

The Farallon Islands



- Island group 28 mi. (45 km) offshore from San Francisco: 85 ha of land area
- Protected as a National Wildlife Refuge, surrounded by the Gulf of the Farallons National Marine Sanctuary
- Five breeding species of pinnipeds:
 - Northern elephant seals (*Mirounga angustirostris*)
 - Harbor seal (*Phoca vitulina*)
 - California sea lion (*Zalophus californianus*)
 - Steller sea lion (*Eumetopias jubatus*)
 - Northern fur seal (*Callorhinus ursinus*)
- Largest seabird breeding colony in continental US: 250,000 birds, 12 species
 - Four Species of Special Concern:
 - Rhinoceros auklet (*Cerorhinca monocerata*)
 - Cassin's auklet (*Ptychoramphus aleuticus*)
 - Ashy storm-petrel (*Oceanodroma homochroa*)
 - Tufted puffin (*Fratercula cirrhata*)

Introduced Species and Island Ecosystems



It is now widely accepted that current rates of species extinctions are dramatically higher than historical rates. Most current extinctions can be directly attributed to human activity, and that for ethical, cultural, aesthetic, and economic reasons, this current rate of extinction is cause for considerable concern. The causes of anthropogenic extinctions can be roughly divided into four broad categories: non-sustainable use of resources, habitat destruction, pollution, and introduction of non-native species.

Problems in the first three categories are often acute and can directly affect human welfare on an observable time scale. These qualities have made them the focus of public environmental concern. The introduction of non-native species has received less publicity and professional attention; however, introduced species are responsible for 39% of all recorded animal extinctions since 1600 for which a cause could be attributed. Thus, some impacts of introduced species are irreversible, and at least as devastating as the other categories. Once established, introduced species often become permanent in ecological time, unless intentionally removed.



Island ecosystems are particularly vulnerable to both extinctions and the impacts of introduced species. Of the 484 recorded animal extinctions since 1600, 75% have been island endemics. Introduced species were completely or partially responsible for 67% of these extinctions.

Islands are important to the conservation of biodiversity for four reasons:

- 1) A large percentage of their biota are endemic species and subspecies;
- 2) They are important breeding areas for seabirds, pinnipeds, and sea turtles, which forage over thousands of square kilometers of ocean but are dependent on relatively small amounts of protected land on islands for breeding and nesting;
- 3) Many islands are sparsely or uninhabited by humans, keeping socioeconomic costs of protection low;
- 4) The species and ecological communities on islands have evolved in natural fragments, making them less susceptible than continental species to the problems of habitat fragmentation caused by small reserve size.

Thus, islands are an obvious target for conservation efforts – the functionality of their ecosystems can be maintained with minimal management and without large expenditures for land acquisition or significant conflict with local human populations.

The most significant single restoration action on many islands is the removal of one or more harmful introduced species, an action that, alone or in conjunction with a comprehensive restoration plan, results in immediate as well as long-term tangible ecosystem recovery.

Introduced Mice and Island Ecosystems

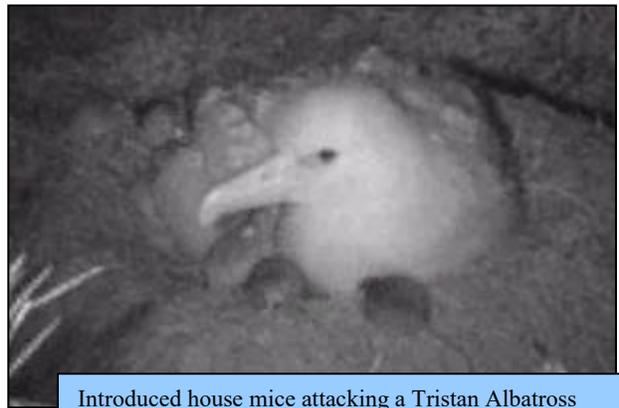


The house mouse (*Mus musculus*) is among the most widespread of all mammals, a result of its close association with humans and the relative ease with which it can be transported and introduced to new locations. House mice are among the vertebrates considered to be “significant invasive species” on islands of the South Pacific and Hawaii, having probably reached all inhabited islands in the Pacific as well as numerous uninhabited islands.

House mice on islands are generalist consumers, eating seeds, invertebrates, small reptiles, and the eggs and even chicks of island birds. Their diet has the potential to harm terrestrial ecosystem functions at numerous trophic levels.

Examples

On Gough Island in the South Atlantic Ocean, house mice appear to be a significant predator of the rare Tristan albatross and Atlantic petrel. Mice have been documented on numerous occasions predated the chicks of these birds, and their low breeding success in recent years (27.3% and 19.9%, respectively) has been attributed to predation by mice. Furthermore, house mice on Gough Island appear to be determining the distribution of the endemic Gough bunting – bunting nests are scarce in areas where mice are abundant, and artificial nest studies have shown a high level of mouse predation in areas of high mouse density.



Introduced house mice attacking a Tristan Albatross chick, Gough Island.

On sub-Antarctic Marion Island, house mice are significantly impacting the island’s invertebrate communities, especially the larvae of endemic moths and adult endemic weevils. At the same time, Marion’s population of lesser sheathbills *Chionis minor*, which feed on the invertebrates affected by the mice, has declined 23% over the past two decades. Lesser sheathbills on a nearby mouse-free island have showed no population change, indicating that mice are out-competing the sheathbills for resources and thereby causing their decline.

Increased predation by house mice caused the capture rate for McGregor’s skink (*C. macgregori*) to decline on Mana Island, New Zealand. After successful mouse eradication, the populations of McGregor’s skink, the gecko *Hoplodactylus maculatus*, and the endemic giant cricket (*Deinacrida rugosa*) increased significantly.

House Mice on the Farallon Islands

History

Although it is unknown when house mice (*Mus musculus*) first appeared on the South Farallon Islands (SFI), composed of Southeast Farallon, West End, and numerous offshore rocks, anecdotal evidence suggests that they arrived early in the sequence of human activities, which began in the late 1700s. They were well established when the US Fish & Wildlife Service incorporated the island into the Farallon National Wildlife Refuge in 1969. Mice could have been introduced, presumably by accident, by any of the island's previous occupants, including Russian sealers, egg collectors, lighthouse keepers, the Navy, or the Coast Guard.

Likely impacts of house mice on species of the Farallons

Seabirds

On SFI, introduced house mice appear to be impacting the breeding success of burrow nesting seabirds, particularly the ashy storm-petrel. House mice are known predators of eggs and chicks of the ashy storm-petrel, and records of mouse predation on ashy storm-petrels exist for the Farallons.

More importantly, the mice appear to be indirectly responsible for declining breeding populations of the ashy storm-petrel (and to a lesser extent the Cassin's auklet) on SFI due to "hyperpredation" by non-resident, predatory owls. This ecological term describes a process in which a local prey species (ashy storm-petrel or Cassin's auklet) declines due to predation pressure from a predator (owls that normally are not resident on the Farallons) sustained by an alternative prey, in this case the non-native house mice. Over-wintering owls, which are artificially sustained by mice during the fall season but forced to find an alternative food source once the mouse population crashes in the winter, are thought to cause significant mortality to the ashy storm-petrel population and have a similar, but less severe impact on the Cassin's auklet population. See "Hyperpredation" for details.

Farallon Arboreal Salamander *Aneides lugubris farallonensis*

There is overlap in the diet of mice and the Farallon endemic arboreal salamander, and the seasonal abundance of the mice likely limits resource availability for salamanders. Furthermore, the food preferences of introduced mice on other islands indicate that mice on the Farallons likely prey directly on salamanders.

Terrestrial Invertebrates

House mice are known to prey on invertebrates on the Farallons. Comparisons to other islands with introduced house mice indicate that mice may have a substantial impact on the invertebrate community.

Native Plants and Weed Dispersal

The native flora of the Farallon Islands has evolved in the absence of rodents, while most of the island's introduced plants have evolved on the mainland, in the presence of rodents. Consequently, house mice are likely to benefit introduced plants, especially those that rely at least partially on rodents for seed dispersal on the mainland, more than Farallon endemics. Seeds of the endemic Farallon weed (*Lasthenia maritima*), in particular, are known to be a common food item for mice on the Farallons.

Introduced plant species are currently identified as a major threat to the Farallon Islands ecosystem. Seeds comprise a substantial portion of the house mouse diet on the Farallons, and thus mice are likely a vector of seed dispersal throughout their habitat. The presence of mice increases the likelihood that introduced plants that have an adaptation to dispersal by rodents will successfully establish and spread on SFI.

Ashy storm-petrel: Endangered on the Farallons

Oceanodroma homochroa



The ash storm-petrel is a small, entirely gray seabird that is found only in the California Current marine system of the west coast of North America. Ashy storm-petrels depend on fewer than 20 breeding sites, all of which are on islands near the coast of California and extreme northern Mexico. Biologists' best estimate is that there are fewer than 10,000 ash storm-petrels, and studies have indicated that their population is undergoing significant decline. The combination of these factors has led the World Conservation Union (IUCN) to list the ash storm-petrel as Endangered.

The Farallon Islands (primarily Southeast Farallon and West End) are the most important single breeding location for ash storm-petrels – it is estimated that 50% of the world's population nests here.

Ashy storm-petrels nest in tight rock crevices. Unlike many other seabirds, they do not dig or in any way alter their nest sites, relying only on the natural crevices of the island. On the Farallons, where ash storm-petrels compete with numerous other seabird species for nesting habitat, they only inhabit crevices with an entrance too small to allow entry for Cassin's auklets, the next-smallest crevice nester on the islands. They come and go from their nests only at night. After choosing a nest, the female ash storm-petrel lays a single egg – the laying of a second egg in one breeding season is extremely rare. Eggs are incubated for an average of 45 days before hatching. Once hatched, chicks are still bound to the nest for an average of 84 days, before finally fledging. Once successfully fledged, ash storm-petrels can live for 35 years or more.



However, between 1972 and 1992, the already small population of ash storm-petrels on the Farallons declined substantially – the number of breeding birds fell by 42%. This decline was attributed primarily to predation on adult breeding birds at the colony. The major known predators of adult ash storm-petrels on the Farallons are resident western gulls, a natural predator of ash storm-petrels throughout their range, and burrowing owls that have chosen to over-winter on the island.

House mice are another documented predator of ash storm-petrels – the only known predation events by mice have been on eggs and unfledged chicks. However, house mice on other oceanic islands prey on juvenile and even adult albatross, which are orders of magnitude larger than petrels.

Hyperpredation

Hyperpredation refers to the ecological phenomenon in which a population of introduced animals provides a population of predators with a new food source that allows the predator population to increase dramatically. This increase in predator numbers in turn leads to dramatically higher predation rates on secondary prey populations, specifically indigenous animals. Hyperpredation has been cited as a cause in declines and extinctions of animals in Australia, as well as on islands throughout the world's oceans. Hyperpredation is also evident on the Farallons – in this case, the players are the visiting predatory burrowing owl, seasonally abundant introduced house mice, and native ashy storm-petrels that use the islands to nest.



Burrowing owls traveling on their migratory route along the coast of California arrive on the Farallons in the fall when there are few or no ashy storm-petrels on the island. However, the island's population of introduced house mouse is at the peak of its annual population cycle coincident with the arrival of the burrowing owls, and food thus appears plentiful on the island to the migrating owls. Lured by the prospect of good hunting, a few owls linger on the island until worsening weather forces them to settle in for the winter.

These over-wintering owls initially have no trouble surviving on the island by preying on the abundant mice, but before long the mouse population crashes precipitously,

once again as a part of their natural population dynamics. With their food resource suddenly depleted, the owls are forced to turn elsewhere for prey. Unfortunately for the ashy storm-petrels, their early winter arrival on the island, to select nest sites and prepare for the breeding season, roughly coincides with the annual mouse population crash.

The hungry burrowing owls turn to these vulnerable seabirds for sustenance. By spring, 70% of the burrowing owl pellets sampled by biologists on the Farallons contain the remains of ashy storm-petrels, indicating that the petrel makes up a large part of the owls' diets. Adult petrel feathers are also commonly found beneath known owl roosting sites.



Ashy storm-petrel feathers below an owl roost

Sadly, a diet rich in seabirds is an unconventional one for burrowing owls, and by the spring season most of the overwintering owls are found dead from undernourishment. Thus, each year this cycle of predation facilitated by introduced house mice claims victims at both ends of the trophic hierarchy, IUCN-listed ashy storm-petrels and burrowing owls (protected under the Migratory Bird Treaty Act).

Proposed Project

Habitat Recovery through House Mouse Control

Farallon National Wildlife Refuge is evaluating potential methods to control or eradicate house mice (*Mus musculus*) from the South Farallon Islands (SFI, composed of Southeast Farallon Island, West End Island, and the surrounding rocks immediately offshore).

Possible methods include control of house mice or total eradication using rodenticides or other techniques. One option that has been used successfully for eradication elsewhere is a precision broadcast of grain-based rodenticide laced pellets delivered into the environment by hand, in bait stations, or aerially with a helicopter.

Conservation Benefits

The removal of house mice is predicted to have a number of positive effects on the ecosystems of SFI:

Seabirds – House mouse removal will eliminate a direct predator to the IUCN-listed Endangered ashy storm-petrel *Oceanodroma homochroa*. More importantly, mouse removal will eliminate a major food source for visiting burrowing owls, and this decrease in food resources will prevent owls from over-wintering and on the islands and consequently preying heavily on ashy storm-petrels.

Native terrestrial vertebrates (Farallon arboreal salamander) – House mice compete for food resources with the Farallon endemic salamander subspecies *Aneides lugubris farallonensis*, and may also prey directly on the salamanders. Mouse removal will increase habitat quality for this unique Farallon species.

Terrestrial invertebrates – House mouse removal from islands has been shown to increase local populations of native invertebrates significantly. Mouse removal is predicted to have a noticeable positive effect on the Farallons' invertebrate communities.

Flora – Native Farallon weed (*Lasthenia maritime*) comprises a substantial portion of the diet of house mice on the Farallons. Mouse removal is predicted to have a positive effect on recruitment in Farallon weed. Furthermore, mice are a known dispersal vector of introduced plant seeds – mouse removal will eliminate this vector from SFI and thereby decrease the likelihood of the establishment and spread of certain introduced plant species.

Precedent

Mice have been successfully removed from over 20 islands worldwide. Brodifacoum rodenticide was used as the primary eradication method in more than 75% of the successful eradications for which methods were documented.

Protecting Non-target Species

The need to protect the Farallons' terrestrial and marine ecosystems from negative impacts due to mouse control activities is of paramount importance. The use of rodenticides may present some risks to non-target individuals, and every reasonable effort will be made to protect individual native species. However, these risks are only biologically significant if rodenticide use might have a population-level effect on one or more species. Initial scoping has not identified any species endemic to the Farallons that would be affected by rodenticide application. The potential risks of

rodenticide use to non-target organisms can be mitigated in two ways: 1) by using a rodenticide that is relatively taxon-specific to eliminate toxicity to non-target organisms; and 2) by minimizing exposure of the rodenticide to non-target organisms by a) timing its application for a period when island natives and migrants are absent or at their lowest seasonal numbers, b) delivering the rodenticide in a form that is unattractive to potentially vulnerable species, and c) carefully calculating the amount of rodenticide applied to effectively reach 100% of the target population with as little excess as possible.

In the case of the Farallons, the rodenticide recommended for mouse control, brodifacoum, is taxon-specific – it affects most vertebrates, but has been shown to be harmless to reptiles and invertebrates. Rodenticide would be applied at a time when there are no breeding seabirds present on the island, and few or no roosting or migratory individuals. Bait pellets would be large enough in size to prevent their consumption by any vagrant small birds, and dyed green, a color that has been shown to be unattractive to granivorous passerines.

Project Status/Next Steps: Compliance

Environmental Compliance Phase

- ◆ NEPA compliance
- ◆ Additional permits

The National Environmental Policy Act (NEPA)

Requirements

- ◆ Environmental Impact Statements
 - Outlines proposed project
 - Alternatives to proposed project
 - Environmental issues & concerns
 - Environmental impact (if any) of each project alternative

The NEPA Process

- ◆ Internal (government) scoping of proposed project
- ◆ Public comment period on proposed project
- ◆ Creation & release of required reports

Additional Permits

- ◆ As required by law, depending on the project actions ultimately chosen as a result of the NEPA scoping process

Funding



National Fish and Wildlife Foundation (NFWF)

Providing funding for the National Environmental Policy Act (NEPA) compliance process (required for US Fish & Wildlife activities)

Cooperating Organizations

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