. However, resources will be in place to ensure that should nearly constant hazing efforts be required over an extended period, they will be implemented. As discussed in Appendix E of the EIS, the hazing trial showed that after all hazing efforts ceased, it still took approximately 2 weeks for large numbers of gulls to return to the island. We believe this supports our assessment that successful hazing will be possible with the effort and resource levels we have proposed.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7: Mitigation measures to protect biological species, Gull hazing and 2.10.11: Contingency plans.

Concern 9.11: How many hazers will be needed for the operation? How many hazers will remain on the island until the island is safe for gulls and other species to return?

Representative Quote*:* 1. Environmental Protection Agency #551, The operational area for the project totals approx. 49 ha (p. 58). This vastly increased area containing bait would appear to require a much greater hazing effort. According the Gull Hazing Trial Report, between 10 and 12 people were employed each day to conduct all monitoring and hazing activities, and when gull numbers were greatest during morning and evening periods during the trial, a 'near constant effort was required to keep all birds off the island. The RDEIS states that for the actual project, a team of up to 10 personnel would deploy a range of hazing techniques (p. 68). It is not clear that this level of effort will be sufficient to avoid significant gull mortality, especially with the risk of habituation that could occur with a longer operation.

Response: The “near constant effort” of hazing described in the gull hazing report included a combination of both active manual, active mechanical and passive techniques. Passive techniques, such as with effigies, were left in place as long as needed. The number of staff needed varied depending on the number of locations requiring targeted active hazing and gull responses to hazing, with declining numbers needed later in the trial. Most of the time, hazing could be performed by a relatively small group of people by strategic staging and utilization of techniques that covered large areas. For example, in the low light conditions of dawn and dusk, only 2 persons using lasers could effectively haze gulls over most of the islands. Only a few more were typically needed for use of strategically placed biosonics or to fire flares. One to two personnel in a helicopter could then haze birds in other difficult to access areas. Once nearly all gulls had been hazed from the islands, only about two hours of active hazing were needed to haze the small numbers of gulls that would land on the islands. Therefore, 10 personnel would be sufficient to handle all of the hazing duties. If additional hazing personnel are needed, the Service would be prepared to add hazing staff and haze for as much time as is necessary to minimize the numbers of gulls consuming rodenticide bait.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.1: Mitigation measures to protect biological species, Gull hazing and 2.10.11: Contingency plans.

Concern 9.12: The FWS must disclose the uncertainties associated with gull hazing success in the EIS.

Representative Quote*:* 1. Environmental Protection Agency #551, We recommend that the FEIS disclose the limitations and uncertainties of applying the results of the trial to the actual project. FWS should discuss the likelihood of reaching a 90% hazing success during the actual project, which the project partners determined is needed if brodifacoum is used so as not to surpass the threshold of 1,700 dead gulls, over which significant population level effects to the Western gull could occur.

Response: Section 2.10.7.1 of the FEIS was revised to address and clarify uncertainties about gull hazing effectiveness. Also, we revised the goal of achieving "90% hazing success" to a goal of limiting gull numbers on the islands to more specific values.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.1: Mitigation measures to protect biological species, Gull hazing and 2.10.11: Contingency plans.

Concern 9.13: The Gull Hazing Report does not provide information regarding the habituation of gulls in the EIS.

Representative Quote*:* 1. Environmental Protection Agency #551, The report states that signs of habituation were noted, but the report does not provide any results of the observations. Regardless, the risk of habituation would tend to increase over time.

Response: As described in a draft manuscript Warzybok et al. (in prep), gull hazing effectiveness in the trial appeared to be greater than many other reported studies which showed that initial response to hazing may be great, but that habituation arises, quickly leading to a reduction in the effectiveness of scaring devices. However, these other studies were conducted at locations such as landfills where abundant food resources produced a high motivation for birds to return to the site. This "high feeding motivation" likely produces an incentive for gulls to continue to visit the site and adapt to hazing methods. This differs from most gulls visiting the Farallones in fall and early winter, when attendance at the islands is mainly to roost and not to feed. If gulls were visiting the islands to feed, hazing effectiveness may have been much lower. Likewise, if hazing were conducted during the breeding season, it may be more difficult to keep birds from attending breeding sites. Another key difference between this and other studies is the use of a large suite of hazing methods and frequently varying the stimuli. Two recent studies have demonstrated deterrence results more similar to those we observed. These studies were able to maintain a high level of deterrence, even in the presence of attractive food resources, for extended periods by using multiple scaring devices in conjunction with each other and combining the effects of visual and auditory stimuli. This approach, which is similar to the Service's, helps to reduce the bird's predictability of hazing treatments and prevent (or at least delay) habituation.

FEIS Revisions Made: Revisions have been added to Sections 2.8.11: Bird mitigation trial.

Concern 10.1: The risk to tourism did not take into account how gull mortalities from the operation in tourist areas will affect the tourism economy. This includes whale and shark tourism.

Representative Quote*:* 1. James Moskito #550, The RDEIS is inadequate because it fails to consider the economic impacts of dead or dying seabirds on the water in eyesight of our guests. Who would want to get into the water with dead seabirds floating by? We would be required to explain that the water is safe to our guests/cage divers.

2. Incredible Adventures, Inc. #549, Wildlife officials have failed to consider the impacts their proposed operations would have on the area's two shark diving companies. The poisoning of our area of operation, during peak shark viewing season, would be economically devastating.

Response: As described in the response to comment theme 8.2 and in Section 2.10.7.1 of the Final EIS, an intensive hazing program targeting gulls would be conducted on the islands during project implementation. It is expected that this hazing program would reduce the number of gulls exposed to rodenticide to low levels. However, the Service recognizes that some number of gulls would be exposed to rodenticide bait and that sickened or dead birds could show up in the waters around the islands. Sections 4.6.2 and 4.5.3 of the FEIS have been updated to provide additional information about the economic and social impacts of rodenticide use. Furthermore, as described in Section 2.10.7 (Mitigation measures), searches for and removal of bird carcasses on and immediately adjacent to the islands would be conducted during the implementation phase of the project. Furthermore, bird and pinniped die-offs, such as from starvation or biotoxin poisoning, occur regularly along the central California coast. When these die-offs occur, dead and dying individuals appear in many public places such as beaches, parks, and on the ocean. We are unaware of any significant negative socio-economic or social impacts from those die-offs (aside from related impacts to fisheries). For the reasons described above, less than significant socio-economic and social impacts are expected.

FEIS Revisions Made: Revisions have been added to Sections 1.5.3: Impact topics, social and economic environment, 2.10.7: Mitigation measures to protect biological species, 2.10.11: Contingency plans, 4.2.2: Impact topics, and 4.6.4: Impacts to social and economic resources.

Concern 10.2: The risk to fisheries has not been satisfactorily evaluated.

Representative Quote*:* 1. Dominque Richards, It also fails to highlight economic impacts to fishing activities (commercial as well as recreational) including reduced catch marketability due to possible reports on contaminated seafood.

2. Ocean Foundation #484, The RDEIS is inadequate because it fails to analyze economic impacts of the project to commercial and sport fishing activities including reduced marketability of catch because it ignores the high probability of adverse fiscal impact resulting from rumors about contaminated seafood, and because the DEIS does not provide any analysis of the economic costs associated with a 'worse case' accident involving discharge of one or more aerial delivery buckets of brodifacoum into the marine environment during transit to the islands.

Response: Several sections of the FEIS were revised to address this concern, with updates to Chapter 2 (Mitigation Measures and Monitoring), Chapter 3 (Intertidal and Nearshore Environment, Social and Cultural), and Chapter 4 (Impact topics, Fishing Resources). In addition, Section 2.10.11, which was added to the FEIS, discusses that a contingency plan for a bait spill would be developed prior to implementation of an eradication.

NEPA does not require that a worst-case scenario be analyzed. Rather, NEPA requires that reasonably expected scenarios be analyzed in the impacts assessments, which is what the Service has done.

FEIS Revisions Made: Revisions have been made to Sections 3.5.3, 3.5.4, 2.10.7, 2.10.11 (added), 4.2.2, and 4.6.3.

Concern 10.3: Shark diving and whale watching operations will be impacted and this impact has not been addressed sufficiently in the EIS.

Representative Quote*:* 1. Bruce Watkins #543, First the author states, "The economic impact to shark diving operations is expected to be minimal and every effort will be made to keep diving operations informed during the operation to minimize any economic impacts" Then follow up with "The significance determination is not significant." Considering the first statement the second statement should read, the impact on shark diving operations is unknown. Budget funds to pay shark diving operations for their loss of income.

2. James Moskito #550, Our estimate is that each guest will spend $2,000-$4,000 to come Great White shark diving with Great White Adventures to the Farallon Islands, as most of our guest fly to California. We will lose thousands of dollars each day if operations are canceled.

Response: A small number (usually 1-3) of operators conduct commercial white shark cage diving tours to the waters surrounding the South Farallon Islands each fall. Typically, shark tours operate from about September 20 to about November 20 each year. Poor weather and other factors lead to some trip cancellations each year. Based on observations from personnel stationed on Southeast Farallon Island, shark diving does not occur on a daily basis during this period. In the months of October to December in2014-2016 (potential bait application period for both action alternatives), there was an average of 18 (Range = 11-26) shark diving boat days recorded per season. For November-December of those years (most likely bait application period), there was an average of 11 (Range = 4-16) boat days per season (all in November; see Table 3.3 of the FEIS). In addition to shark cage diving, a small number of recreational whale watching/sightseeing boats visit the islands during the fall season as well, but these occur less frequently and usually on weekends when sea conditions are favorable.

As a safety precaution, the Service would seek to have a closure to all vessels within about 0.5 miles of the South Farallon Islands implemented during the days when aerial broadcast of bait would be conducted. Notices to potentially affected commercial operators and to the general public would be posted prior to the closures. Most shark cage diving operations are done within 0.5 miles of the islands. It would be expected that the number of closure days would be two to four days for Alternative B and three to six days for Alternative C, depending upon weather and other operational factors.

Boat closures could result in economic impacts to shark cage diving operations if closure days overlapped with days when shark diving trips would have occurred (i.e., were scheduled and not cancelled due to rough seas or other factors). No economic impacts are expected to whale watching/sightseeing boats because their operations do not require that they approach within 0.5 miles of the islands.

In the final EIS, Section 3.5.2 was updated to provide more information on commercial shark diving and whale watching/sightseeing tours. We also reanalyzed economic impacts to these commercial operations and have updated Section 4.6.2.

FEIS Revisions Made: Revisions have been added to Sections 3.5.2 4.2.2, and 4.6.2.

Concern 10.4: The EIS should include a multiplier for the cost of direct and indirect damage to the regional economy should a fishery be shut down.

Representative Quote*:* 1. Ocean Foundation #484, The RDEIS is inadequate in failing to provide a formula which a NRDA would ensure full compensation and reimbursement for any and all damages to the public trust… Such an analysis must be incorporated in the FEIS and must include the methodology of an appropriate NRDA valuation that would be utilized since multiplier values can be assigned to each individual specimen of various taxa under different valuation assumptions in any subsequent NRDA settlement.

Response: The suggestion that the EIS needs to address possible formulas that might be associated with a future NRDA (natural resource damage assessment) action is incorrect. As explained in Chapter 4 of the FEIS, the project has been designed to minimize the risk of bait release into the ocean and the risk of harm to non-target species. CEQ's NEPA regulations only require agencies to address effects that are reasonably foreseeable. 40 CFR Section 1508.8. Given the findings of the FEIS, it is speculative to assume that a NRDA action would be initiated by resource trustees.

FEIS Revisions Made: None.

Concern 10.5: A cost-benefit analysis should be done.

Representative Quote*:* 1. Ocean Foundation #484, Our detailed comments herein reflect the many inadequacies of the NEPA document, the flawed logic behind the project, and the failure of the preparers of the RDEIS to incorporate a reasonable cost-benefit analysis that considers the economic and ecosystem risks, including the unacceptable level of predictable collateral damage, balanced fairly with any hypothetical possible benefits this project may provide.

Response: The RDEIS and FEIS describe the benefits and risks to natural, social and economic resources from all three alternatives. However, the development of a cost-benefit analysis, as requested by the commenter, is not required under NEPA (40 CFR 1502.23) and no cost-benefit analysis was performed.

FEIS Revisions Made: None.

Concern 11.1: FWS will need to have the funds necessary for possible Natural Resource Damage Assessment prior to the implementation.

Representative Quote*:* 1. Ocean Foundation #484, The FEIS shall provide full legally binding assurances that no waiver, implied or express, of the longstanding GFNMS "Enter and Injure" regulations shall be construed in the event that the proposed rodenticide activity eventually secures approval by the DOI, nor should the granting of any related permit, if executed, be implied to represent any waiver of any fines that may be incurred under the Sanctuaries regulations, and any such permit approval by the DOI or GFNMS shall in no instance be misinterpreted to establish any precedent for any future proposed activities affecting GFNMS resources.

Response: The Service has discussed the proposed project with staff from the Greater Farallones National Marine Sanctuary (GFNMS) on several occasions. If the Service approves an action alternative in the Record of Decision, the Service will contact staff at the GFNMS regarding the terms of any required permits to conduct project operations within areas managed by the Sanctuary. The permit terms will be decided upon by the GFNMS in consultation with the Service. NEPA does not require that permit terms be included in an EIS. Rather, the CEQ's regulations (40 CFR 1505.3) envision that mitigation measures developed through the NEPA process and adopted in the Record of Decision be included, as appropriate, in any permits that are required for the project.

FEIS Revisions Made: None.

Concern 12.1: Bait application should not be adaptively managed to accurately assess the risk to the island resources.

***Representative Quote**:* 1. Environmental Protection Agency #551, The RDEIS states that application rates for Brodifacoum-25D Conservation would be determined during the development of the detailed operational plan and adaptively managed as necessary during the operation (p. 77). Because the application rates bear on the assessment of impacts, they should be identified. We are concerned with the proposal to adaptively manage application rates in the field. Once rates are established, they should be adhered to during the operation, and changes only made according to a clear protocol. While on the ground circumstances may warrant changes in bait application during the eradication, these changes must be within the limits of the operative labeling.

Response: As described in Section 2.11 (Features common to both action alternatives) and Section 2.10.2 (Adaptive management) of the FEIS, if either action alternative is selected for implementation the Service will confer with the USDA and Environmental Protection Agency on the potential need for a supplemental label and apply for a supplemental label if necessary. Bait would be applied according to the label or supplemental label (if applicable). The reference to adaptive management refers to the potential need to treat certain areas, such as steep cliffs with large 3-D surface areas, more than once in order to reach targeted application rates, or to make other adjustments because of weather, risk to non-target resources, or other factors. While the operational plan will cover most needed adjustments to site-specific application rates, some adjustments will likely be needed depending on conditions during implementation. Any such changes will remain within the parameters of the approved bait label.

FEIS Revisions Made: Revisions were made in Section 2.10.2: Adaptive management and 2.11: Features common to both action alternatives, 2.11.1: Brodifacoum bait application rate, and 2.11.2: Diphacinone bait application rate.

Concern 12.2: Supplemental label will be needed for both action alternatives.

***Representative Quote**:* 1. Environmental Protection Agency #551, The RDEIS notes that a supplemental label would be needed from Environmental Protection Agency for Alternative C but does not acknowledge that the proposed use of brodifacoum, as proposed in Alternative B, would also require a supplemental label to be in compliance with FIFRA.

Response: If either Alternative B or C is selected by the Service, a Supplemental Bait Label will be obtained. The Service will work with the USDA and Environmental Protection Agency prior to project implementation to determine the potential need for a supplemental label and to apply for a supplemental label (if needed). Sections 2.11, 2.11.2 and 2.12.2 of the FEIS has been revised to clarify that the Service would apply for a Supplemental Bait Label if necessary, for either action alternative.

FEIS Revisions Made: Revisions were made in Sections 2.11: Features common to both action alternatives, 2.11.1: Brodifacoum bait application rate, and 2.11.2: Diphacinone bait application rate.

Concern 12.3: How will the baiting strategy for this project differ from the Rat Island project?

***Representative Quote**:* 1. Environmental Protection Agency #551, The miscommunications and errors made during the Rat Island eradication, which the applicator IC upwardly adjusted bait application rates during the operation, should be avoided. Procedures should be developed to ensure that pesticide labels are not violated, and to avoid the type of on the fly decisions regarding bait application that resulted in pesticide label violations in the Rat Island eradication and may have increased nontarget mortality.

Response: The baiting strategy for the project will follow a carefully developed protocol as outlined in Sections 1.2.7 and 2.6.5 of the FEIS. If either action alternative is selected, the Service will work with USDA and the Environmental Protection Agency to obtain a Supplemental Bait Label, if necessary. The Service will ensure that all label directions are followed, including those related to baiting strategy and application rates. The Service will oversee the project at all times. The Service has closely studied the Rat Island eradication project, and the strategies and procedures described in this FEIS have been developed specifically to limit non-target mortality while maximizing the likelihood of eradication success. See Section 2.6.5 Lessons Learned for more detail.

FEIS Revisions Made: Three sections were added to the FEIS to address lessons learned, including Sections 1.2.7: General lessons learned 2.6.5: Operational lessons learned, and 4.5.1.1: Lessons learned from other rodent eradication.

Concern 12.4: Environmental Protection Agency recommends asking for approval to aerially bait over structures since only operational staff will be on the island during the operation.

***Representative Quote**:* 1. Environmental Protection Agency #551, Consider requesting a supplemental label that would allow broadcast baiting near structures occupied by humans.

Response: If an action alternative is selected, the Service will confer with the USDA and EPA during the development of an operational plan to finalize baiting strategies, including around structures. If it is determined that aerially baiting the area around structures is acceptable and the preferred method, then the Service will seek a supplemental label to allow this activity. Language to this effect has been added to Chapter 2 Section 2.10.5 (Operational specifications).

FEIS Revisions Made: Revisions made in Section 2.10.5: Operational Specifications.

Concern 12.5: Environmental Protection Agency suggests 2 to 4 meter spacing of bait stations.

Representative Quote*:* 1. Environmental Protection Agency #551. The RDEIS indicates that bait stations would be used in these areas but spacing bait stations at 20-meter intervals would not be sufficient and could easily miss some mice. Spacing units at intervals of 2-4 meters would be more appropriate.

Response: Comment Noted. Section 2.10.5.10 (Bait stations) has been updated to reflect the current bait label rates of 2-4 meter spacing for both Brodifacoum-25D and Diphacinone-50.

FEIS Revisions Made: Revisions made in Section 2.10.5.10: Operational Specifications, bait stations.

Concern 12.6: Develop detailed contingency plans for potential problems with the operation.

Representative Quote*:* 1. Environmental Protection Agency #551, "Because of the complexity of this project and the difficulty in predicting ecosystem response, the project partners should develop requirements during planning and project implementation to anticipate and handle unexpected future events. This contingency planning should be part of the adaptive management plan and included in the FEIS.

Response: CEQ regulations interpreting NEPA provide that an EIS must include a discussion of mitigation measures to address potential adverse consequences of an alternative, but there is no requirement that agencies formulate and include complete mitigation plans at the EIS stage (40 C.F.R. § 1502.14). Nonetheless, the Service recognizes the need for contingency plans that cover potential unexpected events that could lead to significant impacts. Section 2.10.11 was added to the FEIS to discuss contingency plans that would be developed.

FEIS Revisions Made: Section 2.10.11: Contingency plans, has been added to the FEIS.

Concern 12.7: Back baiting, adding additional bait applications, and flying steep slopes twice are inconsistent with the pesticide labels.

Representative Quote*:* 1. Environmental Protection Agency #551, For both rodenticides, the RDEIS is proposing the following uses that are inconsistent with the pesticide label and would require a supplemental label: (1) 3rd brodifacoum application at 8 lb/ac if bait from the previous application is severely degraded by rainfall (p. 77). The label allows 2 applications. (2) 3rd and 4th applications at 43 lb/ac of diphacinone... 43 lb/ac is approximately 3.5 times the label rate; it is not clear how this rate was established. (3) Back baiting in case of interrupted operations. (4) Flying steep areas a second time to increase the application rate in these areas during the application because "applying more bait to steeper areas is appropriate as these areas increase the islands' surface area." (p. 77).

Response: As described in the response to Concerns 12.1 to 12.5, the Service will work with EPA and USDA to determine the most appropriate baiting strategy for the project seek a supplemental label one of the action alternatives is selected for implementation and it is determined to be necessary. In addition, Alternative B has been modified to exclude the possibility of a third application of brodifacoum, and Alternative C has been modified to exclude the possibility of a fourth application of diphacinone and to revise the bait application to the current label rate.

FEIS Revisions Made: Revisions have been added to Section 2.10.5: Operational details.

Concern 12.8: Explain the proposed application rate for diphacinone. Why is it so high?

Representative Quote*:* 1. Environmental Protection Agency #551, The higher proposed application rate for diphacinone should be explained. The RDEIS states that a higher bait application would be required for diphacinone to ensure a longer period of bait availability (p. 49).

Response: In Section 2.12.2 (Diphacinone application rate), the base bait application rate for diphacinone has been revised to the rate on the current EPA label for Diphacinone-50 Conservation. For any deviations from this rate, such as for steep areas, a supplemental label would be obtained.

FEIS Revisions Made: Revisions have been added to Section 2.12.2: Diphacinone application rate.

Concern 12.9: How will bait and carcass removal be implemented over the entire island including steep slopes?

Representative Quote*:* 1. Sonce Devries #468, It is unclear how the removal of carcasses and uneaten bait will be accomplished on the very steep and unstable slopes of the targeted island, given the stated need to protect the health and safety of workers.

Response: Worker safety is of utmost importance. We realize that not all areas of the islands would be safely accessible for carcass and bait removal, assuming that both of those activities would be necessary as mitigation measures. However, large portions of the islands are accessible at least on a limited basis. Areas accessible for potential carcass and/or bait removal would be assessed as part of developing an operational plan and as needed during an implementation phase.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7.2: Carcass removal and 2.10.7.3: Manually reducing bait availability.

Concern 12.10: There is an increased risk of pinniped flushing from aerial bait application. The impacts will be greater than stated in the EIS.

Representative Quote*:* 1. Brooke McDonald #464, The DEIS states that before the bait is to be distributed by helicopter, pinnipeds should be herded slowly towards the water in a manner that discourages stampeding, but it does not recommend similar herding techniques prior to commencement of gull hazing or any other helicopter activities. I respectfully ask that mitigation be added to the FEIS to prevent stampeding of pinnipeds prior to daily gull hazing and prior to all helicopter.

Response: As described in Section 2.8.11 (Bird Mitigation trial) of the RDEIS and in response to Concern 9.6, disturbance to pinnipeds during the gull hazing trial was relatively low. Although some flushing did occur within targeted areas, mainly by California sea lions and harbor seals when pyrotechnics were used, no stampeding occurred. Disturbance to pinnipeds by the small piston engine helicopter used in the hazing trial was also observed to be low, even when the helicopter flew low over groups of sea lions. Thus, the Service does not believe that intentional flushing of pinnipeds will be necessary during most hazing or other activities besides bait application. It is the goal of the Service to minimize disturbance to pinnipeds during hazing, and intentional flushing may lead to greater levels of disturbance to pinnipeds. However, the Service may include some level of intentional flushing in its application for a marine mammal take permit for cases when it is considered best for the safety of certain animals.

FEIS Revisions Made: Revisions have been added to Sections 2.8.11: Bird mitigation trial and 4.5: Consequences to biological resources.

Concern 12.11: A detailed Structured Decision-Making Model should be developed for each contingency plan.

Representative Quote*:* 1. Environmental Protection Agency #551, For each contingency, develop a structured decision-making tool that addresses the application of bait other than as planned and that requires a written assessment …

Response: As discussed in the response to comment theme 12.6, NEPA does not require that full contingency plans be prepared at the EIS stage of project development. However, the Service recognizes the needs for certain contingency plans and added Section 2.10.11 to the FEIS to provide information on what contingency plans would be developed prior to an eradication operation and the basic information that would be included. Issues regarding the application of bait would be covered in the operational plan.

FEIS Revisions Made: Revisions have been added to Sections 2.10.11: Contingency plans.

Concern 13.1: Develop a monitoring plan for rodenticide residue, operational success, intertidal invertebrates, mitigation success, and water residue.

Representative Quote*:* 1. Brooke McDonald #464, I respectfully request that the Service develop specific and discreet goals for project mitigation, develop monitoring plans with the goal of determining the success or failure of each mitigation measure, and develop contingency plans in that event that project mitigation is not meeting expectations.

2. Environmental Protection Agency #551, A well-developed mitigation and monitoring plan should accompany the FEIS. The plan should discuss the adaptive management strategy, which identifies mitigation measures that would apply in the event that initial mitigation commitments are not implemented or effective.

3. Environmental Protection Agency #551, The proposed monitoring plan does not include monitoring for rodenticide residues, except for intertidal invertebrates and then only "if greater than negligible bait drift into the marine environmental is detected." It is not clear how this will be determined. The recommendations from USDA Palmyra Atoll Rodent Eradication Monitoring Report, Sept. 2012, states that future projects should include monitoring for toxicant residue in fish, insects, crabs, and other organisms for at least 90 days post broadcast, and noted that residues in nontarget organisms persisted 7 months after the first bait application. Thus, the risk of exposure to organisms may persist for many months post application.

Response: The Service consulted existing monitoring plans for previously implemented rodent eradication projects and worked with subject matter experts to develop monitoring plans for the South Farallon Islands project. Section 2.10.10 contains updated information about monitoring plans. Monitoring plans will be completed prior to any project implementation.

FEIS Revisions Made: Revisions have been added to Sections 2.10.10: Monitoring.

Concern 14.1: Develop a detailed mitigation plan that will provide more detail on the mitigation strategies, the effectiveness of the mitigation, and the impacts from mitigation.

Representative Quote*:* Environmental Protection Agency #551, FWS should discuss mitigation measures, as well as identify the party responsible for implementation. A well-developed mitigation and monitoring plan should accompany the FEIS. The plan should discuss the adaptive management strategy, which identifies mitigation measures that would apply in the event that initial mitigation commitments are not implemented or effective.

2. Brooke McDonald #464, I respectfully request that the Service develop specific and discreet goals for project mitigation, develop monitoring plans with the goal of determining the success or failure of each mitigation measure, and develop contingency plans in that event that project mitigation is not meeting expectations.

Response: While NEPA requires a detailed discussion of mitigation, it does not require the development of complete mitigation plans at the EIS stage. Sections 2.10.7 and 2.10.10 of the FEIS include detailed mitigation measures and monitoring protocols for the two action alternatives. The effectiveness of mitigation measures is discussed in Sections 2.11 (brodifacoum operational details) and 2.12 (diphacinone operational details). Section 2.10.7 (mitigation measures) of the FEIS also reflects updated information and changes to the implementation plans, including new data and contingency plans. Section 2.10.11 (Contingency plans) has been added to provide additional guidance to the Service for managing unexpected contingencies. The Service will be responsible for overseeing the implementation and monitoring of all mitigation measures for the project.

FEIS Revisions Made: Revisions have been added to Sections 2.10.2: Adaptive management and 2.10.7: Mitigation measures.

Concern 14.2: How will the mitigation strategy be different between the two action alternatives?

Representative Quote*:* 1. Environmental Protection Agency #551, In comparing the alternatives, the FEIS should clarify how the difference in toxicity of the two products affects the other comparisons. If reduced toxicity could translate it operational differences (e.g., reduced hazing effort or bird capture), these should be distinguished in the description of the alternatives.

Response: The Service will use the same mitigation strategies for both action alternatives. The mitigation strategy for reducing impacts to biological resources from each of the action alternatives is outlined in 2.10.7. The length and intensity of mitigation activities may be different, however, under the two alternatives. Bait may be available for longer under Alternative C than under Alternative B due to differences in bait degradation. As a result, gull hazing efforts could continue for a longer period of time under Alternative C as compared to Alternative B. Table 2.5 outlines the differences between the two alternatives in terms of how toxicity affects the number and timing of applications, the minimum necessary length of exposure, and the projected bait availability to gulls.

FEIS Revisions Made: Revisions have been added to Sections 2.10.7: Mitigation measures and 2.13: Comparative summary of action alternatives.

Concern 15.1: The risk model does not evaluate the proposed third drop of Brodifacoum-25D or the proposed fourth drop of Diphacinone-50.

Representative Quote*:* 1. Sonce Devries #468, The WGRA included in the Appendices to the DEIS does not reference the source of the model used nor present appropriate literature citations supporting its use and the conclusions drawn. Without this information the WGRA has no basis for presenting the conclusions described. In addition, the WGRA identifies serious data gaps which also seem to render this study of no scientific value.

2. Pacific Islands Fish and Wildlife Service, The RDEIS text discusses the need for up to 3 applications of brodifacoum as part of Alternative B (p. 76-78), yet the studies on effects of Western Gulls modeled only one or two applications - not three... The number of applications of rodenticide bait was identified in the RDEIS as an important determinant of potential gull mortality. Consequently, modeling a third application of brodifacoum is important, since it is part of the description of Alternative B.

Response: After further assessments, the third bait application of Brodifacoum-25D (Alternative B) and fourth application of Diphacinone-50 (Alternative C) proposed in the RDEIS were removed from consideration in the FEIS. The Western Gull Risk Assessment does not need to be adjusted as a result of these changes since the updated aerial application scenarios were evaluated already. Even so, the assessment provided the Service with adequate information to understand and compare the risks of using brodifacoum and diphacinone to eradicate house mice from the South Farallon Islands, as well as develop mitigation plans for their use.

Ecological risk assessment is a common approach of assessing the potential risks associated with toxicant exposure in wildlife. Furthermore, probabilistic risk assessment can be used to quantitatively evaluate relative risks of rodenticide exposure to western gulls and assist in determining what mitigation measures would be the most effective at reducing risk. In addition, the Western Gull Risk Assessment identified as part of a sensitivity analysis potential data gaps for which more information would be beneficial to reduce uncertainty in model results. Hazing effectiveness was identified as an important predictor of risk to western gulls, and because of this uncertainty the Service had a hazing efficacy trial conducted to better understand effectiveness of various western gull hazing techniques. Results of the successful gull hazing trial and resultant gull hazing plan can be found in Section 2.10.7.1.

FEIS Revisions Made: Revisions have been added to Sections 2.11: Brodifacoum operational specification, 2.12 Diphacinone operational specification, 4.5.4.4: Analysis of high-risk species, and 4.5 Consequences to biological resources.

Concern 15.2: The LD50 value and other parameters used in the gull risk assessment for brodifacoum underestimates the potential risk to gulls.

Representative Quote: 1. Environmental Protection Agency #551, The Administrative DEIS included information on the available LD50 data for the 2 rodenticides, noting that it is estimated that it will take approximately 18-24 brodifacoum bait pellets and approximately 1,550-2,004 diphacinone bait pellets to cause a lethal effect in most gulls.

2. Pacific Islands Fish and Wildlife Service, The results of the risk assessment for Western Gulls are skewed in favor of using brodifacoum by using inconsistent parameterization of risk models.

Response: As described in the response to Concern 15.1, the Western Gull Risk Assessment provides the Service with the information necessary to inform operational details, including appropriate mitigation strategies, particularly hazing approaches. The Service intends to use prudent measures to minimize impacts to non-target wildlife, including western gulls. Re-parameterizing the Western Gull Risk Assessment model would not change the mitigation strategies for action alternatives because some model parameters, such as western gull hazing efficacy and above/below ground rodent mortality rates, have been investigated further through field studies or additional literature reviews and appropriate revisions have been made to Section 4.5.4.4 of the Final EIS.

FEIS Revisions Made: Revisions have been added to Sections 4.5.4.4: Analysis of high-risk species.

Concern 16.1: The RDEIS states that diphacinone bait needs to be available for 10 days when the study indicates that 7 days are enough.

Representative Quote: 1. Pacific Islands Fish and Wildlife Service, The RDEIS (p. 41) contains a quote from Swift 1998 study that does not exist in the document. It states, "Swift 1998 found in a study of wild caught ship rats 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 0.0005 ppm diphacinone in bait stations." Swift's study was a serious of laboratory bioassays which actually found that an LD80 for black rats was reached with 7 days of exposure and an LD90 for Polynesian rats was reached after 6 days using bait with 50 ppm diphacinone. This study was designed to support the use of broadcast applications of diphacinone in Hawaiian ecosystems and determined the minimum exposure times and amounts needed to significantly reduce the levels of rats to protect native species.

Response: Sections 2.6.4 (Diphacinone) now contain corrected text reflecting the minimum exposure duration for black rats as determined in the Swift (2008) study.

FEIS Revisions Made: Revisions have been added to Sections 2.6.4: Diphacinone.

Concern 17.1: Brodifacoum is too dangerous and poses too great a risk to the non-target species and the marine environment.

***Representative Quote**:* 1. No Name Given #37, I recommend the Diphacinone option 3. Diphacinone requires multiple feeding by the invasive house mice, minimizing secondary poisoning to non-target animals.

2. No Name Given #482, I believe that the less toxic rodenticide should be used, to at least control the population. This is my view on this problem, however I have a question on how are you going to protect the water around the islands to not get infected? And what barrier are you going to use?

Response: Comments noted. Methods to mitigate for rodenticide entering the marine environment would be the same for either Alternative B or Alternative C and are described in Section 2.10.7.7 Preventing Bait Drift in the Marine Environment.

FEIS Revisions Made: None.

Concern 18.1: Comply with EPA, Cal DPR, SF Environmental Code Ch 3, and WHO regulations on the banishment of these rodenticides.

***Representative Quote**:* 1. San Francisco Environment, …It is very contrary to SF's policies on natural resources protection and pesticide reduction, as manifested in legislation such as the Integrated Pest Management Ordinance (SF Environment Code Ch. 3).

2. Ocean Foundation #484, The RDEIS is inadequate because it fails to acknowledge that both Brodifacoum and Diphacinone have justifiably been the focus of serious public policy controversy and increased regulatory scrutiny, and the DEIS fails to provide noticed that brodifacoum has raised concerns at both the Environmental Protection Agency and Cal DPR, due to the propensity for the compound to transport up the food chain and impact nontarget species to an unacceptable degree...The DEIS fails to disclose that the WHO states that "brodifacoum is toxic to aquatic wildlife." Who further cautions "avoid accidental contamination of water." www.who.int/whopes/quality/en/Brodifacoum.pdf.

Response: The Service understands the public concerns regarding the use of anticoagulant rodenticides and efforts to further limit the use of those products. However, as described in both the RDEIS and FEIS, evidence from hundreds of other rodent eradications using anticoagulant rodenticides showed that these products can be used safely and effectively. The products analyzed in Alternative B and Alternative C of the EIS are currently registered for conservation purposes by the U.S. EPA. We respectfully acknowledge the concerns and policies of the City of San Francisco. However, because this project would be conducted on federal property, the city's policies are not applicable. We also acknowledge the World Health Organization's cautions regarding the use of brodifacoum. While we are not required to cite this information in the EIS, available information on toxicity of both brodifacoum and diphacinone to aquatic/marine life has been provided. Also, the need to avoid all but accidental drift of small amounts of rodent bait, measures that will be taken to keep rodent bait from entering the marine environment, and analyses of expected impacts to at-risk marine life, have been clearly covered in the FEIS.

FEIS Revisions Made: None.

Concern 18.2: Rodenticide use violates the Migratory Bird Treaty Act.

Representative Quote*:*1. Sonce Devries #468, Overall this lack of adherence to both the letter and spirit of the MBTA is unsettling particularly when the USFWS routinely cites the MBTA to prevent unnecessary take of migratory birds. The apparent selective application of the MBTA depending on the goals and desires of the USFWS is unacceptable.

Response: Section 4.5.2.3 of the RDEIS provides an explanation of the special considerations for MBTA-listed species and the Special Purpose Permit process. That section described that the Service will comply fully with all MBTA requirements prior to implementation of either Alternative B or Alternative C. However, recent changes to the MBTA (Department of the Interior Solicitor's Opinion M-37050 and FWS Guidance Memo, April 11, 2018) have removed the requirement to obtain to obtain a permit for unintentional take of migratory birds. Thus, Section 4.5.2.3 was removed from the FEIS. As described in Section 1.6.1 of the FEIS, an MBTA permit would be required for the intentional hazing, capture and holding of migratory birds, as proposed in the action alternatives.

FEIS Revisions Made: Section 1.6.1 was revised, and Section 4.5.2.3 was removed.

Concern 19.1: Consider or evaluate more alternatives. Be more innovative when developing alternatives.

Representative Quote*:* 1. Wildcare #552, 49 options were listed and 42 of those involved poisons - 14 different types dispersed three different ways. New technologies in rodent control are emerging and it is extremely disappointing that in the Bay Area, one of the most progressive places in the world and home to some of the most creative thinkers in the country, the best plan USFWS can come up with is just do what it has done in the past.

2. Environmental Group Letter #546, We encourage the USFWS to find a more targeted and environmentally benign single-species approach at the Farallones, one less dependent on persistent food-chain poisons that have a known record of killing animals that are not part of the problem.

Response: The Service evaluated 49 different alternatives through a Structured Decision-Making process, and two alternatives were chosen based on their operational efficacy and potential to minimize impacts to non-target species with specialized mitigation tools. Alternatives involving non-toxic methods of eradicating mice were evaluated in the Structured Decision-Making process but were found to be incapable of meeting the goals of the project for a variety of reasons, including lack of efficacy, risks to human health and safety, and tool availability for eradication purposes. For a full description of the alternatives considered, the process used to choose alternatives for full analysis in the EIS, and the rationale for dismissing other alternatives, see Sections 2.2 (Alternatives Selection Process), 2.7 (Dismissed alternatives), 2.9 (No action alternative) and 2.10 (Features common to both action alternatives).

FEIS Revisions Made: Revisions were made in Section 2.7: Alternatives considered and dismissed.

Concern 20.1: Supporting reports are insufficient for ashy storm-petrels.

Representative Quote*:* 1. Jamie Ray, More research is needed in this field to find out if the cause of the ashy storm-petrel population stagnation or decline, due to low hatch rate, is a result of consuming fish containing high levels of microplastics.

Response: Ashy storm-petrels, like other related species, are relatively long-lived birds. Annual adult survival is relatively high while annual reproductive success is relatively low. Although reproductive success of ashy storm-petrels monitored on the South Farallon Islands has declined since the 1970-80s, their reproductive success is still within typical values of similar species and there is no evidence that depressed reproductive success caused the recent documented declines of the Farallon population. As described in the EIS appendix (Appendix XX), changes in adult survival rates (same as reductions from predation) have a greater impact on population trends than changes in reproductive success. The modelling effort conducted clearly showed that high levels of owl predation have caused reductions in the Farallon ashy storm-petrel population. Like many other closely related species, ashy storm-petrels likely ingest plastic debris while foraging. However, no published information on the impacts to ashy storm-petrels from plastic ingestion is available and research on this topic was beyond the scope of this project.

FEIS Revisions Made: None.

Concern 20.2: Supporting reports are insufficient for western gulls.

Representative Quote*:* 1. Friends of the Gull #221, The PVA of the Western Gull concluded that population trends for the Farallon Western Gulls will depend on the reoccurrence of years with especially low reproductive success .... If the near-failure in breeding is a continuing trend, the updated analysis should evaluate that trend. The updated analysis should also evaluate the possibility of low reproductive success occurring at a frequency higher than the recent observations (3 out of 12 years).

Response: The Western Gull population viability analysis (PVA) was made available as Appendix N in the RDEIS. In the PVA, population trajectories were modelled based on three scenarios of projected breeding success: "Optimistic" (years of high breeding failure not re-occurring); "Realistic" (years of high breeding failure occurring at low, historic frequency); and "Pessimistic" (years of high breeding failure occurring at the elevated frequency observed in 2009-2011). Based on long-term data, potential changes to the population trajectory from a mortality event, such as from a mouse eradication project, was then modelled using the Realistic model only. The authors of the report have conducted additional models of impacts of an elevated mortality event based on the Optimistic and Pessimistic scenarios. Results, as well as additional description of the methods used in the PVA, have been provided in the FEIS as an Addendum to Appendix N. In 2012-2017, the years following those used in the PVA, western gull reproductive success on Southeast Farallon Island was near the long-term average in 5 out of 6 years and well below the long-term average in one year. Thus, the Service believes that the Realistic scenario is still most appropriate for the western gull impact assessment for the FEIS.

FEIS Revisions Made: Revisions were made in Sections 1.2.2: House mouse impacts on the ecosystem of the South Farallon Islands, 2.8: Pre-eradication studies, and 4.5.4.4: Analysis of high-risk species.

Concern 21.1: It is unlikely that either alternative will eradicate mice from the Farallon Islands.

Representative Quote*:* 1. Jamie Ray Bison Connect, It is unlikely that the proposed action will eradicate all of the mice, given the rocky crevice topography of the islands, despite the vast quantity of poison proposed to be dropped.

2. San Francisco Environment, The poor chances of success in eradicating the mouse population. The bar for success is very high indeed in eradication projects. Literally every individual mouse must be killed. Otherwise, repeat treatments would be required, and these treatments would likely need to be extended indefinitely.

3. Wildcare Petition, The aerial broadcasting of toxic rodenticide pellets over the entire landmass of the Farallon Islands does not fit these criteria and should not even be considered in the eradication proposal. I strongly encourage you to implement other, more environmentally sensitive alternatives.

Response: On all but the very smallest of islets, the only technique that has been used successfully to remove rodents from islands has been the application of bait containing a rodenticide. As described in Section 2.5 of the FEIS, of the 944 documented rodent eradications attempted by 2015, 87 targeted house mice and 61 were successful. Eradication success rates have improved over time, and between the years of 2005 and 2015, 28 of the 30 mouse eradication attempts undertaken have been confirmed as successful. Factors associated with rodent eradication failure were reviewed by Holmes et al. (2015), and the Service considered this information as part of planning for the Farallones project. All but one of the successful mouse eradications that used a rodenticide used brodifacoum or another closely related second-generation anticoagulant. A summary of house mouse eradication attempts utilizing rodenticides with documented results and methods is provided in Table 2.2. Based on thorough analysis and consultation with rodent eradication experts, the Service believes that Alternative B provides a high likelihood at successfully eradicating house mice from the South Farallon Islands and impacts to non-target organisms can be reduced through effective implementation of mitigation measures. See Section 2.10.7 of the FEIS.

FEIS Revisions Made: Revisions were made in Sections 2.5: History of rodent eradications and 2.6: Anticoagulant rodenticides

Concern 22.1: Cumulative impacts are not evaluated properly.

Representative Quote*:* 1. Ocean Foundation #484, The revised DEIS is inadequate because it fails to evaluate and provide suggested mitigations for the cumulative impacts of multiple applications of toxic materials during any one season, and/or during subsequent seasons, in the likely eventuality that future follow-up poison applications are necessary due to incomplete mouse population eradication during the first effort. The DEIS also fails to consider the cumulative impacts of the aerial poison application in combination with bait stations and the other proposed ongoing biosecurity measures, including the potential for continued annual poison applications, that apparently would need to become a routine lasting USFWS wildlife management tool on the islands.

Response: The Service is not proposing to undertake subsequent eradication efforts in the event that the proposed eradication project fails. The action alternatives propose a limited number of bait applications (2 for Alternative B and 3 for Alternative C) along with the use of bait stations and hand baiting in areas where aerial application would not be effective. The impacts (including cumulative) of these bait applications are analyzed in Chapter 4 of the FEIS, along with mitigation measures to reduce the effects of bait use on the human environment. If an action alternative is implemented and mice are eradicated, the revised biosecurity plan would allow for the limited and targeted use of rodenticide if and when a future rodent reintroduction occurs. However, it is strongly believed that the need to respond to future rodent incursions would be rare events, likely with many years in-between, not annually. The biosecurity plan is included as Appendix B of the FEIS.

FEIS Revisions Made: Revisions were made in Sections 4.8: Cumulative impacts.

Concern 23.1: The DEIS fails to describe the physical impacts of the different toxicants on target and non-target species.

***Representative Quote**:* 1. Ocean Foundation #484, The RDEIS fails to disclose the inherently inhumane method of killing embodied by both the Brodifacoum and Diphacinone-50 rodenticides…The FEIS must address a comprehensive evaluation of the inherently inhumane aspect of the protracted suffering resulting from these broad-spectrum poisons and their multi-generational epigenetic effects on various species that will almost certainly come into contact with them.

Response: Section 2.6 (Anticoagulant rodenticides) of the FEIS has been updated with more detailed information about the mechanism of action of anticoagulant rodenticides and their potential signs of toxicity. On the issue of epigenetics, see Concern 7.2.

FEIS Revisions Made: Revisions were made in Sections 2.6: Anticoagulant rodenticides.

Concern 24.1: The DEIS does not provide acceptable mortality numbers based on the description of the 2 alternatives.

***Representative Quote**:* 1. Ocean Foundation #484, The RDEIS fails disclose and justify what the proponents of the project consider their assessment of an 'acceptable' threshold of incidental mortality for all species to be potentially directly or indirectly affected by the poison, and further, the DEIS fails to consider the epigenetic effects of the poison in causing multigenerational mutagenic damage to species poisoned but not killed by the toxic materials used in the project.

Response: In Section 4.2.3 (Significance thresholds) and Section 4.5.2 (Assessing significance to biological resources) of the Final EIS, the Service identified the significance threshold for each species as the "long-term negative or positive impacts in the abundance or distribution of a species at the population level." Changes at both the local and species' range level were analyzed for assessing whether the proposed action would cause significant impacts. The action alternatives were designed to avoid significant adverse impacts, and the analysis in the Final EIS indicates that no such effects would occur to native species under either action alternative. While the Service anticipates non-target mortality in several species as discussed in the Final EIS, these anticipated losses remain within acceptable limits.

FEIS Revisions Made: Revisions were made in Section 4.2.3: Significance thresholds, Section 4.5.2: Assessing significance to biological resources, and 4.5: Consequences to biological resources.

Concern 25.1: The DEIS does not describe the methods that will be used to capture and hold sensitive species.

***Representative Quote**:* 1. Brooke McDonald #464, I respectfully ask that language be added to the FEIS describing proposed capture methods for raptors and common ravens, and that particular effort be made to capture ravens before the start of the project. I further ask that resident common ravens not be released on the mainland after holding, but that they be returned to the islands.

2. Environmental Protection Agency #551, Inconsistent disturbance risk is identified for birds that would be captured. The RDEIS identifies high disturbance risk for burrowing owls that would be captured (p. 154) but does not identify this risk for other raptors that the RDEIS indicates world be captured and held to reduce rodenticide exposure.

Response: Section 2.10.7.4 (Bird capture and hold) has been updated with additional information about bird capture as part of project implementation. The methods used for bird capture will depend on a variety of factors including the species and numbers of birds present on the island, locations of roost sites, available capture tools, and migratory bird permit requirements. Species considered to have a high probability of returning to the islands, such as peregrine falcons and possibly burrowing owls, would likely be held in an approved captive facility until exposure risk is considered to be negligible. Species considered to have a low probability of returning to the islands would likely be released on the mainland following protocols developed as part of the operational plan. At the time of the writing of the RDEIS, a pair of common ravens had been present on the Farallones on and off for a few years, but they no longer occur on the islands.

Section 4.5 (Consequences to biological resources) of the RDEIS evaluated the disturbance impacts from capture, transport, and captive holding of peregrine falcons, burrowing owls and common ravens, stating that these species would experience high disturbance sensitivity if captured, transported, and held during operations. The EIS has been updated to reflect disturbance sensitivity for all species that may be captured during operations.

FEIS Revisions Made: Revisions were made in Section 2.10.7.4: Bird capture and hold, and 4.5: Consequences to biological resources.

Concern 26.1: Operational impacts to nesting birds was not evaluated properly.

***Representative Quote**:* 1. Sonce Devries #468, There is little attention given to the impacts of the eradication operation on both the nesting storm-petrels and the presence of other burrowing seabirds. Again, this implies a complete lack of concern given to potential secondary impacts even when they could negatively impact the very burrowing seabird populations this eradication program is supposed to protect.

Response: Potential impacts to Cassin's auklets, ashy storm-petrels and Leach's storm-petrels were assessed in Section 4.5 of the RDEIS. Upon further review, those sections were revised in the FEIS, including removing suggestion of the possibility of secondary exposure to toxicant from prey sources because the possibility is negligible, to provide further clarification of what bird activity would be expected during the implementation phase, to clarify measures that would reduce potential impacts from disturbance, and to revise the numbers of birds of each species expected to occur on the islands during the implementation of each alternative.

FEIS Revisions Made: Revisions were made in Section 4.5: Consequences to biological resources.

Concern 27.1: The RDEIS does not evaluate the tradeoffs between each alternative objectively.

Representative Quote*:* 1. American Bird Conservancy #485, The variable valuation of these species {under the MBTA} by the refuge is evident, but not articulated well in the RDEIS. For clarity and consistency, an objective summary comparing the tradeoffs of the alternatives for each of the migratory bird species likely to be affected by this project should be provided in the EIS.

Response: Chapter 3 of the FEIS presents information regarding the status of the many species of migratory birds that nest on or visit the Farallon Islands. Chapter 4 of the FEIS evaluates and discloses the varying impacts that would occur to these different species of migratory birds under each alternative. Tables 4.2 and 4.3 provide overviews of the disturbance and toxicant risks for each species that was evaluated in the action alternatives. As is evident from the analysis in Chapter 4, all of the alternatives including the No Action alternative involve differing degrees of impacts on birds. Given the large number of birds included in assessments, comparing and contrasting alternatives for each species was beyond the scope of this EIS. However, comparisons can be gleaned from impacts assessments fairly easily. For example, under the No Action alternative, there would be ongoing adverse impacts to ashy storm-petrels as described in Section 4.5.3.2.1. Under Alternatives B and C, ashy storm-petrels would experience significant beneficial impacts, but there would be greater adverse impacts to gulls and certain other bird species than under the No Action alternative (see Sections 4.5.4.4; 4.5.6.1.1 and 4.5.6.2.1 as well as Tables 4.2 and 4.3). Among action alternatives, potential impacts of toxicant exposure would be greater for Alternative B than Alternative C, but potential impacts from disturbance would be greater for Alternative C than Alternative B. Furthermore, the Service has developed an extensive suite of mitigation measures to reduce the impacts of Alternatives 2 and 3 to a level that is less than significant levels. The Record of Decision (ROD) (40 CFR 1505.2) will describe the Services determination for selecting one alternative over the other.

FEIS Revisions Made: Revisions were made in Section 4.5: Consequences to biological resources.

Concern 28.1: Diphacinone is not properly evaluated or portrayed in the RDEIS. The Service was biased against diphacinone.

***Representative Quote**:* 1. American Bird Conservancy #485, The dose rates proposed in the RDEIS for diphacinone are 3 to 4 times the allowable label application rates. Moreover, the Risk Assessment used an LD-50 for diphacinone that was the lowest for any bird species, even though the LD50 for most non-raptors is between 2000 and 3150 mg/kg (Erickson and Urban 2004. Rattner et al. 2010, EPA RED 1998).

Response: Section 2.12.2 (Diphacinone bait application rate) of RDEIS states: "However, the proposed application rate [for diphacinone] exceeds 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." In the F EIS, the Service chose to adhere to the aerial application rate specified in the current label for Diphacinone-50 Conservation formulation.

The avian LD50 value for diphacinone used in the Western Gull Risk Assessment is the lowest published LD50 value for any bird species and was derived using acceptable acute toxicity test methods with American kestrels. Using the lowest published avian LD50 value in a risk assessment, like the one developed for western gulls, provides for more protection of all island avian species rather than using LD50 values for standard avian test species, like mallard (3,158 mg/kg) and northern bowhite (2,014 mg/kg). In other words, the most sensitive avian species are least 20 to 30 times more sensitive to diphacinone exposure, using lethality as an endpoint, than bobwhite or mallards.

FEIS Revisions Made: Revisions were made in Revisions made to Sections 2.6: Anticoagulant rodenticides, 2.12: Diphacinone operational specifications, 4.5: Consequences to biological resources, and 4.8: Cumulative impacts.

Concern 29.1: The number of mice expected to die below ground is not consistent between the alternatives.

***Representative Quote**:* 1. American Bird Conservancy #485, In addition, the predicted availability of dead mice in the diphacinone model is 100%, all dying above ground, while the brodifacoum model suggest that only 13% will remain above ground…lower than IC's own data showing a 40% rate for rats."

Response: Sick, injured, or dying wildlife often retreat to areas of shelter, including dense vegetation or burrows, where they can hide from predators. A review of mostly gray literature found the percentage of rats dying underground after brodifacoum exposure ranged from 87 to

100% (Taylor 1993, Howald 1997, Buckelew et al. 2008). For eradications where diphacinone was used, all of the data are from Hawaii in forested situations, which may not be relevant to the South Farallon Islands. In those studies, the percentage of poisoned rats found below-ground varied widely from 20 to 95% (Lindsey and Mosher 1994; Spurr et al. 2003 (2 studies); Spurr et al. 2015). Based on reports mentioned above, predicted availability of dead mice used in the western gull risk assessment appear to be consistent with available data.

The Western Gull Risk Assessment assumed that 87% of mice exposed to brodifacoum on the South Farallon Islands would retreat to burrows to die as an estimate of the proportion of the mouse population available for consumption by gulls or other predators. This percentage is the lowest reported underground death percentage for rats exposed to brodifacoum in an eradication scenario. There are no comparable data for mice. For the diphacinone exposure scenario in the risk assessment, the above-ground mouse mortality rate used in the model was 100% (a worst-case scenario) because no data on the topic could be identified prior to public comment. The Western Gull Risk Assessment has not been re-parameterized since the Revised Draft EIS was released to the public because above-ground mouse mortality estimates appear to be either 1) consistent with available data (for brodifacoum) or 2) more conservative than what is likely to be observed in an actual house mouse eradication event on the South Farallon Islands (for diphacinone). However, the Service realizes that above ground mortality of mice exposed to diphacinone likely will be considerably greater than 0%. Regardless, the mitigation plans developed for both action alternatives would consider the potential for both high and low percentages of above ground mortality.

FEIS Revisions Made: Revisions were made in Revisions made to Sections 2.6: Anticoagulant rodenticides, 2.11: Brodifacoum specifications, 2.12: Diphacinone operational specifics, and 4.5: Consequences to biological resources.

Concern 30.1: The flying time for hazing under Alternative B is not correct.

Representative Quote*:* 1. Environmental Protection Agency #551, Clarify/correct Table 2.5 (p. 82) which states that flight time required for hazing for Alternative B is 5 weeks; elsewhere the RDEIS states that 60 days would be required.

Response: Table 2.5 in Section 2.13 has been updated to reflect the correct estimated flying times for both alternatives.

FEIS Revisions Made: Revisions were made to Section 2.13: Comparative summary of actions by alternative.

Concern 31.1: EPA suggests that the Service should invest in researching less toxic eradication techniques.

Representative Quote*:* 1. Environmental Protection Agency #551, We encourage FWS to take a leadership role and invest in research on less-toxic eradication methods for future eradication projects.

Response: This comment suggests that the Service invest resources in researching less toxic methods of rodent eradication for use in future eradication projects. Future eradication projects are beyond the scope of this EIS. The Service is aware of ongoing research into new methods for eradicating non-native rodents. Should such measures become available, they could be considered as options in any future eradication projects proposed by the Service.

FEIS Revisions Made: None.

Concern 32.1: EPA stated that the Service needs to confer with Cal DPR prior to bait application - Get Pesticide Applicator Certification.

Representative Quote*:* 1. Environmental Protection Agency #551, Please note that this certification {applicator pesticide certification} must be in the appropriate category and FWS must confer with Cal DPR for this determination.

Response: The Service has conferred with the California Department of Pesticide Regulation (CDPR). Because the project would be conducted on federal property, CDPR informed the Service that the only state requirement would be that the applicator must obtain a California Certified Applicator License. An applicator license will be obtained if an action alternative is selected.

FEIS Revisions Made: No revisions were made to the FEIS.

Concern 33.1: Update Section 2.5 to include most recent eradications that used the compounds in question.

Representative Quote*:* 1. Environmental Protection Agency #551, The discussion of history of rodent eradication in Section 2.5 should be updated to include results of more recent eradication efforts, especially those involving house mice and/or either of the products under consideration in Alternatives B and C...

Response: Section 2.5 (History of rodent eradications) has been updated to reflect documented eradication projects that have been implemented since the RDEIS was released in December 2013.

FEIS Revisions Made: Revisions made in Section 2.5: History of rodent eradication.

Concern 33.2: Why classify anticoagulants as first and second generation?

***Representative Quote**:* 1. Environmental Protection Agency #551, In the discussion of anticoagulant rodenticides in Section 2.6 (p39), we recommend indicating the basis for classifying anticoagulants as being 'first generation' or 'second generation' and explaining why having a delay between time of ingestion and onset of symptoms is especially useful to eradication efforts.

Response: The classification of rodenticides into 'first generation' or 'second generation' is common terminology in the discipline of toxicology and throughout the literature on the subject matter. Examples of first-generation rodenticides include warfarin, chlorophacinone, and diphacinone, and they require multiple feeds to cause death in rodents; their use resulted in the emergence of genetic resistance in rats and house mice. Examples of second-generation rodenticides, also known as "superwarfarins", include brodifacoum, difethialone, bromadiolone, and difenacoum, and were developed to overcome resistance by rats and mice. These points have been clarified in Section 2.6 (Anticoagulant rodenticides) of the Final EIS.

FEIS Revisions Made: Revisions made in Section 2.6: Anticoagulant rodenticides.

Concern 33.3: Page 44 error. Compound 1080 is no longer registered as a rodent control agent, but it is available for other purposes.

***Representative Quote**:* 1. Environmental Protection Agency #551, There is an error on page 44 regarding the use of toxicants other than diphacinone or brodifacoum (Section 2.7.1). The second sentence erroneously states that Compound 1080 is "not registered with EPA for any purpose." This substance no longer is registered as a rodent control agent. There are valid US registration for use of Sodium Fluoroacetate in Livestock Protection Collars to kill coyotes that prey on sheep and goats.

Response: Comment noted. Section 2.7.1 has been updated accordingly.

FEIS Revisions Made: Revisions made in Section 2.7: Alternatives considered and dismissed from further consideration.

Concern 33.4: Page 48. Bait Palatability and Preference trials. Pyranine is incorrectly called a biomarker.

***Representative Quote**:* 1. Environmental Protection Agency #551, The discussion of 'Bait Palatability and Preference Trials" on page 48 correctly identifies the substance pyranine as fluorescent dye, but it should not be identified as a biomarker, as it is not systemic and is not likely to show up in secondary consumers.

Response: The term biomarker is defined by the National Academy of Sciences as a xenobiotically induced alteration in cellular or biochemical components or processes, structures, or functions that is measurable in a biological system or sample. Biomarkers can be broadly categorized as markers of exposure, effect, or susceptibility. Pyranine is a chemical tracer that can be detected in animal excreta. Pyranine is properly described as a chemical tracer in Section 2.6 (Anticoagulant rodenticides) of the Final EIS.

FEIS Revisions Made: Revisions made in Section 2.6: Anticoagulant rodenticides.

Concern 33.5: Page 58 Bait Application Rate. Clarify that registrant of product must make all requests for a modification to the bait label.

Representative Quote*:* 1. Environmental Protection Agency #551, The discussion of "Bait Application Rate" on p. 58 should make it clear that the registrant of the candidate products must be the party that would have to request any modifications to current acceptable labeling.

Response: The USDA is the registrant for the bait products of both action alternatives, and they must approve and apply for any Supplemental Bait Labels the Service may request. This information has been included in the FEIS in Section 2.10.5.4 (Bait application rate).

FEIS Revisions Made: Revisions made in Section 2.10.5.4: Bait application rate.

Concern 34.1: Discuss bird capture results from Anacapa, Rabida, Bartolome islands, and Palmyra Atoll.

Representative Quote*:* 1. Environmental Protection Agency #551, Discuss bird capture results from Anacapa, and Rabida and Bartolome islands in the Galapagos as well as from Palmyra. Indicate the percentage of birds captured in each case, and any mortalities that occurred among captive birds and known mortalities of their conspefics that were not captured. Consider this information when projecting success of this mitigation measure on the Farallones, comparing and contrasting project and island conditions in order to disclose, and apply to the proposed project, and most relevant lessons learned.

Response: Information from available literature has been added to Section 2.10.7.4 on bird capture, holding, and release from the Anacapa Island, Palmyra Atoll, and Pinzon Island (Galapagos Islands) rat eradications, which reported high success rates. Publications or reports could not be obtained for the Rabida and Bartolome islands projects.

FEIS Revisions Made: Revisions made in Section 2.10.7.4: Bird capture and hold.

Concern 35.1: Explicitly identify Best Management Practices from the U.S. Fish and Wildlife Service - Alaska for rodent eradications.

Representative Quote*:* 1. Environmental Protection Agency #551, Identify the best management practices established by the USFWS in Alaska and discuss them in relation to the project. All project mitigation and best management practices should be explicitly identified in the FEIS, with commitments to their implementation included in FWS's Record of Decision.

Response: Sections 1.5.2 (Lessons learned) and 2.6.5 (Operational lessons learned) have been updated to include discussion of lessons learned from previous eradication projects, including the Rat Island project in Alaska. This section reviews and incorporates as appropriate the Best Management Practices developed by the Fish and Wildlife Service in Alaska. If an eradication alternative is selected, the Record of Decision will identify applicable mitigation measures, and the Service will ensure that those measures are complied with during project implementation.

FEIS Revisions Made: Revisions made in Sections 1.5.2: Lessons learned and 2.6.5: Operational lessons learned.

Concern 36.1: Significance can be short-term or long-term. The EIS needs to reevaluate its classification of significance.

Representative Quote: 1. Environmental Protection Agency #551, The CEQ regulations clearly state that, in assessing the context of an impact when determining significance, 'both short and long-term effects are relevant' (40 CFR 1508.27(a)). The CEQ regulations do state that the impact discussion will include "the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity."

Response: FWS policy 601 FW3 "calls for refuge managers to maintain biological integrity, diversity, and environmental health at the appropriate landscape scale for each element. Biological integrity, diversity, and environmental health can be described at various landscape scales from refuge to ecosystem, national, and international. Individual refuges contribute to biological integrity, diversity, and environmental health at larger landscape scales, especially when they support populations and habitats that have been lost at an ecosystem, national, or even international level. In pursuit of refuge purposes, individual refuges may at times compromise elements of biological integrity, diversity, and environmental health at the refuge scale in support of those components at larger landscape scales." Consistent with Service policy, the Service has determined that it is appropriate to address significance at the regional or global population level for the majority of species on the South Farallon Islands because 1) the refuge plays an important role in sustaining regional and global populations of certain species and 2) for many species, individuals occurring on the islands are migratory and thus are part of larger regional or global populations. The Service has determined that short-term impacts to individuals of these species would not constitute significant impacts. Species listed under the Endangered Species Act or Marine Mammal Protection Act were evaluated for significant short-term impacts as described in Section 4.5.2 and in accordance to their specific regulatory requirements. The potential for short-term impacts is also recognized and described where appropriate for all other categories of resources. Finally, the FEIS discusses the relationship between short-term uses of the environment and long term productivity.

FEIS Revisions Made: Revisions made in Sections 4.2.3: Significance thresholds for the Farallon Islands and 4.5.2: Assessing significance to biological resources.

Concern 36.2: What is the risk if the project is not successful after implementation?

Representative Quote*:* 1. Environmental Protection Agency #551, The impact assessment should also include an analysis of risks should the eradication not be successful.

Response: Assessments of potential impacts assuming eradication failure is beyond the scope of this EIS. If an action alternative is chosen for implementation, the Service assumes that the eradication will be successful. However, if a house mouse eradication attempt is unsuccessful at eliminating mice from the islands, impacts of invasive mice to the Farallon Islands ecosystem would continue (see impacts from Alternative A). Depending on the action alternative implemented, short-term impacts associated with eradication operations would be the same as those described in the in FEIS.

FEIS Revisions Made: None.

Concern 37.1: Impacts to salamanders were not properly evaluated.

Representative Quote*:* 1. Environmental Protection Agency #551, Impacts to Farallon arboreal salamanders are predicted to not be significant (p. 203) despite a medium toxicant risk from brodifacoum and available secondary pathways from consuming invertebrates who have consumed toxicant (p. 139).

2. Environmental Protection Agency #551, Considering these factors and the uncertainty regarding toxicity, it is not clear that the statements that impacts would be not significant (p. 203) or that no unavoidable adverse impacts to amphibians are anticipated (p. 214-215) are sufficiently supported.

Response: Section 2.8.12 (Salamander toxicity study) of the Final EIS includes a summary of findings from an investigation of the acute toxicity of anticoagulant rodenticides (Brodifacoum-25D Conservation and Diphacinone-50 Conservation) to Plethodontid salamanders. In general, results from the study support the assessment that impacts to Farallon arboreal salamanders from the application of rodenticide will not be significant.

FEIS Revisions Made: Section 2.8.12: Salamander toxicity study was added to the FEIS, and Section 4.5: Consequences to biological resources was updated to reflect the most up to date information.

Concern 38.1: Do gulls or other species on the Farallon Islands eat mice? How will mouse removal impact their dietary needs?

***Representative Quote**:* 1. Environmental Protection Agency #551, The RDEIS states that gulls could be exposed to rodenticide through secondary uptake from consuming carcasses, including mice (p. 140), which implies that gulls consume mice. The RDEIS does not discuss what portion of gull's diets consists of house mice, and what food items would likely replace this component of their diet if mice are eliminated.

Response: Western Gulls are omnivores and eat a variety of things including fish, marine invertebrates, human refuse, eggs, carrion, and other birds (adults and young). Mice likely comprise an extremely small proportion of the Farallon western gull diet. Gulls are primarily diurnal feeders, whereas mice are most active at night. Furthermore, island mouse populations are at their lowest when gulls return to breed on the island, and at their peak when the gull population is lowest. Removing this introduced species should little effect on gulls' diets.

FEIS Revisions Made: None.

Concern 39.1: Set up funding assistance to treat birds that have been impacted by secondary poisoning or sublethal impacts from rodenticide.

***Representative Quote**:* 1. Environmental Protection Agency #551, As recommended in our scoping comments and comments on the Administrative DEIS, we suggest that FWS consider, as a potential mitigation measure, provide funding assistance to organizations that treat secondary rodenticide poisoning of birds.

Response: Supplies of anticoagulant antidote, Vitamin K, will be on hand during the implementation phase of the eradication until it is determined that the risk from rodenticide exposure has declined to negligible. A veterinarian will be on the island or on call to respond as necessary to apply antidote, care or euthanasia of captured wildlife that were exposed to rodenticide. In outreach materials, the public will be provided instructions on what they should do if they find any wildlife potentially exposed to rodenticides on the mainland. If funds are available, the Service may consider collaborating with interested wildlife rehabilitation organizations to care for wildlife impacted as a result of the Farallon mouse eradication project.

FEIS Revisions Made: Revisions were added to Section 2.10.7: Mitigation measures for biological resources.

Concern 40.1: It does not appear that sufficient planning and consideration occurred to anticipate outcomes other than the optimistic ones predicted in the DEIS.

***Representative Quote**:* 1. Environmental Protection Agency #551, The premise of the project and the accurate assessment of impacts rely on predictions as to how several aspects of the ecosystem would respond to the elimination of mice. Even in cases of direct impact by rodents, predicting treatment effects has proven difficult and has resulted in more nontarget mortality than expected. The complexity and uncertainties of the proposed project must be considered in assessing the significance of the impacts of the eradication effort, with the level of planning and needed forethought commensurate with the levels of uncertainty and risk. It does not appear that sufficient planning and consideration has occurred to anticipate outcomes other than the optimistic ones predicted in the DEIS.

Response: The RDEIS and FEIS were developed based on years of data related to the species and conditions present on the Farallon Islands, relevant peer-reviewed literature, and an extensive review of prior rodent eradication projects and the lessons learned from those projects. Also, the Service engaged in a number of trials specifically for this project. For example, the Service conducted a bait trial, a gull hazing trial, and salamander toxicity trial. All of these trials can be found summarized in Chapter 2 and in full in the Appendices of the FEIS. Furthermore, a detailed, independent analysis was conducted to assess non-target risk to western gulls from each of the action alternatives. The results of these studies have informed the development of the alternatives, the types of mitigation measures that are incorporated into each alternative, and the associated monitoring protocols. In the FEIS, it is also described that the Service will develop contingency plans in preparation for unexpected events that could jeopardize non-target resources or the success of the project. The Service does not agree that there has been insufficient planning and consideration or that that the projected impacts are overly optimistic.

FEIS Revisions Made: Revisions were made in Section 4.5: Consequences to biological resources.

Appendix Q:

Salamander Toxicity Study

Final Report, QA-2688:

An assessment of the potential hazards of anticoagulant rodenticides to Plethodontid salamanders

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A Report to:

U. S. Fish and Wildlife Service, Farallon Islands National Wildlife Refuge, Fremont, California through Interagency Agreement No. F16PG00129

Final Report
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Suggested Citation and Abstract

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The USDA/APHIS National Wildlife Research Center conducted an assessment of the hazards of the anticoagulants diphacinone and brodifacoum to salamanders of the family Plethodontidae or lungless salamanders. This was done in anticipation of an attempt to eradicate the invasive house mouse (*Mus musculus*) from the Farallon Islands National Wildlife Refuge, California where the endemic subspecies Farallon arboreal salamander (*Aneides lugubris farallonensis*) occurs. Live-captured salamanders of three species (*Aneides lugubris*, *Ensatina eschscholzii xanthoptica*, and *Batrachoseps attenuatus*) were exposed to each of the anticoagulant rodenticides by both oral and dermal exposure routes. Each trial had an exposure period of ten days, followed by a ten day post-exposure period with no rodenticide exposure. There were some deaths (9 of 37 treated salamanders; 24.3% mortality). By species this was 25% of the *Aneides*, 0% of the *Ensatina*, and 75% of the *Batrachoseps* treated salamanders. It appeared that dermal exposure posed the greatest hazard; however, it is important to note that the level of dermal exposure used in this trial was much higher than what would be expected in a rodent eradication project. In essence, this was a worst-case scenario. We did not note the sub-lethal effects of weight loss or reduced food (cricket) consumption that has been observed in studies of other taxa. Skin sloughing and sores on the undersides of certain salamanders exposed to rodenticide as well as some controls left it unclear whether or not this affect was caused by the anti-coagulant. However, for salamanders in the exposure groups, it appeared that skin sloughing and sores began to recede during the post-exposure period, suggesting that some animals began to recover after rodenticide exposure. Following trial completion, samples of salamanders were analyzed for rodenticide residues. Residue concentrations were very low (in parts per billion) when compared with results from some other studies (parts per million). We concluded that while anticoagulant rodenticide pose some hazards (both lethal and sub-lethal) to salamanders, the level appears to be relatively low, especially given the very high exposure rates applied in this study compared to the exposure they would encounter in an aerial broadcast of rodenticide baits in an invasive rodent eradication project.

Introduction

House mice (*Mus musculus*) cause many types of damage and when introduced to islands, house mice can cause significant damage to natural resources, including both flora and fauna (Witmer and Jojola 2007, Howald et al. 2015). For example, on Gough Island in the South Atlantic, house mice fed on nestling albatross chicks (Cuthbert and Hilton, 2004). Invasive house mice are also negatively impacting bird populations on the USFWS's Midway Atoll (USFWS 2018). Additionally, Witmer et al. (2012) documented seedling damage by house mice in a pen study. House mice are omnivores, yet their diet is largely dominated by insects (at least on tropical Pacific islands), some of which are likely plant pollinators (Shiels et al. 2013; Shiels and Pitt 2014). Diet, however, varies depending on habitat, environmental conditions, and food availability. Because of the damage caused by mice on islands, there have been numerous attempts to control or eradicate them. The U.S. Fish and Wildlife Service (USFWS) is conducting plans for an eradication of the house mouse on the Farallon Islands National Wildlife Refuge off the coast of central California (USFWS 2013).

There have been numerous successful eradications of invasive rodents on islands (Howald et al. 2007, Witmer et al. 2011) and these projects have relied upon rodenticides for their completion (Witmer et al. 2007). The U.S. Department of Agriculture - Animal and Plant Health Inspection Service (APHIS) maintains the registrations for two rodenticide active ingredients for invasive rodent eradication: diphacinone and brodifacoum. In most eradication efforts, these are aerially applied by helicopter at an application rate of 18 kg/ha or less. This results in about two rodenticide pellets per m^2. However, in some cases, the project personnel request a higher application rate because of rodenticide pellet consumption by non-target animals and, in particular, land crabs. The rodenticide labels also allow for a second aerial application to help assure that all targeted rodents are exposed to a lethal dose of the rodenticide. Rodenticides can pose hazards to non-target animals so careful considerations and measures must be taken to reduce those risks (Witmer et al. 2007, van den Brink et al. 2018). In the case of salamanders, they could be exposed to rodenticides during an eradication project by contact with the material (dermal exposure) or by consuming invertebrates that have consumed baits (secondary oral exposure). Because salamanders respire through the skin, dermal exposure may be of greater concern than with other vertebrates.

Invasive house mice are present on the Farallon Islands National Wildlife Refuge (Refuge) and are causing damage to seabirds, the endemic arboreal salamander (*Aneides lugubris farallonensis*), terrestrial invertebrates, and native plants. The USFWS would like to eradicate the invasive mice from the Refuge and in their analyses of action alternatives for the mouse eradication, the USFWS would like an assessment of the potential hazards of brodifacoum and diphacinone to salamanders. They requested that NWRC conduct the assessment based on our extensive animal research facilities and staff and our previous experience of assessing hazards of anticoagulants to reptiles (Witmer and Mauldin 2012).

This study was conducted because of concerns about the potential hazards of anticoagulant rodenticides to salamanders. No scientific literature could be located on this topic, however, the potential hazards to reptiles has been studied extensively (e.g., Hoare and Hare 2006, Weir et al. 2016). The objective of this study was to assess the potential hazards of the rodenticides brodifacoum and diphacinone to Farallon arboreal salamanders (family *Plethodontidae*, the lungless salamanders), using conspecifics from another population of closely related salamanders as surrogates because of the Farallon population's relatively small and endemic status. Ultimately, three closely related species of Plethodontid salamanders were used in the study: yellow-eyed ensatina (*Ensatina eschscholzii xanthoptica*), arboreal salamander (*Aneides lugubris*; mainland variety), and California slender salamander (*Batrachoseps attenuatus*); see Figures 1-3. For a description of the phylogenetic relationships of the largest family of salamanders, the *Plethodontidae*, see Vieites et al. (2011). Salamanders were exposed to rodenticides through two routes: 1) oral exposure, and 2) direct dermal exposure. It was assumed that these would be the main routes of exposure in a rodent eradication project. We hypothesized that the rodenticide exposure would cause some mortality, internal or external bleeding, or other sub-lethal effects (e.g., decline in food consumption and/or loss of weight).

Methods

The salamanders used in this study were live-captured in California and shipped to NWRC, Fort Collins, CO, by the herpetology lab of Dr. Vance Vredenburg of San Francisco State University (SFSU). Dr. Vredenburg has considerable experience in capturing and maintaining salamanders for research purposes. He acquired the permits required to capture, maintain, and transport salamanders. Personnel of SFSU operated under a separate contract with the USFWS to conduct those activities. The salamanders are not sexually dimorphic and we did not know the age or genders of the salamanders brought to NWRC.

Salamanders were housed individually in plastic mouse shoebox cages (26.5 cm long, 15.5 cm wide, 20.5 cm high) and fed small crickets (5-7 crickets twice weekly). Although salamanders eat a variety of invertebrates, crickets were used because they are readily available from a variety of commercial sources, are easily maintained, and are readily consumed by captive salamanders (V. Vredenburg, pers. comm.). The floor of each cage was lined with wet paper towels to provide needed moisture and a plastic tube for shelter (Fig. 1-3). Paper towels were kept saturated with water at all times. Cages were cleaned/changed weekly throughout the study unless mildew became obvious at which time the cage was changed. Salamanders were maintained as per the university-approved Standard Operating Procedure on salamander maintenance that was provided by San Francisco State University. Salamanders were quarantined for two weeks to help assure their healthy condition before starting the trials. We presumed that this also allowed the salamanders to stabilize in body mass prior to initiation of the trials.

Two anticoagulant rodenticides (diphacinone and brodifacoum) were tested for their potential hazards to salamanders. Two U.S. Environmental Protection Agency registered products, Brodifacoum-25D Conservation and Diphacinone-50 Conservation, were used in the study. Initially, we planned to have a control and two treatment groups for each of these two rodenticides with each providing a different route of exposure (oral exposure and direct dermal exposure). However, because of a shortage of salamanders captured for the study, we had to modify these plans as explained below. Because of their known abundance in the San Francisco Bay area and close relationship with *Aneides*, initially we planned to use *Ensatina* as our main sample species with a smaller sample of the less abundant and harder to obtain *Aneides* for confirmation of results with *Ensatina*. However, when both of these species proved more difficult to obtain than expected, we added the more abundant but somewhat less similar (to *Aneides*) *Batrachoseps* to the study.

We had planned to use 10 salamanders in each group; however, because we did not obtain enough of the first two species of salamanders (*Aneides* and *Ensatina*), we combined the two routes of exposure and had some of each species in each group. This was called Trial 1. The control group had no rodenticide exposure, but was otherwise maintained like the treatment groups. See Table 1 for the number of salamanders used in these groups. Because we had enough *Batrachoseps* salamanders, we were able to have separate treatment groups for each route of exposure along with a control group (Trial 2).

Next we describe the methods used in Trial 2 for the two separate exposure routes used for the *Batrachoseps* salamanders. See Table 2 for the number of salamanders used in each group. The methods used in Trial 1 for the groups of *Aneides* and *Ensatina* salamanders were the same except that the two exposure routes were combined. That is, there was only one treatment group for each rodenticide.

Treatment 1 Procedures; oral exposure. Ten *Batrachoseps* were to be used in this treatment group for each rodenticide. However, group size varied somewhat because of the number of salamanders available at the start of the study. In this trial, the salamanders were to be fed crickets that had been exposed to the rodenticide by only allowing the crickets to feed on powdered/crushed rodenticide pellets for about 10 days. However, when we first fed rodenticides to the crickets, they all died shortly thereafter. (But note that when we later fed rodenticides to a different batch of crickets, all the crickets survived; see below.) Consequently, we amended the study protocol so that the powdered rodenticide was sprinkled on the crickets just before putting them in with the salamanders. This was done by placing crickets in a small plastic container containing the powdered rodenticide, replacing the cover, and then gently shaking the container. We did not try to quantify the amount of rodenticide on the crickets, but relied on the chemical residue analyses to give an idea of the burden. Additionally, we presume that much of the powdered rodenticide on the underside of the crickets came off quickly in the salamander cages as they walked around on the wet paper towels. Initially, some crickets were fed to salamanders twice weekly. However, because many salamanders ate the crickets very quickly, they then went several days without any food (crickets) available. This was a concern because they might then start losing body mass which we might interpret as an anticoagulant effect. Hence, we began feeding crickets to the salamanders more frequently to assure that they always had crickets available in their cages. The treated crickets were fed to the salamanders for 14 days. At the end of the 14-day exposure period, salamanders were placed in clean cages and observed for another 14 days (post-exposure period). During this period, they were fed “clean” crickets that had not been exposed to rodenticide.

Treatment 2 Procedures; direct dermal exposure. Ten *Batrachoseps* salamanders were to be used in this treatment group for each rodenticide. However, group size varied somewhat because of the number of salamanders available at the start of the study. In this trial, the salamanders were exposed dermally to powdered/crushed pellets sprinkled on the ground cover material and by spraying the ground cover paper towels with water in which crushed pellets were allowed to dissolve for 7 days. With this treatment group, there may also have been some direct oral exposure if the salamanders chose to eat some of the crushed pellets. As in the other treatment group, the salamanders were exposed to the crushed pellets and treated water for 10 days. At the end of the 10-day exposure period, salamanders were placed in clean cages and observed for the 14-day post-exposure period. During this entire treatment, the salamanders were fed crickets that had not been exposed to the rodenticide.

The control groups were maintained with no rodenticide exposure during Trials 1 and 2.

Salamanders were fed 5-7 crickets twice weekly. Staff monitored cricket consumption over the course of the trials to determine if there was a decline in food consumption as the trial progressed from the exposure period to the post-exposure period. Additionally, salamanders were weighed at the start and end of the trials to determine if a change in weight occurred. These data provided measures of potential sub-lethal effects. Generally, mammals that have consumed enough anticoagulants to exhibit signs of toxicosis will stop feeding and lose weight as the signs of toxicosis advance (e.g., Witmer 2011). With birds, however, they typically do not show weight loss when fed sub-lethal doses of anticoagulants, but birds that are severely intoxicated (and perhaps succumbing/dying) stop feeding and lose weight (Rattner et al. 2012).

Salamanders were examined twice daily by laboratory staff and their condition and any mortalities were recorded. Animals were examined more frequently as signs of toxicity progressed, but frequency of examination depended on how quickly the signs progressed. If any animal was observed to be experiencing more than momentary pain or distress, laboratory staff contacted the Study Director and/or the Attending Veterinarian to have the animal examined and possibly euthanized. Signs of severe pain and distress and of a moribund condition that was used as criteria for humane killing of study animals listed by the Organisation for Economic Co-operation and Development (OECD 2000) and included abnormal vocalization, persistent labored breathing, prolonged impaired ambulation preventing the animal from reaching food or water, persistent convulsions, and significant blood loss. Dead salamanders were rinsed in clean water, weighed and placed in individual, labeled re-sealable bags and frozen for later rodenticide residue determination by the Analytical Chemistry Unit (ACU) staff. See Appendix A for the methods used by the ACU. All surviving salamanders were euthanized at the end of the study using a liquid formulation of MS222 (which also served to rinse the animals of surface residues) for later submission to ACU staff. *Aneides* and *Ensatina* salamanders were necropsied at the end of the study to check for signs of internal hemorrhaging (Stone et al. 1999). Because of their very small size (see Fig. 3), we did not necropsy the *Batrachoseps* salamanders. Additionally, some unrinsed crickets dusted with rodenticide powder and some control crickets were submitted for rodenticide residue analyses along with samples of the water that had been exposed to the powdered pellets. We also had a sample of rodenticide pellets analyzed for the concentration of active ingredients in them.

For each treatment and control group, we compared salamander weights at the start of the trial with their weights at the end of the trial using ANOVA statistical tests. We also compared cricket consumption during the rodenticide exposure period to cricket consumption during the post-exposure period. We used a significance level of $P \leq 0.05$. Other ANOVAs included comparisons of starting weights of the groups of salamanders in Trial 1 and again in Trial 2. We also compared brodifacoum residue levels in dusted versus fed crickets. Finally, we compared brodifacoum residue levels between salamanders that died during trial 2 versus those that lived.

Results

Trial 1

Table 1 summarizes the results of Trial 1. Because of the relatively small number of *Aneides* and *Ensatina* salamanders available for this trial, we combined the two exposure routes for each treatment group. The starting weights of the 3 groups of salamanders in Trial 1 were not significantly different (F = 1.87, P = 0.18). In the brodifacoum group, two (both *Aneides*) of the seven salamanders died (28.6% mortality); while one of these salamanders had skin sloughing and external bleeding, the other showed none of these symptoms. The 2 salamanders that died appeared to have higher brodifacoum residue levels than the 5 that lived, but these levels were not significantly different (F = 5.82, P = 0.06). We noted a sloughing of skin in some animals (four of seven; 57.1%) and sores, mainly on the underside of animals (one of seven; 14.3%). An NWRC chemist noted that the pellets for both brodifacoum and diphacinone are rather acidic so this may have been responsible for some skin sloughing and sores.

There was a considerable difference in cricket consumption by the salamanders. During the brodifacoum exposure period, individual cricket consumption ranged from 3-14 crickets, while in the post-exposure period consumption by remaining salamanders ranged from 1-32 crickets. There was an increase in cricket consumption in the post-exposure period in 3 of 4 salamanders. However, overall cricket consumption was not significantly (F = 3.83, P = 0.08) different between the two periods. The total cricket consumption for the 3 groups of salamanders is presented in Table 3. Additionally, the presence and severity of skin sloughing and sores seemed to decrease in the post-exposure period. Over the course of the trial, there was some loss of weight in the treatment salamanders (0.4-3.4g) and this was marginally significant (F = 4.80, P = 0.05). Upon necropsy of the two dead *Aneides* salamanders, internal hemorrhaging was noted. After euthanasia of the surviving salamanders, necropsy revealed no internal bleeding. Brodifacoum residues in salamanders were quite variable, but low (see discussion for comparisons with other studies): *Aneides* 42.7-226 ng/g or parts per billion (ppb); *Ensatina* 48.3-101 ppb.

In the diphacinone group, one (*Aneides*) of the seven salamanders died (14.3% mortality); this individual exhibited sores and external bleeding and was euthanized. We noted a sloughing of skin in three of seven salamanders (42.7%) and sores on two of these individuals (mainly on the underside of animals; 28.6%). During the diphacinone exposure period, salamanders consumed 3-24 crickets, while in the post-exposure period they consumed 5-38 crickets. There was an increase in cricket consumption in the post-exposure period in 4 of 6 salamanders. However, overall cricket consumption was not significantly different (F = 1.40, P = 0.26) between the two periods. Additionally, the presence and severity of skin sloughing and sores decreased in the post-exposure period. Over the course of the trial, the change in weight of the salamanders was not significant (F = 0.50, P =0.49). Upon necropsy of the dead *Aneides* salamander, internal hemorrhaging was noted. After euthanasia of the surviving salamanders, necropsy revealed no internal bleeding. Diphacinone residues in salamanders were quite variable, but low: *Aneides* 10.8-174 ppb (parts per billion); however, no residues were detected in the *Ensatinas*.

There were no deaths in the control group and we did not note any sloughing of skin or sores. However, one of the six salamanders in the control group showed some internal bleeding upon necropsy. Cricket consumption increased some over the course of the trial in this group, but the difference was not significant (F = 2.20, P = 0.17). However, the control salamanders ate more crickets than the other 2 groups of salamanders (F = 4.43, P = 0.03). Over the course of the trial the weight loss in salamanders was not significant (F = 0.14, P = 0.71). While all salamanders in the 3 groups tended to lose a little weight, the differences between groups was not significant (F = 1.02, P = 0.38).

<u>Trial 2</u>

In trial 2, we used *Batrachoseps* salamanders only. Because we had considerably more salamanders in trial 2 than in trial 1, we were able to divide the exposure routes, resulting in four treatment groups. The starting weights of the salamanders in the 5 groups were not significantly different (F = 0.41, P = 0.80). One brodifacoum group (n= 7) received oral exposure (dusted crickets) only, while the second brodifacoum group (n= 8) received dermal exposure. Similarly, one diphacinone group (n = 8) received oral exposure only, while the second diphacinone group (n = 8) received dermal exposure. This was done to compare toxicity between the exposure routes. The control group (n = 7) received no rodenticide exposure.

Table 2 summarizes the results of Trial 2. In the brodifacoum oral exposure group, no salamanders died. There was no skin sloughing or sores observed. Cricket consumption was quite variable: 13-70 per individual during the exposure period and 4-59 in the post-exposure period, but the differences were not significant (F = 0.01, P = 0.92). The total cricket consumption for the 5 groups of salamanders is presented in Table 4. Salamanders mostly maintained the same weight over the duration of the trial; the most substantial change was 0.1g in one individual. Weight changes were not significantly different (F = 0.15, P = 0.71) over the course of the trial. Brodifacoum residues in the oral exposed salamanders ranged from 51.3-91.1 ppb.

In the brodifacoum dermal exposure group, six of eight salamanders died (75.0%). There was no skin sloughing or sores observed in any of the salamanders including those that died. The salamanders that died tended to have higher brodifacoum residue levels than the ones that lived, but these levels were not significantly different (F = 0.98, P = 0.37). Cricket consumption was somewhat variable: 9-27 in the exposure period, but increased in the two surviving salamanders (44 and 55) in the post-exposure period. This was a significant increase (F = 20.9, P = 0.002) in cricket consumption between the two periods, but it should be noted that this statistic is based on only two data points in the post-exposure period. Salamanders mostly lost a small amount of weight from the start to the end of the trial, but the differences were not significant (F = 0.49, P = 0.50). Brodifacoum residues in the dermal exposed salamanders ranged from 16.5-95.1 ppb. While the salamanders fed dusted crickets tended to have somewhat higher brodifacoum residue levels, these differences were not significant (F = 1.02, P = 0.33).

No animals died in the diphacinone oral exposure group. Skin sloughing or sores on the salamanders was not observed. Cricket consumption was somewhat variable: 6-68 in the exposure period, but stayed about the same (range of 4-66) in the post-exposure period. These differences were not significant (F = 0.31, P = 0.58). Weight gain in this treatment group ranged from 0.02-0.15g and were not significantly different (F = 0.39, P = 0.54). There were no diphacinone residues detected in the oral exposed salamanders.

In the diphacinone dermal exposure group, no animals died, but 50% of salamanders had some skin sloughing. Cricket consumption ranged from 6-57 during the exposure period, but stayed about the same (range of 5-59) in the post-exposure period. These differences were not significant (F = 1.89, P = 0.19). Salamander weights were mostly stable over the course of the trial, with changes ranging from -0.11-0.11g. The differences between the start and end of the trial were not significant (F = 0.05, P = 0.83). There were no diphacinone residues detected in the dermal exposed salamanders.

There was one death (20% mortality) in the control group. Interestingly, 20% of the control animals had sloughing skin and sores. Cricket consumption was also variable in the control group, ranging from 18-145 per salamander, but these differences were not significant (F = 0.56, P = 0.47) during the two periods (treatment versus post-treatment). Overall, there was no significant difference in the cricket consumption between the 5 groups of salamanders (F = 0.84, P = 0.51). Control animals also showed only small changes in weights during the study period: -0.02-0.43g and these differences were not significant (F = 0.28, P = 0.61). However, there was a significant difference in weight changes in the 5 groups of salamanders (F = 3.47, P = 0.02) with the brodifacoum salamanders losing the most weight and the control salamanders losing the least amount of weight.

<u>Analyses of crickets, water, bait pellets and other findings</u>
In Trial 1 and 2, we fed crickets that had been dusted with rodenticide powder rather than using crickets that had been fed powdered rodenticides (see explanation near the end of the Discussion section). Brodifacoum residue concentrations in crickets fed brodifacoum pellets (ranging from 296-688 ppb) were much lower than the residue concentrations in crickets dusted with powdered brodifacoum (2887-3340 ppb) (F = 330.8, P = 0.0001).

Diphacinone residues in crickets fed diphacinone pellets were quite variable (954-2930 ppb), as were crickets dusted with powdered diphacinone (1823-3980 ppb). Differences in residues between the two groups were not significant (F = 1.78, P = 0.25).

Residues in water used to soak crushed and powder rodenticide pellets were very low, likely due to the low water solubility of brodifacoum and diphacinone. Brodifacoum residues in water varied from 5.75-29.7 ppb. Diphacinone residues in water were similar to brodifacoum levels and varied from 0.08-17.7 ppb.

Because of the low rodenticide residue levels in the salamanders (i.e., ppb instead of ppm), we tested the brodifacoum and diphacinone pellets for rodenticide concentrations. These were very close to the label concentrations. For the diphacinone pellets, the mean concentration was 46.4

µg/g (= ppm) which is 93% of the desired 50 ug/g. For the brodifacoum pellets, the mean concentration was 26.3 ug/g (= ppm) which is 105% of the desired 25 µg/g.

Rodenticide residues were found in some samples where they were not expected. For example, very low concentrations of brodifacoum were found in two control *Batrachoseps* salamanders and one *Batrachoseps* salamander fed diphacinone-exposed crickets had a low concentration of brodifacoum residues. However, those concentrations of rodenticides were so low as to be considered unquantifiable (i.e., below the limit of quantitation). In addition to a few salamanders, the three groups of crickets dusted with brodifacoum had very low levels of diphacinone residues; but, again, these concentrations were not quantifiable. One possible explanation for these findings is cross-contamination of samples, processing equipment, or from latex gloves used to handle samples. Because the quality control samples are within acceptable limits and relatively few samples appeared potentially contaminated, we do not think such low level contamination of these samples compromises the quality of the analytical results.

All the residue analyses results are presented in Appendix A.

Discussion

From our Trial 1 results, it appears that rodenticide exposure poses some risk to salamanders, but that hazard appears to be relatively low in terms of mortality and sub-lethal effects, especially considering the experimental design optimized salamander exposure to rodenticides. It also appeared that salamanders can begin recovery after exposure ceases, as suggested by reduced skin sloughing and fewer sores during the post-exposure period. However, because some skin sloughing and sores were also noted in control salamanders, it is unclear whether or not skin damage was caused by anticoagulant exposure. One must also realize that in this trial there was a very high exposure rate in the treatment groups which combined oral and dermal exposures. In the brodifacoum group, the high exposure rates were from the feeding of dusted crickets instead of crickets that had fed on the rodenticides; the former had much higher concentrations of rodenticide residues. Additionally, the level of dermal exposure was much higher than it would be in an eradication project (see Figure 1). Hence, this trial presents, in essence, a worst case scenario. In an actual aerially-applied rodenticide baiting operation, using the U.S. Environmental Protection Agency's label application rate, there is generally only about two rodenticide pellets per m^2. Given that this was a worst-case scenario, the low residue concentrations in the salamanders suggests that there would be a relatively low risk to predators or scavengers consuming a salamander.

The Trial 2 results basically confirmed the results from Trial 1. However, Trial 2 seems to suggest that the higher hazard to *Batrachoseps* salamanders from anticoagulants is from dermal exposure versus oral exposure based on mortality. This could be determined because we had enough *Batrachosep*r salamanders to separate the two types of exposure into separate groups. It is cautioned, however, that we gave very high exposure rates to the salamanders in this study (Figure 1). Aerial broadcast baiting as part of an invasive rodent eradication project would likely result in much lower dermal exposure to all animals. Hence, Trial 2 also presents a worst case scenario.

The residue concentrations in this study were so low that our Analytical Chemistry Unit had to modify the normal method of detection. Normally they use High Performance Liquid Chromatography (HPLC) or the more sensitive mass spectrometer (MS). In the case of this study, they combined those methods (HPLC-MS) which greatly increased the sensitivity and probability of detecting residues.

With regard to the residue concentrations in crickets fed rodenticides, we need to clarify an early assumption that we made. When we first tried to feed powdered/crushed rodenticides to crickets, all the crickets died shortly thereafter. We assumed crickets might be sensitive to anticoagulants even though most invertebrates are known to not be sensitive to anticoagulants. Because of that early result, for the study we chose to dust crickets with powdered anticoagulants just before feeding them to the salamanders. However, when we later fed rodenticides to a different batch of crickets, all the crickets survived; those were the crickets used for residue analyses. We now surmise that we got a bad batch of crickets early on in the study. This is consistent with the scientific literature which has shown little or no impacts to invertebrates from anticoagulants even though some have been found to have substantial residues in them (Hoare and Hare 2006; Loof et al. 2011). It should be noted that dusted crickets were the only ones used in the salamander exposure trials.

A search of the scientific literature revealed no publications concerning the toxicity of anticoagulants to amphibians. Thus, little is known about the risk of anticoagulants to amphibians, but it is generally considered to be low (Eason, 1995; Chris et al., 2010). The native *Batrachoseps* salamanders on Anacapa Island are thriving 10 years after the invasive rats were eradicated using Brodifacoum-25D (Newton et al. 2016). There is considerable uncertainty regarding the toxicity of rodenticides to amphibians, but based on the fate and transport of the two rodenticides in the environment, we would anticipate relatively low risk to amphibians/salamanders under most island rodent eradication exposure scenarios. Published studies have focused on risks to mammals, birds, invertebrates, and to a lesser extent, on reptiles. These taxonomic groups are thought to be either the most sensitive or the groups most likely to consume either baits (primary exposure) or animals that have consumed baits (secondary exposure).

As such, we have little to compare our results with salamanders to with the exception of the taxonomic groups listed above. This information and residue levels comes from eradication projects with non-target monitoring before and after rodenticide application. The following paragraphs provide a brief synopsis of relevant and readily available literature for reptiles and other island fauna, where rodenticide body burdens have been used to demonstrate rodenticide accumulation potential and associated with acute toxicity, often lethality.

Witmer and Mauldin (2012) assessed the potential hazards of anticoagulant rodenticides to reptiles and reported concentrations of diphacinone and brodifacoum residues in whole bodies of captive snakes, turtles, and lizards that had been twice orally gavaged with solutions containing those anticoagulants. Body residues ranged from lows of 0.07 µg/g (= ppm) to highs of 1.58 µg/g. They also noted that 5 of 37 (13%) *Ameiva* lizards died during the study with one showing external hemorrhaging. One of 38 (3%) green iguanas died and it had external hemorrhaging.

Pitt et al. (2015) also reported concentrations of brodifacoum residues in various taxonomic groups and in environmental substrates after the rat eradication project on Palmyra Atoll in the tropical Pacific Ocean. While the concentrations were higher than they expected, they note that there were very high application rates of the rodenticide in that project (6 times higher than the EPA recommended label rate). Using whole body carcasses found after the baiting operation, they reported concentrations of 0.10-0.76 µg/g (= ppm) in birds, 0.34-0.44 µg/g in fish, and below the detection level to 0.97 µg/g in crabs. These concentrations are much lower than those found in rats that died from brodifacoum exposure: 3.75 µg/g. Pitt et al. (2015) also reported that only one fresh water sample had a residue concentration (0.05 µg/g (= ppm) above the detection level and none were detected in the salt water samples. They also reported very low soil residue concentrations of 0.007-0.018 µg/g (= ppm).

Shiels et al. (2017) reported concentrations of brodifacoum residues in various taxonomic groups and in environmental substrates after the rat eradication project on Desecheo Island in the Caribbean. Most fresh carcasses found from various taxonomic groups (rats, birds, lizards, crabs) had detectible residues of brodifacoum. Liver residues were quite variable, but rats had higher levels (8,930-27,700 ng/g (= ppb) than non-target animals (127-2,780 ng/g). They also live-harvested various lizard species about 3 weeks after the baiting operation. While all these animals appeared healthy, 65-100% had detectable residue concentrations ranging from 12.2-1100 ng/g (= ppb). Additionally, some insect and crabs had detectable residue concentrations ranging from 10.3-1580 ng/g.

This preliminary study suggests relatively low risk to salamanders from anticoagulant rodenticides. Additionally, it does appear that there would not be population-level effects on the salamander population if a mouse eradication was carried out. Because of the low residue levels in salamanders, it also appears that the hazard to animals preying or scavenging on salamanders would be low. However, more information and studies are needed to confirm these findings and to clarify various aspects. A study with larger sample sizes of animals per group might help reduce the wide variability observed in this study and would allow for more robust statistical analyses. There is also a need to fill information gaps (e.g., better exposure and robust toxicity data and histopathology data). Further study could also better explain the reason(s) behind skin sloughing and sores in salamanders. Trials with other species of amphibians would also be useful to compare with the results of this study. Finally, a small scale field application of anticoagulant rodenticides in an area containing amphibians might provide better insight to the real risk of these toxins to amphibians in a rodent eradication.

Acknowledgments

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Figure 1. *Aneides* salamander in its plastic cage showing the high level of dermal exposure in this study.

Figure 2. *Ensatina* salamander in its plastic cage in dermal exposure trial.

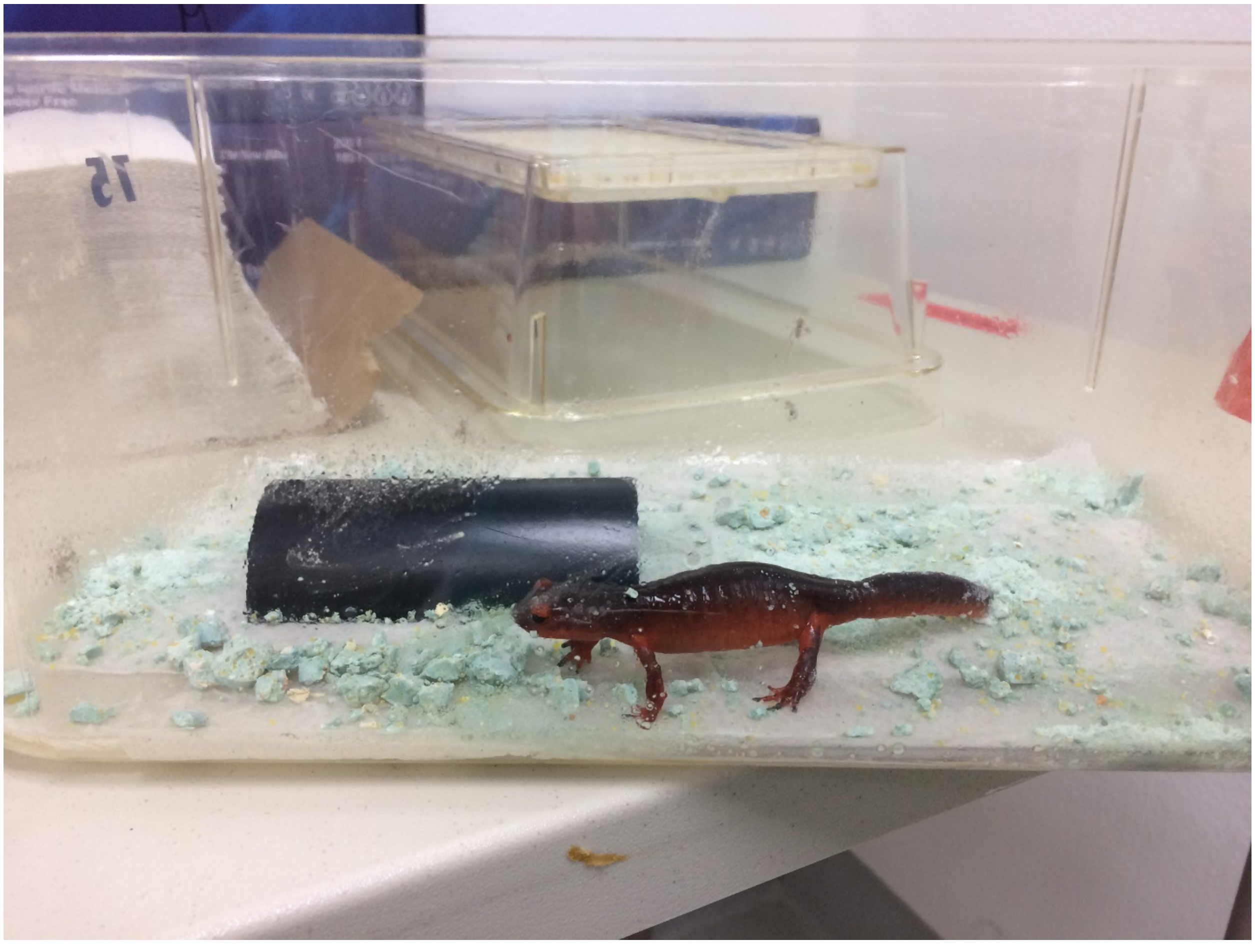

Figure 3. *Batrachoseps* salamander in its plastic cage. This was a control salamander, hence no rodenticides are present.

Table 1. Summary of the *Aneides* and *Ensatina* trial (Trial 1). Animals coded QO are *Aneides*; those coded QP are *Ensatina*.

Treatment	ID #	Initial Weight (g)	Final Weight (g)	Weight Change (g)	Comments	% Sloughing Skin	% Sores	% Mortality
Brodifacoum /oral & dermal exposure	QO1	9.4	6.1	-3.3	Died	57.14%	14.29%	28.57%
	QO4	9.0	7.8	-1.2	Euthanized at end of trial			
	QO7	9.7	7.5	-2.2	Euthanized at end of trial			
	QO10	9.4	6.0	-3.4	Died			
	QP1	7.7	6.8	-0.9	Euthanized at end of trial			
	QP4	7.3	6.9	-0.4	Euthanized at end of trial			
	QP7	13.0	10.5	-2.5	Euthanized at end of trial			
Diphacinone /oral & dermal exposure	QO2	10.5	7.7	-2.8	Euthanized due to condition	42.86%	28.57%	14.29%
	QO5	17.3	15.8	-1.5	Euthanized at end of trial			
	QO8	12.9	12.2	-0.7	Euthanized at end of trial			
	QO11	20.7	17.3	-3.4	Euthanized at end of trial			
	QP2	9.6	8.6	-1.0	Euthanized at end of trial			
	QP5	9.3	8.1	-1.2	Euthanized at end of trial			
	QP8	8.0	6.8	-1.2	Euthanized at end of trial			
Control	QO3	19.4	18.5	-0.9	Euthanized at end of trial	0.00%	0.00%	0.00%
	QO6	10.8	10.4	-0.4	Euthanized at end of trial			
	QO9	20.3	18.2	-2.1	Euthanized at end of trial			
	QO14	10.4	10.0	-0.4	Euthanized at end of trial			

QP3	6.0	4.8	-1.2	Euthanized at end of trial
QP6	15.4	13.3	-2.1	Euthanized at end of trial

Table 2. Summary of the *Batrachoseps* trial (Trial 2).

Treatment	Animal ID	Initial Weight (g)	Final Weight (g)	Weight Change (g)	Days Until Death	% Sloughing Skin	% Sores	% Mortality
Brodifacoum /oral exposure	QS5	0.73	0.73	0.00		0.00%	0.00%	0.00%
	QS10	0.45	0.55	0.10				
	QS19	0.84	0.94	0.10				
	QS27	0.52	See footnote	N/A				
	QS35	0.46	0.54	0.08				
	QS42	1.17	1.21	0.04				
	QS56	0.78	0.83	0.05				
Brodifacoum /Dermal exposure	QS6	0.52	0.42	-0.10	2	0.00%	0.00%	75.00%
	QS11	1.03	0.97	-0.06	9			
	QS30	0.81	0.60	-0.21	14			
	QS36	0.41	0.34	-0.07	10			
	QS38	0.30	0.23	-0.07	10			
	QS43	0.52	0.52	0.00				
	QS51	0.80	0.67	-0.13	10			
	QS57	0.58	0.57	-0.01				
Diphacinone /oral exposure	QS7	0.50	0.64	0.14		0.00%	0.00%	0.00%
	QS13	0.69	0.79	0.10				
	QS23	0.56	0.70	0.14				
	QS31	1.15	1.27	0.12				
	QS39	0.30	0.32	0.02				
	QS44	0.89	1.04	0.15				
	QS52	0.29	0.34	0.05				
	QS58	0.56	0.61	0.05				
Diphacinone /Dermal exposure	QS8	0.31	0.36	0.05		50.00%	0.00%	0.00%
	QS14	0.39	0.48	0.09				
	QS24	0.88	0.88	0.00				
	QS33	0.88	0.92	0.04				
	QS40	0.83	0.89	0.06				
	QS48	0.86	0.97	0.11				
	QS53	0.82	0.71	-0.11				
	QS55	0.93	0.89	-0.04				
Control	QS9	0.45	0.55	0.10		20.00%	20.00%	20.00%
	QS17	0.75	0.81	0.06				
	QS22	0.54	0.52	-0.02	6			

	QS26	0.90	0.94	0.04				
	QS34	0.38	0.40	0.02				

This carcass was lost.

Table 3. Total cricket consumption by salamanders in trial 1 by group and time period.

Brodifacoum Group	Treatment Period	Post-treatment Period	Total/Both Periods
QO1	13	X	X
QO4	3	1	4
QO7	14	32	46
QO10	11	X	X
QP1	6	13	19
QP4	8	29	37
QP7	12	22	34
Diphacinone Group			
QO2	10	X	X
QO5	24	38	62
QO8	12	9	21
QO11	6	5	11
QP2	3	9	12
QP5	9	21	30
QP8	3	14	17
Control Group			
QO3	22	10	32
QO6	22	28	50
QO9	24	60	84
QO14	25	64	89
QP3	19	17	36
QP6	23	37	60

QO = *Aneides*; QP = *Ensatina*
X = died

Table 4. Total cricket consumption by *Batrachoseps* salamanders in Trial 2 by group and time period.

Brodifacoum Oral Group	Treatment Period	Post-treatment Period (X = died)	Total/Both Periods (X = died)
QS5	59	54	113
QS10	54	47	101
QS19	50	59	109
QS27	13	7	20
QS35	28	48	76
QS42	13	4	17
QS56	70	59	129
Brodifacoum Dermal Group			
QS6	1	X	X
QS11	9	X	X
QS30	13	X	X
QS36	11	X	X
QS38	10	X	X
QS43	9	44	53
QS51	31	X	X
QS57	27	54	81
Diphacinone Oral Group			
QS7	64	55	119
QS13	57	60	117
QS23	29	46	75
QS31	68	66	134
QS39	8	4	12
QS44	25	46	71
QS52	64	45	109
QS58	25	57	82
Diphacinone Dermal Group			
QS8	6	40	46
QS14	57	59	116
QS24	23	54	77
QS33	10	5	15
QS40	34	57	91
QS48	34	55	89
QS53	10	8	18
QS55	12	20	32
Control Group			
QS9	70	54	124
QS17	48	42	90
QS22	2	X	X

QS26	74	71	145
QS34	18	19	37

Appendix A. Residue report of the NWRC Analytical Chemistry Unit.

Wildlife Services
NWRC
National Wildlife Research Center

To:	Dr. Gary Witmer Research Wildlife Biologist NWRC
Subject:	Determination of Diphacinone and Brodifacoum in Salamanders, Crickets, Water, and Baits (QA-2688); Invoice #17-019, Nov. 6, 2017
Methods:	Non-GLP (salamanders, crickets, water); Method 163A (baits)
Analysis Dates:	9/12, 9/13, 9/14, 9/19, 9/25, 9/27, 9/28, 10/13, 10/27, and 10/30/2017
Notebook Reference:	AC-161, pp. 86-109
QC Notebook Reference:	QC-33, p. 137; AC-162, p. 4
Analyst:	Steve Volker

Sample Descriptions:

Ensatina salamanders (n=8), *Aneides* salamanders (n=14), *Batrachoseps* salamanders (n=36), crickets (n=24 composite samples), water (saturated with ground bait, n=12), and baits (n=4) were received between 6/2/2017 and 9/25/2017 for analysis of diphacinone and brodifacoum. All samples were stored at -20°C until time of analysis.

Sample Preparation and Extraction:

Homogenization:

Baits and salamanders (whole bodies) were homogenized with a SPEX 6875D liquid nitrogen freezer mill. Homogenized samples were transferred immediately to vacuum sealable bags while still frozen and stored at -20°C. Cricket samples, consisting of between 11 and 27 individual crickets, were ground into a paste using a glass rod and stored at -20°C.

Extraction of salamanders and crickets:

Homogenized sample (70-80 mg) was weighed into a 1.5-mL microcentrifuge tube, 50 µL DI water added, and the sample vortex mixed 4-5 s to form a suspension. Surrogate analytes (20 µL, 16 µg/mL D_4-diphacinone and 17 µg/mL chlordifacoum in acetonitrile) and 1.180 mL of acetonitrile (ACN) were added and the sample vortex mixed twice for 15-20 s. An excess of NaCl (~120 mg) was added to produce a water:ACN phase separation and the sample vortex mixed twice for 15-20 s. The extract was clarified by centrifugation (12,000 RCF) and 0.900 mL of supernatant transferred to a dispersive solid-phase extraction (dSPE) tube containing $MgSO_4$ (150 mg), C18 sorbent (25 mg), and primary-secondary amine (PSA) sorbent (25 mg). The extract was exposed to the sorbents and $MgSO_4$ by vortex mixing for 4-5 s followed by centrifugation at 12,000 RCF for 2-3 s to clarify the supernatant. 0.400 mL of supernatant was then transferred to a 1.5-mL microcentrifuge tube and the solvent removed in a 60°C N-Evap with a gentle flow of nitrogen. The analytes were reconstituted with 100 µL ACN followed by 400 µL pH 9.5 20-mM ammonium acetate, with vortex mixing after each addition. The sample was then transferred to an autosampler vial for LC/MS analysis.

Extraction of Water:

Water samples (10-50 mL) were warmed to room temperature (overnight in a hood), vortex mixed 4-5 s, centrifuged at 1400 RCF for 2 minutes, and then 8-10 mL of supernatant filtered through a 0.7-µm glass fiber syringe filter into a 15-mL polypropylene tube. A portion of the filtered sample (1.5 mL) was transferred to a 10-mL glass tube and surrogate analytes (10 µL) added. Acetonitrile (2.0 mL), 1M HCl (0.5 mL), and excess NaCl (~1 g) were added and the sample vortex mixed 4-5 s. Chloroform (0.5 mL) was added and the sample vortex mixed 4-5 s, let set for 5-10 minutes, and then vortex mixed again. The sample was then centrifuged at 1400 RCF for 1 minutes and 1.5 mL of the upper ACN/chloroform layer transferred to a 1.5-mL microcentrifuge tube. The solvents were removed in a 45°C N-Evap with a gentle flow of nitrogen. The analytes were reconstituted with 90 µL ACN followed by 360 µL pH 9.5 20-mM ammonium acetate, with vortex mixing after each addition. The sample was then transferred to an autosampler vial for LC/MS analysis.

Baits:

All baits were assayed by NWRC Method 163A. To assess trace level residues of rodenticides, 0.600 mL of microwave extract from Method 163A procedure was transferred to a 1.5-mL microcentrifuge tube and the solvent removed in a 60°C N-Evap with a gentle flow of nitrogen. The analytes were reconstituted with 300 µL ACN followed by 1200 µL pH 9.5 20-mM ammonium acetate, with vortex mixing after each addition. The sample was then transferred to an autosampler vial for LC/MS analysis.

Instrument methods:

Salamanders and Crickets:

Agilent 1290 Infinity II HPLC with G6470A QQQ

Column	Xbridge C18, 2.5-µm, 2.1 x 50 mm, Waters P/N 186003085
Mobile phase A	90%(pH 9.5 20-mM ammonium acetate)/10%(Acetonitrile)
Mobile phase B	Acetonitrile
Flow rate	0.800 mL/min
Column temp.	60°C
Injection volume	7.5 µL
Run time	4.0 min
Source	AJS ESI, negative mode
Gas temp.	300°C
Gas flow	5 L/min
Nebulizer	45 psi
Sheath gas	250°C, 7 L/min
Capillary	-4500 V
Nozzle	-500 V

Time (min)	%A	%B
0.00	90%	10%
0.50	90%	10%
3.00	20%	80%
3.01	0%	100%
3.50	0%	100%
3.51	90%	10%

Analyte	Precursor Ion (m/z)	Product Ion (m/z)	Fragmentor (V)	Collision Energy (V)
Diphacinone	339.1	**167.1** 145	100	23 18
D4-Diphacinone	343.1	167.1	120	23
Chlordifacoum	477.1	135.1	61	37
Brodifacoum	522.9	135.0 **80.9**	165	44 50

BOLD = product ion used for quantitation

Water:

Same conditions as for salamanders and crickets with the following changes:

Flow rate	0.650 mL/min
Run time	3.5 min

Time (min)	%A	%B
0.00	85%	15%
0.50	85%	15%
2.30	30%	70%
2.31	0%	100%
2.90	0%	100%
2.91	85%	15%

Baits (LCMS):

Same conditions as for water, but 1.5 µL injection volume.

Baits (Method 163A):

Agilent 1100 Series HPLC with G1315B Diode Array Detector (DAD) and G1321A Fluorescence Detection (FLD)

Column	Gemini C18, 3-µm, 3 x 150 mm, Phenomenex P/N 00F-4439-Y0			
Mobile phase A	5-mM tetrabutylammonium phosphate (TBAP) in 50%(pH 8.5 6-mM phosphate)/50%(methanol)			
Mobile phase B	5-mM TBAP in methanol			
Flow rate	0.650 mL/min	Time (min)	%A	%B
Column temp.	60°C	0.00	85%	15%
Injection volume	10 µL	1.00	85%	15%
Run time	26 min	17.00	45%	55%
		17.01	0%	100%
Detector	UV (DAD); 325 nm	23.00	0%	100%
		23.01	85%	15%
Detector	Fluorescence (FLD)			
Excitation	310 nm			
Emission	390 nm			

Detection and Quantitation Limits:

The Detection Limit (DL) is the lowest concentration of analyte in a sample that can be detected but not necessarily quantified as an exact value. The Quantitation Limit (QL) is the lowest concentration of brodifacoum that can be quantitatively determined with suitable precision and accuracy. The signal-to-noise (S/N) ratio was used to determine the DL and QL for each analyte. This was performed by comparing the analyte response observed in fortified control matrix with the baseline noise observed at the same retention time in control matrix. The DL and QL are defined as analyte concentrations corresponding to S/N ratios of 3 and 10, respectively. The following table presents the average DL and QL concentrations for diphacinone and brodifacoum in each control matrix.

Detection Limit (DL) and Quantitation Limit (QL)

	Diphacinone		Brodifacoum	
Control Matrix	DL	QL	DL	QL
Ensatina Salamanders (whole body)	5.9 ng/g	19.6 ng/g	6.6 ng/g	21.9 ng/g
Aneides Salamanders (whole body)	7.5 ng/g	25.1 ng/g	8.6 ng/g	28.6 ng/g
Batrachoseps Salamanders (whole body)	8.9 ng/g	29.8 ng/g	8.9 ng/g	29.7 ng/g
Crickets	4.9 ng/g	16.2 ng/g	5.9 ng/g	19.7 ng/g
Water (saturated with ground bait)	0.080 ng/mL	0.267 ng/mL	0.13 ng/mL	0.419 ng/mL
Baits (Method 163A)	2.8 µg/g	9.40 µg/g	0.043 µg/g	0.142 µg/g
Baits (LCMS)	0.0072 µg/g	0.0241 µg/g	0.0081 µg/g	0.0270 µg/g

Results:

Triplicate preparations of all samples were prepared, except when sample size was insufficient. Rodenticide residues for salamanders and crickets are reported in units of ng/g, equivalent to parts per billion (ppb). Water results are reported in units of ng/mL, also equivalent to ppb. Rodenticide concentrations in bait formulations are reported in units of µg/g, equivalent to parts per million (ppm).

If no analyte response was recorded by the data acquisition software or if the observed concentration was less than the DL, an entry of "ND" is reported to indicate that the analyte was not detected. Results that are greater than the DL, but less than the QL are identified by an asterisk "*". Care should be taken when evaluating results below the QL as the variability will be significantly greater than the variability observed in quality control (QC) samples. Results above the QL are reported to three significant figures.

***Ensatina* salamanders (whole body)**

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170602-13	QP3 (Control)	9/14/2017	ND	ND
S170602-14	QP6 (Control)	9/14/2017	ND	ND
S170602-19-A	QP1 (Brodifacoum, Dermal + Cricket)	9/14/2017	ND	101
S170602-19-B		9/14/2017	ND	95.9
S170602-19-C		9/14/2017	ND	100
S170602-20-A	QP4 (Brodifacoum, Dermal + Cricket)	9/14/2017	ND	86.9
S170602-20-B		9/14/2017	ND	85.7
S170602-20-C		9/14/2017	ND	85.5
S170602-21-A	QP7 (Brodifacoum, Dermal + Cricket)	9/14/2017	ND	50.1
S170602-21-B		9/14/2017	ND	50.7
S170602-21-		9/14/201	ND	48.3

C		7		
S170602-26-A		9/14/2017	ND	ND
S170602-26-B	QP2 (Diphacinone, Dermal + Cricket)	9/14/2017	ND	ND
S170602-26-C		9/14/2017	ND	ND
S170602-27-A		9/14/2017	ND	ND
S170602-27-B	QP5 (Diphacinone, Dermal + Cricket)	9/14/2017	ND	ND
S170602-27-C		9/14/2017	ND	ND
S170602-28-A		9/14/2017	ND	ND
S170602-28-B	QP8 (Diphacinone, Dermal + Cricket)	9/14/2017	ND	ND
S170602-28-C		9/14/2017	ND	ND
		DL (ng/g) =	5.9	6.6
		QL (ng/g) =	19.6	21.9

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentration less than the Quantitation Limit (QL).

Aneides salamanders (whole body)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170602-09	QO3 (Control)	9/19/2017	ND	ND
S170602-10	QO6 (Control)	9/19/2017	ND	ND
S170602-11	QO9 (Control)	9/19/2017	ND	ND
S170602-12	QO14 (Control)	9/28/2017	ND	ND
S170711-31-A		9/28/2017	ND	ND
S170711-31-B	QO13 (Control)	9/28/2017	ND	ND
S170711-31-C		9/28/2017	ND	ND
S170711-32-A		9/28/2017	ND	ND
S170711-32-B	QO12 (Control)	9/28/2017	ND	ND
S170711-32-C		9/28/2017	ND	ND
S170602-15-A		9/28/2017	ND	108
S170602-15-B	QO1 (Brodifacoum, Dermal + Cricket)	9/28/2017	ND	98.0
S170602-15-C		9/28/2017	ND	103
S170602-16-A		9/28/2017	ND	45.6
S170602-16-B	QO4 (Brodifacoum, Dermal + Cricket)	9/28/2017	ND	46.6
S170602-16-C		9/28/2017	ND	38.8
S170602-17-A		9/28/2017	ND	85.5
S170602-17-B	QO7 (Brodifacoum, Dermal + Cricket)	9/28/2017	ND	97.1
S170602-17-C		9/28/2017	ND	89.3
S170602-18-A		9/28/2017	ND	239
S170602-18-B	QO10 (Brodifacoum, Dermal + Cricket)	9/28/2017	ND	214
S170602-18-C		9/28/2017	ND	224

S170602-22-A	QO2 (Diphacinone, Dermal + Cricket)	9/28/2017	182	ND
S170602-22-B		9/28/2017	176	ND
S170602-22-C		9/28/2017	165	ND
S170602-23-A	QO5 (Diphacinone, Dermal + Cricket)	9/28/2017	ND	ND
S170602-23-B		9/28/2017	ND	ND
S170602-23-C		9/28/2017	ND	ND
S170602-24-A	QO8 (Diphacinone, Dermal + Cricket)	9/28/2017	9.0 *	ND
S170602-24-B		9/28/2017	13.7 *	ND
S170602-24-C		9/28/2017	9.8 *	ND
S170602-25-A	QO11 (Diphacinone, Dermal + Cricket)	9/28/2017	ND	ND
S170602-25-B		9/28/2017	ND	ND
S170602-25-C		9/28/2017	ND	ND
		DL (ng/g) =	7.5	8.6
		QL (ng/g) =	25.1	28.6

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Batrachoseps salamanders (whole body)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170602-30-A		9/19/2017	ND	ND
S170602-30-B	QS22 (control)	9/19/2017	ND	ND
S170602-30-C		9/19/2017	ND	ND
S170711-04-A		9/19/2017	ND	22.0 *
S170711-04-B	QS9 (Control)	9/19/2017	ND	22.6 *
S170711-04-C		9/19/2017	ND	21.2 *
S170711-08-A		9/19/2017	ND	ND
S170711-08-B	QS17 (Control)	9/19/2017	ND	8.8 *
S170711-08-C		9/19/2017	ND	ND
S170711-12-A		9/19/2017	ND	ND
S170711-12-B	QS26 (Control)	9/19/2017	ND	ND
S170711-12-C		9/19/2017	ND	ND
S170711-17-A		9/19/2017	ND	ND
S170711-17-B	QS34 (Control)	9/19/2017	ND	ND
S170711-17-C		9/19/2017	ND	ND
S170602-31-A		9/19/2017	ND	22.8 *
S170602-31-B	QS6 (Brodifacoum, Dermal)	9/19/2017	ND	16.5 *
S170602-31-C		9/19/2017	ND	18.2 *
S170602-32-A		9/19/2017	ND	82.1
S170602-32-B	QS11 (Brodifacoum, Dermal)	9/19/2017	ND	61.9

S170602-32-C		9/19/2017	ND	74.4
S170602-33-A	QS36 (Brodifacoum, Dermal)	9/19/2017	ND	29.8
S170602-33-B		9/19/2017	ND	38.5
S170602-34-A	QS38 (Brodifacoum, Dermal)	9/19/2017	ND	103
S170602-35-A	QS51 (Brodifacoum, Dermal)	9/19/2017	ND	64.4
S170602-35-B		9/19/2017	ND	71.4
S170602-35-C		9/19/2017	ND	71.3
S170711-01-A	QS5 (Brodifacoum, Cricket)	9/19/2017	ND	87.9
S170711-01-B		9/19/2017	ND	72.5
S170711-01-C		9/19/2017	ND	95.1
S170711-02-A	QS7 (Diphacinone, Cricket)	9/19/2017	ND	10.1 *
S170711-02-B		9/19/2017	ND	12.7 *
S170711-02-C		9/19/2017	ND	9.3 *
S170711-03-A	QS8 (Diphacinone, Dermal)	9/25/2017	ND	ND
S170711-03-B		9/25/2017	ND	ND
		DL (ng/g) =	8.9	8.9
		QL (ng/g) =	29.8	29.7

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Batrachoseps salamanders (whole body)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170711-05-A	QS10 (Brodifacoum, Cricket)	9/25/2017	ND	54.7
S170711-05-B		9/25/2017	ND	54.6
S170711-05-C		9/25/2017	ND	60.4
S170711-06-A	QS13 (Diphacinone, Cricket)	9/25/2017	ND	ND
S170711-06-B		9/25/2017	ND	ND
S170711-06-C		9/25/2017	ND	ND
S170711-07-A	QS14 (Diphacinone, Dermal)	9/25/2017	ND	ND
S170711-07-B		9/25/2017	ND	ND
S170711-07-C		9/25/2017	ND	ND
S170711-09-A	QS19 (Brodifacoum, Cricket)	9/25/2017	ND	48.0
S170711-09-B		9/25/2017	ND	55.9
S170711-09-C		9/25/2017	ND	49.9
S170711-10-A	QS23 (Diphacinone, Cricket)	9/25/2017	ND	ND
S170711-10-B		9/25/2017	ND	ND
S170711-10-C		9/25/2017	ND	ND
S170711-11-A	QS24 (Diphacinone, Dermal)	9/25/2017	ND	ND
S170711-11-B		9/25/2017	ND	ND
S170711-11-C		9/25/2017	ND	ND
S170711-13[a]	QS27 (Brodifacoum, Cricket)	N/A	N/A	N/A
S170711-14-A		9/25/2017	ND	73.5

S170711-14-B	QS30 (Brodifacoum, Dermal)	9/25/2017	ND	84.4
S170711-14-C		9/25/2017	ND	83.7
S170711-15-A		9/25/2017	ND	ND
S170711-15-B	QS31 (Diphacinone, Cricket)	9/25/2017	ND	ND
S170711-15-C		9/25/2017	ND	ND
S170711-16-A		9/25/2017	ND	ND
S170711-16-B	QS33 (Diphacinone, Dermal)	9/25/2017	ND	ND
S170711-16-C		9/25/2017	ND	ND
S170711-18-A		9/25/2017	ND	64.1
S170711-18-B	QS35 (Brodifacoum, Cricket)	9/25/2017	ND	65.6
S170711-18-C		9/25/2017	ND	64.0
S170711-19-A		9/25/2017	ND	ND
S170711-19-B	QS39 (Diphacinone, Cricket)	9/25/2017	ND	ND
S170711-19-C		9/25/2017	ND	ND
		DL (ng/g) =	8.9	8.9
		QL (ng/g) =	29.8	29.7

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

[a] No sample available.

Batrachoseps salamanders (whole body)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170711-20-A		9/27/2017	ND	ND
S170711-20-B	QS40 (Diphacinone, Dermal)	9/27/2017	ND	ND
S170711-20-C		9/27/2017	ND	ND
S170711-21-A		9/27/2017	ND	ND
S170711-21-B	QS42 (Brodifacoum, Cricket)	9/27/2017	ND	ND
S170711-21-C		9/27/2017	ND	ND
S170711-22-A		9/27/2017	ND	33.0
S170711-22-B	QS43 (Brodifacoum, Dermal)	9/27/2017	ND	34.1
S170711-22-C		9/27/2017	ND	34.7
S170711-23-A		9/27/2017	ND	ND
S170711-23-B	QS44 (Diphacinone, Cricket)	9/27/2017	ND	ND
S170711-23-C		9/27/2017	ND	ND
S170711-24-A		9/27/2017	ND	ND
S170711-24-B	QS48 (Diphacinone, Dermal)	9/27/2017	ND	ND
S170711-24-C		9/27/2017	ND	ND
S170711-25-A		9/27/2017	ND	ND
S170711-25-B	QS52 (Diphacinone, Cricket)	9/27/2017	ND	ND
S170711-25-C		9/27/2017	ND	ND
S170711-26-A		9/27/2017	ND	ND
S170711-26-B	QS53 (Diphacinone, Dermal)	9/27/2017	ND	ND

S170711-26-C		9/27/2017	ND	ND
S170711-27-A	QS55 (Diphacinone, Dermal)	9/27/2017	ND	ND
S170711-27-B		9/27/2017	ND	ND
S170711-27-C		9/27/2017	ND	ND
S170711-28-A	QS56 (Brodifacoum, Cricket)	9/27/2017	ND	90.8
S170711-28-B		9/27/2017	ND	91.4
S170711-28-C		9/27/2017	ND	86.6
S170711-29-A	QS57 (Brodifacoum, Dermal)	9/27/2017	ND	37.3
S170711-29-B		9/27/2017	ND	35.0
S170711-29-C		9/27/2017	ND	34.2
S170711-30-A	QS58 (Diphacinone, Cricket)	9/27/2017	ND	ND
S170711-30-B		9/27/2017	ND	ND
S170711-30-C		9/27/2017	ND	ND
		DL (ng/g) =	8.9	8.9
		QL (ng/g) =	29.8	29.7

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Crickets

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170711-51	Control Tissue 1/2"	9/13/2017	ND	ND
S170711-52	Control Tissue Pinheads	9/12/2017	ND	ND
S170711-45	Placebo Diphacinone + no potato (PDFC1), n=20	9/13/2017	31.5	ND
S170711-45-A		9/12/2017	31.2	ND
S170711-46	Placebo Diphacinone + no potato (PDFC2), n=21	9/13/2017	18.8	ND
S170711-46-A		9/12/2017	15.8 *	ND
S170711-47	Placebo Diphacinone + no potato (PDFC3), n=24	9/13/2017	19.5	ND
S170711-47-A		9/12/2017	14.6 *	ND
S170711-48	Placebo Brodifacoum + no potato (PBFC1), n=22	9/13/2017	ND	ND
S170711-49	Placebo Brodifacoum + no potato (PBFC2), n=23	9/13/2017	ND	ND
S170711-50	Placebo Brodifacoum + no potato (PBFC3), n=21	9/13/2017	ND	ND
S170602-36-A	Brodifacoum + potato (BFC1), n=15	9/13/2017	ND	296
S170602-36-B		9/13/2017	ND	282
S170602-36-C		9/13/2017	ND	309
S170602-37-A	Brodifacoum + potato (BFC2), n=14	9/13/2017	ND	589
S170602-37-B		9/13/2017	ND	687
S170602-38-A	Brodifacoum + potato (BFC3), n=13	9/13/2017	ND	538
S170602-38-B		9/13/2017	ND	672
S170602-38-C		9/13/2017	ND	528
S170602-39-A	Diphacinone + potato (DFC1), n=11	9/13/2017	1490	ND
S170602-		9/13/2017	1600	ND

39-B				
S170602-40-A	Diphacinone + potato (DFC2), n=15	9/13/2017	3130	ND
S170602-40-B		9/13/2017	3040	ND
S170602-40-C		9/13/2017	2620	ND
S170602-41-A	Diphacinone + potato (DFC3), n=14	9/13/2017	1140	ND
S170602-41-B		9/13/2017	1260	ND
S170711-33-A	Brodifacoum + no potato (BFC4), n=24	9/13/2017	ND	495
S170711-33-B		9/13/2017	ND	519
S170711-33-C		9/13/2017	ND	530
S170711-34-A	Brodifacoum + no potato (BFC5), n=23	9/13/2017	ND	423
S170711-34-B		9/13/2017	ND	420
		DL (ng/g) =	4.9	5.9
		QL (ng/g) =	16.2	19.7

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Crickets

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170711-35-A	Brodifacoum + no potato (BFC6), n=23	9/13/2017	ND	560
S170711-35-B		9/13/2017	ND	638
S170711-35-C		9/13/2017	ND	490
S170711-36-A	Diphacinone + no potato (DFC4), n=27	9/12/2017	1060	ND
S170711-36-B		9/12/2017	950	ND
S170711-36-C		9/12/2017	943	ND
S170711-37-A	Diphacinone + no potato (DFC5), n=27	9/12/2017	907	ND
S170711-37-B		9/12/2017	1140	ND
S170711-37-C		9/12/2017	1050	ND
S170711-38-A	Diphacinone + no potato (DFC6), n=21	9/12/2017	2040	ND
S170711-38-B		9/12/2017	2350	ND
S170711-38-C		9/12/2017	1720	ND
S170711-39-A	Diphacinone + dusted (DD1), n=23	9/12/2017	1740	ND
S170711-39-B		9/12/2017	1950	ND
S170711-39-C		9/12/2017	1780	ND
S170711-40-A	Diphacinone + dusted (DD2), n=25	9/12/2017	3090	ND
S170711-40-B		9/12/2017	3490	ND
S170711-40-C		9/12/2017	3410	ND
S170711-41-A	Diphacinone + dusted (DD3), n=18	9/12/2017	4200	ND
S170711-41-B		9/12/2017	4280	ND

S170711-41-C		9/12/2017	3460	ND
S170711-42-A	Brodifacoum + dusted (BD1), n=16	9/12/2017	9.9 *	3320
S170711-42-B		9/12/2017	7.8 *	3080
S170711-42-C		9/12/2017	9.5 *	3260
S170711-43-A	Brodifacoum + dusted (BD2), n=23	9/12/2017	9.7 *	3620
S170711-43-B		9/12/2017	7.1 *	3220
S170711-43-C		9/12/2017	6.2 *	3180
S170711-44-A	Brodifacoum + dusted (BD3), n=18	9/12/2017	7.1 *	2670
S170711-44-B		9/12/2017	7.5 *	3160
S170711-44-C		9/12/2017	6.0 *	2830
		DL (ng/g) =	4.9	5.9
		QL (ng/g) =	16.2	19.7

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Water (saturated with ground bait)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)
S170602-03-A		10/13/2017	6.31	ND
S170602-03-B	Water/Diphacinone #1	10/13/2017	6.44	ND
S170602-03-C		10/13/2017	6.15	ND
S170602-04-A		10/13/2017	9.02	ND
S170602-04-B	Water/Diphacinone #2	10/13/2017	9.63	ND
S170602-04-C		10/13/2017	8.74	ND
S170602-05-A		10/13/2017	17.6	ND
S170602-05-B	Water/Diphacinone #3	10/13/2017	18.0	ND
S170602-05-C		10/13/2017	17.6	ND
S170606-01-A		10/13/2017	3.52	ND
S170606-01-B	Water/Diphacinone #4	10/13/2017	3.34	ND
S170606-01-C		10/13/2017	3.39	ND
S170606-02-A		10/13/2017	4.84	ND
S170606-02-B	Water/Diphacinone #5	10/13/2017	4.89	ND
S170606-02-C		10/13/2017	4.77	ND
S170606-03-A		10/13/2017	3.89	ND
S170606-03-B	Water/Diphacinone #6	10/13/2017	3.57	ND
S170606-03-C		10/13/2017	3.36	ND
S170602-06-A		10/13/2017	ND	5.78
S170602-06-B	Water/Brodifacoum #1	10/13/2017	0.080 *	5.78
S170602-		10/13/2017	ND	5.69

06-C				
S170602-07-A	Water/Brodifacoum #2	10/13/2017	0.125 *	29.3
S170602-07-B		10/13/2017	0.147 *	29.6
S170602-07-C		10/13/2017	0.133 *	29.5
S170602-08-A		10/13/2017	0.131 *	29.9
S170602-08-B	Water/Brodifacoum #3	10/13/2017	0.110 *	28.6
S170602-08-C		10/13/2017	0.127 *	30.7
S170606-04-A		10/13/2017	0.134 *	26.5
S170606-04-B	Water/Brodifacoum #4	10/13/2017	0.109 *	24.7
S170606-04-C		10/13/2017	0.127 *	25.2
S170606-05-A		10/13/2017	0.121 *	18.5
S170606-05-B	Water/Brodifacoum #5	10/13/2017	0.140 *	19.4
S170606-05-C		10/13/2017	0.123 *	19.5
S170606-06-A		10/13/2017	0.100 *	18.9
S170606-06-B	Water/Brodifacoum #6	10/13/2017	0.171 *	18.8
S170606-06-C		10/13/2017	0.119 *	18.4
		DL (ng/mL) =	0.080	0.13
		QL (ng/mL) =	0.267	0.419

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

Baits (Method 163A)

NWRC ID	Sample Description	Analysis Date	Observed Diphacinone Concentration (µg/g)	Observed Brodifacoum Concentration (µg/g)
S170925-01-D	Placebo Diphacinone Bait	10/27/2017	0.424 [a]	ND
S170925-01-E		10/27/2017	0.266 [a]	ND
S170925-01-F		10/27/2017	0.278 [a]	ND
S170925-02	Placebo Brodifacoum Bait	10/27/2017	ND	ND
S170925-03-D	Diphacinone Conservation 50 (0.0050%) Bait	10/27/2017	46.8	ND
S170925-03-E		10/27/2017	46.3	ND
S170925-03-F		10/27/2017	46.1	ND
S170925-04-D	Brodifacoum Conservation 25 (0.0025%) Bait	10/27/2017	ND	26.0
S170925-04-E		10/27/2017	ND	27.2
S170925-04-F		10/27/2017	ND	25.8
		DL (µg/g) =	2.8	0.043
		QL (µg/g) =	9.40	0.142

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

* Results reported with an asterisk denote concentrations less than the Quantitation Limit (QL).

[a] Method 163A is not sufficiently sensitive to detect diphacinone concentrations less than 2.8 µg/g. To better assess trace level contamination in the baits extracts were also tested by a more sensitive LCMS method with detection limits of 0.0072 µg/g for diphacinone and 0.0081 µg/g for brodifacoum. The placebo diphacinone bait (S170925-01) had diphacinone concentrations of 0.278 – 0.424 µg/g. None of the other baits had detectable contamination.

QC Results:

QC Recoveries – *Ensatina* Salamander (whole body, S170602-13)

ID	Analysis Date	Theoretical Diphacinone Concentration (ng/g)	Observed Diphacinone Concentration (ng/g)	% Recovery	Theoretical Brodifacoum Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)	% Recovery
QC-41	9/14/2017	0	ND	N/A	0	ND	N/A
QC-42	9/14/2017	0	ND	N/A	0	ND	N/A
QC-43	9/14/2017	0	ND	N/A	0	ND	N/A
QC-44	9/14/2017	52.9	53.4	101%	52.7	61.3	116%
QC-45	9/14/2017	53.5	54.8	102%	53.3	66.7	125%
QC-46	9/14/2017	52.0	51.1	98.3%	51.8	64.6	125%
QC-47	9/14/2017	427	400	93.7%	425	508	120%
QC-48	9/14/2017	393	364	92.6%	391	472	121%
QC-49	9/14/2017	400	364	91.0%	398	448	113%
QC-50	9/14/2017	4400	4240	96.4%	4380	4750	108%
QC-51	9/14/2017	4360	4250	97.5%	4340	4720	109%
QC-52	9/14/2017	4380	4200	95.9%	4370	4850	111%
		DL (ng/g) =	5.9		DL (ng/g) =	6.6	
		QL (ng/g) =	19.6		QL (ng/g) =	21.9	

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

QC Recoveries – *Aneides* Salamanders (whole body, S170711-31)

ID	Analysis Date	Theoretical Diphacinone Concentration (ng/g)	Observed Diphacinone Concentration (ng/g)	% Recovery	Theoretical Brodifacoum Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)	% Recovery
QC-29	9/28/2017	0	ND	N/A	0	ND	N/A
QC-30	9/28/2017	0	ND	N/A	0	ND	N/A
QC-31	9/28/2017	0	ND	N/A	0	ND	N/A
QC-32	9/28/2017	53.3	64.1	120%	53.1	62.1	117%
QC-33	9/28/2017	52.6	48.3	91.8%	52.4	60.1	115%
QC-34	9/28/2017	51.5	49.4	95.9%	51.3	50.3	98.1%
QC-35	9/28/2017	407	389	95.6%	405	428	106%
QC-36	9/28/2017	401	382	95.3%	400	400	100%
QC-37	9/28/2017	409	406	99.3%	407	428	105%
QC-38	9/28/2017	4110	4010	97.6%	4090	4140	101%
QC-39	9/28/2017	4410	4310	97.7%	4390	4570	104%
QC-40	9/28/2017	4340	4330	99.8%	4320	4400	102%
		DL (ng/g) =	7.5		DL (ng/g) =	8.6	
		QL (ng/g) =	25.1		QL (ng/g) =	28.6	

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

QC Recoveries – *Batrachoseps* Salamanders (whole body, S170602-29)

ID	Analysis Date	Theoretical Diphacinone Concentration (ng/g)	Observed Diphacinone Concentration (ng/g)	% Recovery	Theoretical Brodifacoum Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)	% Recovery
QC-53	9/19/2017	0	ND	N/A	0	ND	N/A
QC-54	9/19/2017	0	ND	N/A	0	ND	N/A
QC-55	9/19/2017	0	ND	N/A	0	ND	N/A
QC-65	9/25/2017	0	ND	N/A	0	ND	N/A
QC-66	9/25/2017	0	ND	N/A	0	ND	N/A
QC-67	9/25/2017	0	ND	N/A	0	ND	N/A
QC-77	9/27/2017	0	ND	N/A	0	ND	N/A
QC-78	9/27/2017	0	ND	N/A	0	ND	N/A
QC-79	9/27/2017	0	ND	N/A	0	ND	N/A
QC-56	9/19/2017	53.9	47.7	88.5%	53.7	56.3	105%
QC-57	9/19/2017	51.7	46.5	89.9%	51.5	57.0	111%
QC-58	9/19/2017	52.2	52.8	101%	51.9	55.0	106%
QC-68	9/25/2017	53.9	51.9	96.3%	53.7	64.1	119%
QC-69	9/25/2017	52.9	56.3	106%	52.7	57.9	110%
QC-70	9/25/2017	54.8	55.7	102%	54.5	69.5	128%
QC-80	9/27/2017	53.2	56.7	107%	53.0	57.2	108%
QC-81	9/27/2017	52.2	48.4	92.7%	51.9	61.2	118%
QC-82	9/27/2017	52.7	59.3	113%	52.5	63.0	120%
QC-59	9/19/201	398	371	93.2%	396	346	87.4%

	7						
QC-60	9/19/2017	389	384	98.7%	388	363	93.6%
QC-61	9/19/2017	393	376	95.7%	392	381	97.2%
QC-71	9/25/2017	404	412	102%	402	462	115%
QC-72	9/25/2017	412	395	95.9%	410	483	118%
QC-73	9/25/2017	415	423	102%	413	471	114%
QC-83	9/27/2017	472	483	102%	470	527	112%
QC-84	9/27/2017	468	462	98.7%	466	426	91.4%
QC-85	9/27/2017	469	446	95.1%	467	543	116%
QC-62	9/19/2017	4330	4210	97.2%	4320	4040	93.5%
QC-63	9/19/2017	4410	4200	95.2%	4390	3880	88.4%
QC-64	9/19/2017	4210	4110	97.6%	4200	3640	86.7%
QC-74	9/25/2017	4140	4080	98.6%	4120	4190	102%
QC-75	9/25/2017	4250	4240	99.8%	4230	4330	102%
QC-76	9/25/2017	4320	4320	100%	4300	4380	102%
QC-86	9/27/2017	3570	3490	97.8%	3560	3980	112%
QC-87	9/27/2017	3720	3540	95.2%	3700	4150	112%
QC-88	9/27/2017	3670	3540	96.5%	3650	4060	111%
		DL (ng/g) =	8.9		DL (ng/g) =	8.9	
		QL (ng/g) =	29.8		QL (ng/g) =	29.7	

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

QC Recoveries – Crickets (S170711-52)

ID	Analysis Date	Theoretical Diphacinone Concentration (ng/g)	Observed Diphacinone Concentration (ng/g)	% Recovery	Theoretical Brodifacoum Concentration (ng/g)	Observed Brodifacoum Concentration (ng/g)	% Recovery
QC-1	9/13/2017	0	ND	N/A	0	ND	N/A
QC-2	9/13/2017	0	ND	N/A	0	ND	N/A
QC-3	9/13/2017	0	ND	N/A	0	ND	N/A
QC-13	9/12/2017	0	ND	N/A	0	ND	N/A
QC-14	9/12/2017	0	ND	N/A	0	ND	N/A
QC-15	9/12/2017	0	ND	N/A	0	ND	N/A
QC-4	9/13/2017	54.3	54.2	99.8%	54.1	61.4	113%
QC-5	9/13/2017	54.3	50.4	92.8%	54.0	63.3	117%
QC-6	9/13/2017	57.7	50.8	88.0%	57.5	60.5	105%
QC-16	9/12/2017	54.8	51.1	93.2%	54.6	65.1	119%
QC-17	9/12/2017	53.3	59.5	112%	53.1	59.0	111%
QC-18	9/12/2017	56.5	53.7	95.0%	56.3	62.1	110%
QC-7	9/13/2017	390	349	89.5%	389	447	115%
QC-8	9/13/2017	426	387	90.8%	425	436	103%
QC-9	9/13/2017	399	376	94.2%	397	452	114%
QC-19	9/12/2017	421	408	96.9%	420	464	110%
QC-20	9/12/2017	430	400	93.0%	428	465	109%
QC-21	9/12/2017	404	382	94.6%	403	450	112%

QC-10	9/13/2017	4620	4390	95.0%	4600	4870	106%
QC-11	9/13/2017	4480	4250	94.9%	4460	4780	107%
QC-12	9/13/2017	4480	4150	92.6%	4470	4620	103%
QC-22	9/12/2017	4560	4420	96.9%	4540	4720	104%
QC-23	9/12/2017	4280	4130	96.5%	4270	4310	101%
QC-24	9/12/2017	4610	4440	96.3%	4590	4660	102%
		DL (ng/g) =	4.9		DL (ng/g) =	5.9	
		QL (ng/g) =	16.2		QL (ng/g) =	19.7	

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

QC Recoveries – Water (saturated with ground placebo brodifacoum bait (S170925-02))

ID	Analysis Date	Theoretical Diphacinone Concentration (ng/mL)	Observed Diphacinone Concentration (ng/mL)	% Recovery	Theoretical Brodifacoum Concentration (ng/mL)	Observed Brodifacoum Concentration (ng/mL)	% Recovery
QC-113	10/13/2017	0	ND	N/A	0	ND	N/A
QC-114	10/13/2017	0	ND	N/A	0	ND	N/A
QC-115	10/13/2017	0	ND	N/A	0	ND	N/A
QC-116	10/13/2017	0.924	1.06	115%	0.920	1.04	113%
QC-117	10/13/2017	0.924	1.12	121%	0.920	1.11	121%
QC-118	10/13/2017	0.924	1.03	111%	0.920	1.01	110%
QC-119	10/13/2017	10.4	11.0	106%	10.3	11.0	107%
QC-120	10/13/2017	10.4	11.1	107%	10.3	11.0	107%
QC-121	10/13/2017	10.4	11.0	106%	10.3	10.8	105%
QC-122	10/13/2017	74.8	79.0	106%	74.5	64.7	86.8%
QC-123	10/13/2017	74.8	79.0	106%	74.5	67.0	89.9%
QC-124	10/13/2017	74.8	78.7	105%	74.5	66.6	89.4%
		DL (ng/mL) =	0.080		DL (ng/mL) =	0.13	
		QL (ng/mL) =	0.267		QL (ng/mL) =	0.419	

ND Not Detected. This was reported when no response was detected or when the result was less than the Detection Limit (DL).

QC Recoveries – Baits (Method 163A, S170925-02)

ID	Analysis Date	Theoretical Diphacinone Concentration (µg/g)	Observed Diphacinone Concentration (µg/g)	% Recovery	Theoretical Brodifacoum Concentration (µg/g)	Observed Brodifacoum Concentration (µg/g)	% Recovery
QC-137	10/27/2017	0	ND	N/A	0	ND	N/A
QC-138	10/27/2017	0	ND	N/A	0	ND	N/A
QC-139	10/27/2017	0	ND	N/A	0	ND	N/A
QC-140	10/27/2017	52.5	51.6	98.3%	27.1	25.9	95.6%
QC-141	10/27/2017	51.8	53.4	103%	26.7	26.3	98.5%
QC-142	10/27/2017	52.5	52.2	99.4%	27.1	26.6	98.2%
		DL (µg/g) =	2.8		DL (µg/g) =	0.043	
		QL (µg/g) =	9.40		QL (µg/g) =	0.142	

QC Recoveries – Baits (LCMS Method, S170925-02)

ID	Analysis Date	Theoretical Diphacinone Concentration (µg/g)	Observed Diphacinone Concentration (µg/g)	% Recovery	Theoretical Brodifacoum Concentration (µg/g)	Observed Brodifacoum Concentration (µg/g)	% Recovery
QC-137	10/27/2017	0	ND	N/A	0	ND	N/A
QC-138	10/27/2017	0	ND	N/A	0	ND	N/A
QC-139	10/27/2017	0	ND	N/A	0	ND	N/A
QC-140	10/27/2017	52.5	64.7	123%	27.1	18.0	66.4%
QC-141	10/27/2017	51.8	64.6	125%	26.7	17.7	66.3%
QC-	10/27/20	52.5	64.7	123%	27.1	17.3	63.8%

142	17				
		DL (µg/g) =	0.0072	DL (µg/g) =	0.0081
		QL (µg/g) =	0.0241	QL (µg/g) =	0.0270