KAHO`OLAWE
Island Seabird Restoration Project

A BUSINESS PLAN
for the Restoration of Hawaiian Bird Life & Native Ecosystems on **KAHO`OLAWE**




Kahoʻolawe Island Reserve Commission
July 2015

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Pilina ‘Āina – Renewing Connections


Ka manu kāhea i ka wa‘a e holo
The kioea bird that calls to the canoe to go fish

‘Ōlelo No‘eau: Hawaiian Proverbs and Poetical Sayings. Mary Kawena Pukui, 1983.

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Front Cover(Clockwise): Red-Tailed Tropicbird Chick - photo by James Bruch/KIRC, Kumu Sabra Kauka releases a Newell's Shearwater – photo by Tracy Anderson, Island of Kahoʻolawe – KIRC Archive, Laysan Millerbird Nest – photo by Megan Dalton.

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Executive Summary

The Kahoʻolawe Island Seabird Restoration Project business plan for the restoration of Hawaiian birdlife and native ecosystems on Kahoʻolawe outlines the restoration of Kahoʻolawe Island through the removal of feral cats, rats and mice (*Felis catus, Rattus exulans, Mus musculus*). This document investigates and addresses the biological, cultural, financial and regulatory implications associated with the eradication. This document is part of the Kahoʻolawe Island Reserve Commission (KIRC) decision making process as the organization explores this conservation action.

Kahoʻolawe Island is approximately 45 mi² (116.5 km²), and is located 6 mi (9.7 km) southwest of Maui. The island and its surrounding waters extending 2 mi (3.2 km) offshore comprise the Kahoʻolawe Island Reserve. Kahoʻolawe has a rich history. The entire island is included in the National Register of Historic Places, with 544 recorded archeological and historic sites and over 2,000 individual features. Situated on the leeward side of Maui, Kahoʻolawe experiences persistent trade winds and limited rainfall ranging from 10-25 inches annually. Large areas are eroded and bare of vegetation with approximately one third of island as exposed hardpan. Much of the erosion was caused by cattle and sheep, when the island was used for ranching, and by goats, which ran unchecked for almost over 100 years until they were eradicated in 1993 (Kolman 2011).

At the onset of World War II, martial law was declared and Kahoʻolawe was taken over by the U.S. Navy resulting in the island being usedas a military training ground, firing range, and bombing target. In 1976 a grass roots movement led by the Protect Kahoʻolawe ʻOhana sued the U.S. Navy, seeking enforcement of laws governing protection of the island's environment, preservation of historic sites, and freedom to practice their religion. A Federal consent decree signed in 1980 restricted the bombing and gave the group regular access to the island for religious, cultural and educational activities. As a result of the consent decree the island was transferred to the State of Hawaiʻi. In 1993, Act 340 was passed by the Hawaiʻi State Legislature which established the KIRC under the Hawaiʻi Revised Statutes, Chapter 6K. Today, the KIRC's mandate is to manage Kahoʻolawe, its surrounding waters, and its cultural and environmental resources, in trust for the general public and for a future Native Hawaiian sovereign entity. The eradication of feral cats, rats and mice and the rehabilitation of Hawaiian birdlife and native ecosystems support this goal.

The KIRC Vision Statement is:

> The kino of Kanaloa is restored. Forests and shrublands of native plants and other biota clothe its slopes and valleys. Pristine ocean waters and healthy reef ecosystems are the foundation that supports and surrounds the island.
>
> Na poʻe Hawaiʻi care for the land in a manner which recognizes the island and the ocean of Kanaloa as a living spiritual entity. Kanaloa is a *puʻuhonua* and *wahi pana* where Native Hawaiian cultural practices flourish.
>
> The piko of Kanaloa is the crossroads of past and future generations from which the Native Hawaiian lifestyle spreads throughout the islands.

As stated in the KIRCs vision statement, cultural integration is emphasized in all facets of Kaho'olawe's restoration. "Kaho'olawe serves as a cultural resource, particularly for Native Hawaiians, because it links the past traditions with contemporary practices. It is a place where cultural practices continue to be observed" (KICC 1993). The KIRC staff maintains the cultural essence of Kaho'olawe by adhering to the cultural protocols outlined by the Edith Kanaka'ole Foundation's *'Aha Pāwalu, A Cultural Protocol for Kanaloa-Kaho'olawe*. "Protocol re-establishes an awareness of relationship between people and place. It provides a pervading attitude toward ecological sensitivity tantamount to "*mālama*" and "*aloha āina*". It communicates a code of behavior in respect to places, peoples and things. It is a unifying mechanism giving strength to purpose" (KIRC 1995).

Kaho'olawe is the only island in the Hawaiian archipelago that is dedicated to one of the four major *akua* "gods" and is distinguished by the ancient name of Kanaloa. In Hawaiian context, Kanaloa is associated with the ocean, long distance voyaging and healing. Kanaloa also has many *kinolau* "physical manifestations", one of the most prominent being the *he`e* (octopus) from which there are modern *oli* (chants) used on the island today that refer to the connection of Kanaloa to the island. Referred to as a spiritual wellspring, Kaho'olawe was historically renowned for its adze quarry, excellent fishing grounds and as a training center for celestial navigation in long distance voyaging. Unique to Maui Nui and in particular, Kaho'olawe several "birdmen" petroglyphs are found at various locations on the island; evidence of the indigenous peoples of Kaho'olawe spiritual connection with birds (KICC 1993, Lee and Stasack 1993).

This document is divided into six chapters. Chapter 1 addresses the purpose and need for the eradication of invasive mammalian predators from Kaho'olawe. The eradication action proposed would aid in the protection and restoration of Kaho'olawe's native species and habitats. The 2014-2026 strategic plan for Kaho'olawe addresses the environmental restoration of the island by Renewing Cultural Connections (Pilina 'Āina). Free of introduced vertebrate predators, Kaho'olawe will provide the needed sanctuary for many Hawaiian species at risk [e.g., Laysan Duck (*Anas laysanensis*), Millerbird (*Acrocephalus familiaris*,and Hawaiian Petrel (*Pterodroma sandwichensis*)] from extinction due to habitat loss, introduced predators, and climate change (sea level rise). The removal of feral cats and rodents will support the return of Hawaiian bird life to the island and the return of traditional Hawaiian practices relating to the natural environment including the art of celestial navigation using seabirds for wayfinding for long distance voyaging. The return of an abundance of seabirds will also promote Hawaiian ceremonial practices and the creation of *mele, oli,* and *hula*.

Chapter 2 identifies the cultural protocols that are necessary in order to implement the eradication of invasive vertebrates from Kaho'olawe. The identification of cultural protocols would be developed under the guidance of the *'Aha Pāwalu*and developed with the KIRC and the Protect Kaho'olawe 'Ohana (PKO). Chapter 2 also identifies the steps needed to be undertaken to adhere to both state and federal regulatory compliance processes.

Chapter 3 identifies the possible approaches to the eradication of feral cats and rodents from Kaho'olawe including single and simultaneous multiple-taxa eradication strategies. The eradication would be accomplished by ensuring that every individual within the feral cat and rodent populations could be removed in a manner that minimizes harm to the ecosystem while maintaining a high probability of success. An interdisciplinary team of natural resource managers, cultural experts, and environmental scientists has analyzed the proposed eradication in light of existing conditions and has deemed the eradication feasible and identified relevant effects associated with the implementation compared to taking no action. The options for implementation of the eradication are limited due to the presence of unexploded ordnance (UXO). The strategy for eradicating feral cats and rodents from Kahoʻolawe should balance the need to maximize efficacy while minimizing risk to both personnel and non-target species (native and non-native), while maintaining efficiency (project costs) from the implementation of the project. The preferred approach would remove both feral cats and invasive rodents concurrently, recognizing that there would be a need to employ multiple eradication methods (pesticides, trapping, and hunting) to achieve this goal.

Chapter 4 identifies components of an environmental monitoring program and ecosystem response monitoring to the eradication, undertaken prior to, during and following an eradication. The goal of the environmental monitoring would be to document the presence, fate, and persistence of pesticide(s) in the environment, to identify pathways of exposure to non-target species, and to identify and quantify impacts to non-target animals caused by the eradication. Ecosystem response monitoring identifies ecosystem changes in response to the eradication. Pre-eradication monitoring of target species would be necessary in order to plan for the implementation of the eradication and to determine success of the operation. Post-eradication monitoring of target species would be necessary to document eradication success or to identify the need to implement contingency measures in the event of the continued detection of individuals of the targeted populations.

Chapter 5 outlines the timeline and logistics for the eradication of feral cats and rodents from Kahoʻolawe. The timeline is based on an assumed approach of starting the cat eradication one year prior to the onset of the rodent eradication. Activities associated with the planning of operations for the cat and rodent eradication for Kahoʻolawe are divided into five phases:

- Phase I – Operational planning, compliance, funding acquisition, pre-eradication monitoring
- Phase II – Eradication implementation
- Phase III – Post-eradication monitoring
- Phase IV – Demobilization
- Phase V – Evaluation and Reporting

Chapter 6 describes the budget for the overall project by each phase (described in Chapter 5) based on 2015 $US dollars. The total project budget is estimated to be $9,099,528. Chapter 6 also evaluates different strategies that may be undertaken to acquire funding for all phases of the project.

There are few conservation opportunities in Hawaii, or the United States, that can match the potential of Kahoʻolawe. This one time investment to remove invasive mammalian predators from the island will pay long term dividends both biologically and culturally. As sea level rise and climate change reduce habitat in other parts of the state, an invasive mammal free Kahoʻolawe will provide refuge and critical habitat for displaced species and individuals long into the future.Combined with appropriate management of wetland habitats, Kahoʻolawe coul dserve as releasesites for nēnē and Laysan ducks (Henry 2006). Coastal habitat for endangered turtles and seals would also be enhanced and native Hawaiian dry upland forests would provide culturally important natural resources in the form of plants and animals. In total, 16 endangered species and 27 species of concern listed in conservation and recovery plans (Appendix B) can benefit from this unparalleled conservation opportunity while providing refugia and a thriving native Hawaiian ecosystem.

Invasive species eradications are complex conservation actions that involve the cooperation and coordination of stakeholders, state and federal agencies, private institutions and community members. While daunting in scope and scale, eradication of invasive mammals from islands is a relatively brief endeavor that can result in long-term benefits. The cultural and biological value of creating nearly 45 square miles of invasive mammalian predator-free habitat for native Hawaiian species threatened with extinction and ensuring that culturally important natural resources (e.g., plants, seabirds) are safeguarded within the main Hawaiian Islands cannot be overstated.

KAHO`OLAWE ISLAND • SEABIRD RESTORATION PROJECT

Chapter 1- Purpose and Need

Purpose of this Business Plan

The “Kaho‘olawe Island Seabird Restoration Project: A Business Plan for the restoration of Hawaiian birdlife and native ecosystems on Kaho‘olawe" is a scoping document that is part of the Kaho‘olawe Island Reserve Commission (KIRC) decision making process to address the biological, cultural, financial, social and regulatory implications associated with the eradication of feral cats and introduced rodents (*Felis catus, Rattus exulans, Mus musculus*) from Kaho‘olawe.

Description of Kaho‘olawe Island

Kaho‘olawe Island is approximately 11,520 ha (45 sq. mi) and is located 9.7 km (6 mi) southwest of Maui (Figure 1.1).The island and its surrounding waters extending 3.2 km (2 mi) offshore comprise the Kaho‘olawe Island Reserve, which is currently managed by the KIRC.The KIRC is charged with protecting and restoring the Reserve’s cultural and environmental resources while it is held in trust for a future Native Hawaiian sovereign entity.The entire island is included in the National Register of Historic Places, with 544 recorded archeological and historic sites and over 2,000 individual features.

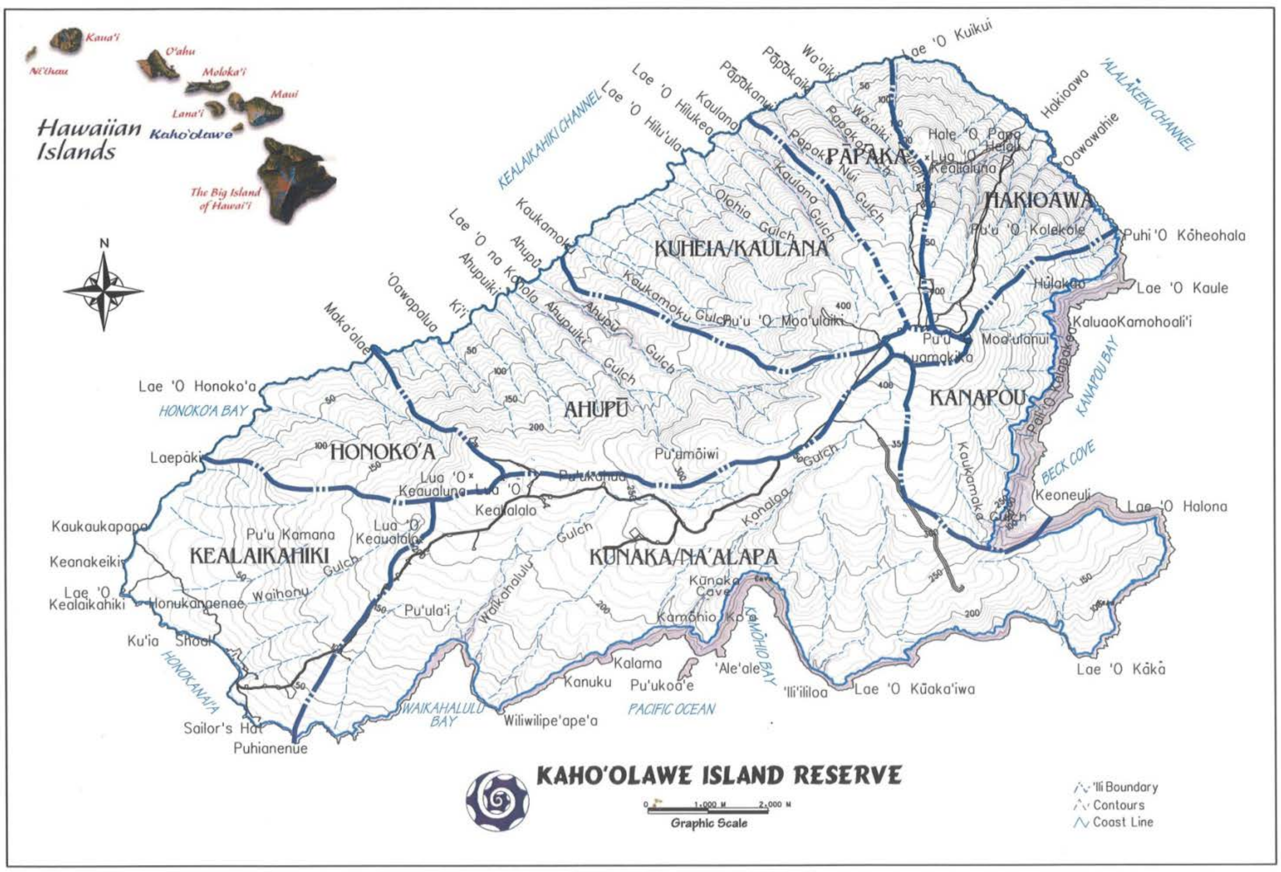

Figure 1.1. Kaho‘olawe showing its nine ‘ili (land divisions) and other place names. Kaho‘olawe’s location within the Hawaiian Islands is indicated in the upper left-hand corner.

Kahoʻolawe has a long history of human use and habitat modifications and the island ecosystems has been extensively degraded by human activities over the last 1000 years. The island was once inhabited by Native Hawaiian subsistence farmers and fisherman. Hawaiian dryland agriculture, seabird harvesting and the introduction of Polynesian rats (*Rattus exulans*), dogs and pigs impacted the native biota (Spriggs 1985, quoted in Lindsey et al. 1997), and it is possible that the dogs removed seabirds from accessible areas of the island in prehistoric times.The introduction of feral goats in 1793 and of domestic sheep, cattle and horses in the 19th century (King 1993, Tomich 1986) destroyed much of the vegetative cover on the island, resulting in its current degraded state. Uncontrolled grazing by feral ungulates was perhaps the most destructive, as goats and cattle removed much of the island's vegetation, exposing topsoil and leading to widespread erosion.Over 30% of the island is now barren hardpan, and the rest is dominated by alien vegetation, primarily kiawe (*Prosopis pallida*) and buffel grass (*Cenchrus ciliaris*).

Feral dogs were present before the island was occupied by European ranchers (King 1993). European rodents (mice and possibly black rats) probably arrived on Kahoʻolawe soon after they arrived in Hawai'i (in 1816 and after 1870, respectively; Tomich 1986). Cats were first reported in 1937 but it is probable that they arrived soon after the first ranching ventures – if not before. The island was used exclusively as a U.S. Navy live fire training area andbombing range from 1941-1990.

Feral dogs, pigs, goats, and domestic stock have all now been removed with the last goat removed in 1993. A ten-year clearance project of unexploded ordnance (UXO) ended in 2004 with only 10% of the island cleared to a depth of four feet and 69% of the island surface-cleared. Environmental restoration efforts have since preceded including reforestation and coastal restoration with native Hawaiian plants and invasive species control.

Purpose of the Proposed Action

The purpose of the proposed action is to aid the protection and restoration of the native species and habitats of Kahoʻolawe by eradicating all feral cats and introduced rodents from the island. This will be accomplished by ensuring that every individual within the feral cat and introduced rodent populations could be removed in a manner that minimizes harm to the ecosystem while maintaining a high probability of success.

Need for Action

The 2014-2026 strategic plan for Kahoʻolawe addresses the environmental restoration of the island by Renewing Cultural Connections (Pilina ʻĀina). The removal of feral cats and rodents will support the return of Hawaiian bird life to the island and the return of traditional Hawaiian practices relating to the natural environment.

Despite the impacts of the now extirpated ungulates, remnant native habitats and wildlife persist in some areas on Kahoʻolawe, and the surrounding waters support one of the most valued marine ecosystems in the state. Five native terrestrial communities have been identified and include the ʻAkiʻaki (*Sporobolus virginicus*) Coastal Dry Grassland, the Hawaiian Mixed Shrub Coastal Dry Cliff, the ʻIlima (*Sida fallax*) Coastal Dry Shrubland, the Maʻo (Hawaiian cotton - *Gossypium tomentosum*) Coastal Dry Shrubland, and the Pili (*Heteropogon contortus*) Lowland Dry Grassland (Gon et al. 1992)

The sea cliffs and offshore islets, ʻAleʻale and Puʻu koaʻe, are significant nesting areas for seabirds including ʻuʻau kani (Wedge-tail Shearwater -*Puffininus pacificus*), koaʻe ula (red-tailed tropicbird - *Phaethon rubricauda)*and ʻou (Bulwer's Petrel -*Bulweria bulwerii*) and home to rare plants (e.g., the federally listed endangered ʻohai [*Sesbania tomentosa*], Ka palupalu o Kanaloa [*Kanaloa kahoolawensis*]). The coastal ecosystem and nearshore waters support honu (Green sea turtle - *Chelonia mydas*), ʻea (Hawksbill sea turtle - *Eretmochelys imbricata*), naiʻa (Hawaiian spinner dolphin - *Stenella longirostris longirostris*), the endangered īlio holo i ka uaua (Hawaiian monk seal - *Monachus schauinslandi*), and some of the healthiest fish populations in the main Hawaiian Islands (Friedlander and DeMartini 2002). Migratory shorebirds e.g., kōlea (Pacific Golden Plover - *Pluvialis dominica*),kioea (Bristle-thighed Curlew - *Numenius tahitiensis*) use the island as a stopover during migrations to and from arctic breeding grounds. The endangered Blackburn's sphinx moth (*Manduca blackburni*) is also found on Kahoʻolawe. (Mitchell et al. 2005).

Kahoʻolawe, the smallest of the eight main Hawaiian Islands at 45 sq. miles, provides an unprecedented opportunity to protect threatened Hawaiian species, including seabirds. At present, seabird nesting on Kahoʻolawe is restricted to remote cliffs and small offshore islets (Figure 3.5). However, even these remote sites do not provide refuge from feral cats. Cat sign and cat-killed carcasses of seabirds have been observed on the remote seastack of ʻAleʻale (Lindsey et al. 1997). The devastating impacts that feral cats and introduced rodents have on seabirds and other integral components of island ecosystems are well documented (Towns et al. 2006, Hilton and Cuthbert 2010), and it is reasonable to expect that native bird, invertebrate, and plant communities will respond favorably after the eradication of invasive predators.

Seabirds are keystone species that can act as a barometer for the health of ecosystems in Hawaiʻi on the terrestrial and marine level. There are several Management Plans for the native Hawaiian seabirds which address the need for protection of habitat (Lindsey et al. 1997, Mitchell et al. 2005, Morin and Conant 2007, USFWS 1983, USFWS 2004a, and USFWS 2004b). Hawaiʻi's Comprehensive Wildlife Conservation Strategy (Mitchell et al. 2005) calls for the restoration of Kaho'olawe to support native species recovery on the Island. The Regional Seabird Conservation Plan and the United States Shorebird Conservation Plan also call for restoration on Kaho'olawe to support seabird recovery and for the protection of shore bird habitat (Brown et al. 2001, U.S. Fish and Wildlife Service, 2005).

Species of avifauna such as the Laysan albatross (*Phoebastria immutabilis)* are at risk in low lying atolls in the Pacific Northwest Hawaiian Islands. A severe storm during the winter of 2010 caused waves to wash over and destroy albatross and other seabird nests, killing thousands of birds in the process. After the Japan earthquake of March 11, 2011, the subsequent tsunami that was generated displaced and/or killed hundreds of Laysan albatross due to the force of the wave that swept over their nesting habitat at Midway. These events could be harbingers of the future when higher sea levels and more intense storms will make habitat in the North Western Hawaiian Islands less suitable for wildlife. Furthermore, recent research on the potential impacts of climate change in Hawaiʻi suggests that many native species are at risk of habitat loss, population decline, or extinction. USFWS Species Recovery plans for Laysan duck, Laysan Finch, Hawaiian Goose (nēnē), Nihoa Millerbird, and Nihoa Finch all mention a restored Kaho'olawe Island, as a possible reintroduction site.

When free from invasive predators, Kahoʻolawe will provide an unprecedented opportunity to protect Hawaiian species threatened by climate change. This project would improve the habitat for native seabirds on Kahoʻolawe and address the fragmentation of seabird populations which has occurred in the Pacific Islands region.

The Hawaiian Cultural Landscape on Kahoʻolawe

In addition to restoring the environment the proposed action will help rebuild and restore the cultural landscape of Kahoʻolawe. The reestablishment of traditional Hawaiian practices such as Makahiki, and voyaging help reaffirm the goals and vision for the island. The following sections outline traditional cultural practices once practiced on or near Kahoʻolawe that would be enhanced if invasive mammals were removed.

Fig 1.2. *Left*: A *koʻa* at the summit on Kahoʻolawe was built for ceremonial purposes and to attract rain. *Right*: Voyaging canoes are welcomed with the blowing of the *Pū* (Conch shell) at Honokanaiʻa.

The Significance of Seabirds in Hawaiian Culture

Seabirds played an important role in the daily lives of ancient Hawaiians. Observations of the flight paths and behaviors of certain seabirds were used to predict weather, to locate schools of fish, and to indicate the proximity of land when navigating. Some seabirds provided food through their meat and eggs, and others provided feathers for kāhili (feathers standards), ʻahu ʻula (feather capes), and lei. Many expressions and legends also featured seabirds. There are also archeological and historical records of Hawaiian birds from Kahoʻolawe specifically (see Chapter 2).

<u>Navigation</u>

Traditionally important as guides to Polynesian seafarers were the Manu-o-kū (White Tern- *Gygisalba*) and noio (Black Noddy – *Anous minutus*). These birds headout to sea at sunrise to feed for the day but return to land each night, so their flight paths are like compass bearings for voyaging canoe navigators seeking landfall (Thompson 2012). The presence of noio, with its known general range of 40 miles and manu-o-kū, of 120 miles, their presence indicates the proximity of land. Nainoa Thompson, while on the Hokulea voyaging canoe described “a second way of finding the island is to get inside its circle of birds”. (Polynesian Voyaging Society 2007).

<u>Fishing</u>

Polynesian fishermen were often able to locate and even identify schools of fish by paying close attention to the feeding habits and behaviors of the local seabirds. For example, aku (skipjack tuna) could be found where the noio birds gathered above the pīhā (herring), nehu pala (anchovy) and the other small fishes that leaped above the surface to escape the predatory aku. These birds were thought to be companions to the kawakawa (pacific mackerel) and aku (Kamakau 1976). Behaviorally, when in large flocks and unaccompanied by other birds, ā (boobies) are apt be following a fast moving school of ʻahi (yellow-finned tuna), or naiʻa (dolphins). Noio unaccompanied by other birds means very small aku not apt to take hook and individual manu-o-ku circling rapidly would indicate mahi-mahi to the fisherman. Additionally the presence of ʻiwa (great frigatebird) above a flock of ʻā, while a sign of good fishing is also an indication that bad weather is on the way. (Nordhoff 1930).

Featherwork

While not commonly used, someseabird feathers were incorporated into kāhili, ʻahu ʻula, and lei featherwork. Among them the greenish-black, iridescent feathers of the ʻiwa and the white feathers and red or white tail streamers of koaʻe were prized.

Food

ʻUaʻu (Hawaiian petrel - *Pterodroma sandwichensis*) chicks were harvested from burrows and considered a delicacy reserved for aliʻi (Hawaiian royalty). Adult birds were captured in nets or by lighting fires along flight paths to disorient and ground birds (Mitchell et al. 2005). The discovery of archeological "platforms" on Puʻu koaʻe suggests that subsistence harvesting of seabirds may have occurred on Kahoʻolawe (Wood et al. 2003).

Legends and Expressions

In the legend of Nihoʻoleki, noio are guardians of apā (pearl shell lure). The legend of ʻIwa recounts the activities of a smart thief named ʻIwa, and like the main character in this story, ʻiwa birds are known for thievery, or stealing food from other birds. Many Hawaiian proverbs wereindications of weather patterns fishing cues and also included in every day expressions (Appendix D).Among these are:

- *Ka manu ka ʻupu halo ʻalo o ka moana.* The albatross that observes the ocean. Said of a careful observer.
- *Pōhai ka manu maluna, he iʻa ko lalo.* When the birds circle above, there are fish below.
- *Ua hoʻi ka noio ʻau kaiiI uka, ke ʻino nei ka moana*. The seafaring noddy tern has returned to land, for a storm rages at sea.
- *Ua mālie, ke au nei koaʻe*. The weather is clear, the koaʻe (tropicbirds) are leisurely flying.
- *He ʻiwa hoʻohaehae nāulu.* An ʻiwa that teases the rain clouds. Refers to a beautiful maiden or handsome youth who rouses jealousy in others.
- *He koaʻe, manu o ka pali kahakō.* It is the koaʻe bird of the sheer cliffs. An expression of admiration for an outstanding person.

(Pukui 1983)

The Problem of Feral Cats and Introduced Rodents on Islands–Negative Impacts

Impact of feral cats on island ecosystems

Islands support a high diversity of life rich in endemic species and provide critical habitat for seabirds and marine mammals. However, between 80 and 90% of all extinctions in the past 500 years have been island species; more than half of these have been a direct result of invasive species. Feral cats are among the most detrimental of invasive species, causing population decline, extirpation, and extinction in a diverse array of animals (Duffy & Capece 2012), including insects, reptiles, birds, and mammals (Lowe et al. 2000, Nogales et al. 2004). The effects of feral cats are particularly severe on islands (Whittaker 1998).

Feral cats are known to cause numerous extinctions of endemic vertebrates on islands and are included in the list of the 100 worst invasive species (Lowe et al. 2000). Feral cats are the most widespread and possibly the most damaging of the four carnivores on that list. At least 175 vertebrate taxa (25 reptiles, 123 birds, and 27 mammals) are threatened by or were driven to extinction by feral cats on at least 120 islands (Medina et al. 2011). Feral cats on islands contributed to at least 14% (33 species: 2 reptiles, 22 birds, and 9 mammals) of all 238 vertebrate extinctions recorded globally by the *International Union for Conservation of Nature (*IUCN) and feral cats threaten 8% (38) of the 464 species listed as critically endangered (Nogales et al. 2013).

Impact of introduced rodents on island ecosystems

Introduced rodents to island ecosystems have detrimental and fatal consequences to native and endemic species. The impacts from invasive predatory mammals are one of the leading causes of species extinction on islands (Blackburn et al. 2004, Duncan and Blackburn 2007). Specifically, the extinction of many island species of mammal, bird, reptile, and invertebrate have been attributed to the impacts of invasive rats (Andrews 1909, Daniel and Williams 1984, Meads et al. 1984, Atkinson 1985, Tomich 1986, Hutton et al. 2007), and estimates of 40 – 60 percent of all recorded bird and reptile extinctions globally were directly attributable to invasive rats (Atkinson 1985, e.g. Island Conservation analysis of World Conservation Monitoring Centre data).

House mice are an omnivorous species that eat a variety of seeds, fungi, insects, reptiles, other small animals, as well as bird eggs, chicks, and adults. In addition, they are known to have dramatic, negative impacts on endemic arthropods (Rowe et al. 1989, Cole et al. 2000). This direct impact on arthropods in turn has the potential to cause other impacts within an ecosystem, as arthropods are often crucial in the pollination and recruitment strategies used by plants, the decomposition of dead plant and animal matter, and as a food source for other native species (Seastedt and Crossley 1984, Angel et al. 2008). On Marion Island in the southern Indian Ocean, house mice affect populations of a number of endemic invertebrates, especially the Marion flightless moth (*Pringleophaga marioni*), the single most important decomposer on the island (Angel et al. 2008). Furthermore, house mice may affect the amount of food available for native insectivorous species. For example, lesser sheathbill (*Chionis minor*) flocks on Marion Island are much smaller than those on nearby, mouse-free Prince Edward Island, suggesting that food competition from house mice is affecting the Marion Island's lesser sheathbill population (Rowe et al. 1989, Crafford 1990). Mice have also altered the vegetation community on Marion Island, through seed predation, showing a preference for seeds of native plants over introduced ones (Angel et al. 2008).

One of the more surprising effects of mice on islands, given their relatively small size, is the negative impact they can have on seabird and native landbird populations through direct predation on eggs and chicks. This impact appears to be particularly acute when mice are the only invasive mammals present (Angel et al. 2008). On Gough Island in the southern Atlantic Ocean, introduced house mice prey on chicks of the rare Tristan Albatross (*Diomedea dabbenena*), contributing to an unusually low breeding success rate of 27 percent in this declining seabird species (Cuthbert and Hilton 2004). Dramatic video footage has shown mice in the process of killing these large seabirds chicks (up to 10 kg) by burrowing inside the birds and eating their organs while the birds are still alive. The level of predation on the tristan albatross population is unsustainable and if it continues would lead to the extinction of this critically endangered (IUCN) seabird (Wanless et al. 2007). In addition, mice on Gough Island appear to limit the breeding range of the endemic Gough Bunting (*Rowettia goughensis*) to the small amount of mouse-free habitat remaining on the island (Cuthbert and Hilton 2004). Similarly, on Marion Island, where the recent eradication of feral cats left mice as the only invasive mammal on the island, researchers recorded several wandering albatrosses (*Diomedea exulans*) killed by mice (Wanless et al. 2007, Angel et al. 2008).

Even if species are not extirpated, rodents can have negative direct and indirect effects on native species and ecosystem functions. For example, comparisons of rat-infested and rat-free islands, and pre- and post-rat eradication experiments have shown that rats depressed the population size and recruitment of birds (Campbell 1991, Thibault 1995, Jouventin et al. 2003), reptiles (Whitaker 1973, Bullock 1986, Towns 1991, Cree et al. 1995), plants (Pye et al. 1999), and terrestrial invertebrates (Bremner et al. 1984, Campbell et al. 1984). In particular, rats have significant impacts on seabirds, preying upon eggs, chicks, and adults and causing population declines, with the most severe impacts on burrow-nesting seabirds (Atkinson 1985, Towns et al. 2006, Jones et al. 2008). The introduction of rats on Midway Atoll during 1943 decreased seabird populations there and caused the extinction of the Laysan Rail and Laysan Finch (Fisher and Baldwin 1946).

In addition to preying on seabirds, introduced rodents feed opportunistically on plants, and alter the flora communities of island ecosystems (Campbell and Atkinson 2002) in some cases degrading the quality of nesting habitat for birds that depend on the vegetation. On Tiritiri Matangi Island, New Zealand, ripe fruits, seeds, and understory vegetation underwent significant increases after rats were eradicated from the island, indicating the rats' previous impacts on the vegetation (Graham and Veitch 2002).

Rodents are documented to affect the abundance and age structure of intertidal invertebrates directly (Navarrete and Castilla 1993), indirectly affect species richness and abundance of a range of invertebrates (Towns et al. 2009), and contribute to the decline of endemic land snails in Hawaiʻi (Hadfield et al. 1993), Japan (Chiba 2010), and American Samoa (Cowie 2001).

There is also increasing evidence that rats alter key ecosystem properties. For example, total soil carbon, nitrogen, phosphorous, mineral nitrogen, marine-derived nitrogen, and pH are lower on rat-invaded islands relative to rat-free islands (Fukami et al. 2006). In rocky intertidal habitats, invasive rats affected invertebrate and marine algal abundance, changing intertidal community structure from an algae-dominated system to an invertebrate dominated system (Kurle et al. 2008). Such changes led to indirect negative effects of rats causing a reduction in seabird populations and predation by rats often drives seabird colonies to near-extirpation (Moller 1983, Atkinson 1985, McChesney and Tershy 1998). This predation further leads to the loss of seabird-derived nutrients on islands (Fukami et al. 2006). Where rats co-exist with other predators (such as cats or predatory birds) the collective direct effect of introduced predators on seabirds is greater than the sum of the individual impacts because rats also act as a food resource to higher level predators when seabirds are absent from the islands (Moors and Atkinson 1984, Atkinson 1985).

Given the widespread successful colonization of rats on islands and their effect on native species, rats are identified as key species for eradication (Howald et al. 2007) by many managers of island wildlife.

Impacts of feral cats and introduced rodents on Kaho‘olawe’s ecosystem

The lack of suitable habitat for nesting and foraging and the presence of introduced predators are believed to be the principal factors preventing re-establishment of seabirds, waterbirds, and other native wildlife on the main island of Kaho‘olawe (Lindsey et al. 1997, KIRC 1998, Mitchell et al. 2005) (Fig.1.3).

This project looks to eradicate feral cats (*Felis catus*) and rodents and restore Hawaiian plant and wildlife populations to Kaho‘olawe. Hawai‘i’s Wildlife Conservation Strategy also notes the threat posed by cats, and rodents to ground-nesting seabirds and reinforces the need to manage these predators – with emphasis directed towards cats (Mitchell et al. 2005). Mice (*Mus musculus*) are the dominant rodent species on the island and are fairly common year round. Polynesian rats (*Rattus exulans*) are present but uncommon and are the only known rat species on the island. The rodent population experiences seasonal irruptions that coincide with rainfall and vegetation production. Trapping data demonstrates that during years of normal rainfall the abundance of house mice irrupts exponentially within a short period of one to two months. Mouse surveys are carried out on a regular basis and average catches of multiple catch traps range from less than one per trap to over eight per trap during population irruptions. Over a four month periodafter the food resources are used up, the mouse population crashes back down to low levels. This correlation is investigated in more detail in Chapter 3.

Cats and rats are common causes of extirpation of nesting seabirds (Jones et al. 2008), while mice are often seen merely as relatively minor pests and mostly to insular invertebrates (Marris 2000). However, the severe impacts of mice as predators on albatross chicks on Gough Island, are well documented (Cuthbert & Hilton 2004) so their potential impacts on seabird chicks on Kaho‘olawe cannot be discounted.

The removal of sheep, cattle and feral goats from Kaho‘olawe in the last century was a prerequisite for the restoration of the island’s flora and some fauna, but insufficient by itself to achieve all the potential restoration goals. Mice, largely as seed predators, will have some effect on the plants, but their main impact is likely to be on the invertebrate and smaller vertebrate species. Feral cats are probably the main factor inhibiting the natural recolonization of Kaho‘olawe by nesting seabirds. The presence of rodents and feral cats limit the opportunities for active restoration options such as the reintroduction of native species or translocation of rare or endangered species thus utilizing the island as a place of refugia (Parkes 2009). Removal of rodents and cats will also eliminate the risks to human health from zoonoses, such as toxoplasmosis and leptospirosis. (Appendix G)

Figure 1.3. Feral cats are often photographed by camera traps nearby where these seabird carcasses were discovered at Puhianenue.

Eradication of Feral Cats and Introduced Rodents from Islands

The eradication, or complete removal, of one or more invasive alien vertebrates from an island is an exceedingly complex objective that requires detailed planning and thorough engagement of all key stakeholders and the local community (Cromarty et al. 2002). Eradication involves a unique action that results in the complete removal of the target species from the treatment area (typically an entire island). The costs associated with eradications are generally high (Oppel et al. 2010); however, the benefits accumulate in perpetuity if reintroduction is prevented.

Feral cats

Feral cats have been successfully eradicated from 83 islands worldwide (Figure 1.4) (Campbell et al. 2011). Eradicating feral cats from islands has been shown to be an important tool for protecting threatened island species (Donlan and Keitt 1999, Keitt et al. 2002, Keitt and Tershy 2003, Nogales et al. 2004). Island size is one of the most important determinants of successful eradication. The majority of these islands (68 percent) have been smaller than 1,000 acres, with the development of more effective methods, it has become possible to achieve successful results on larger islands (Nogales et al. 2013).

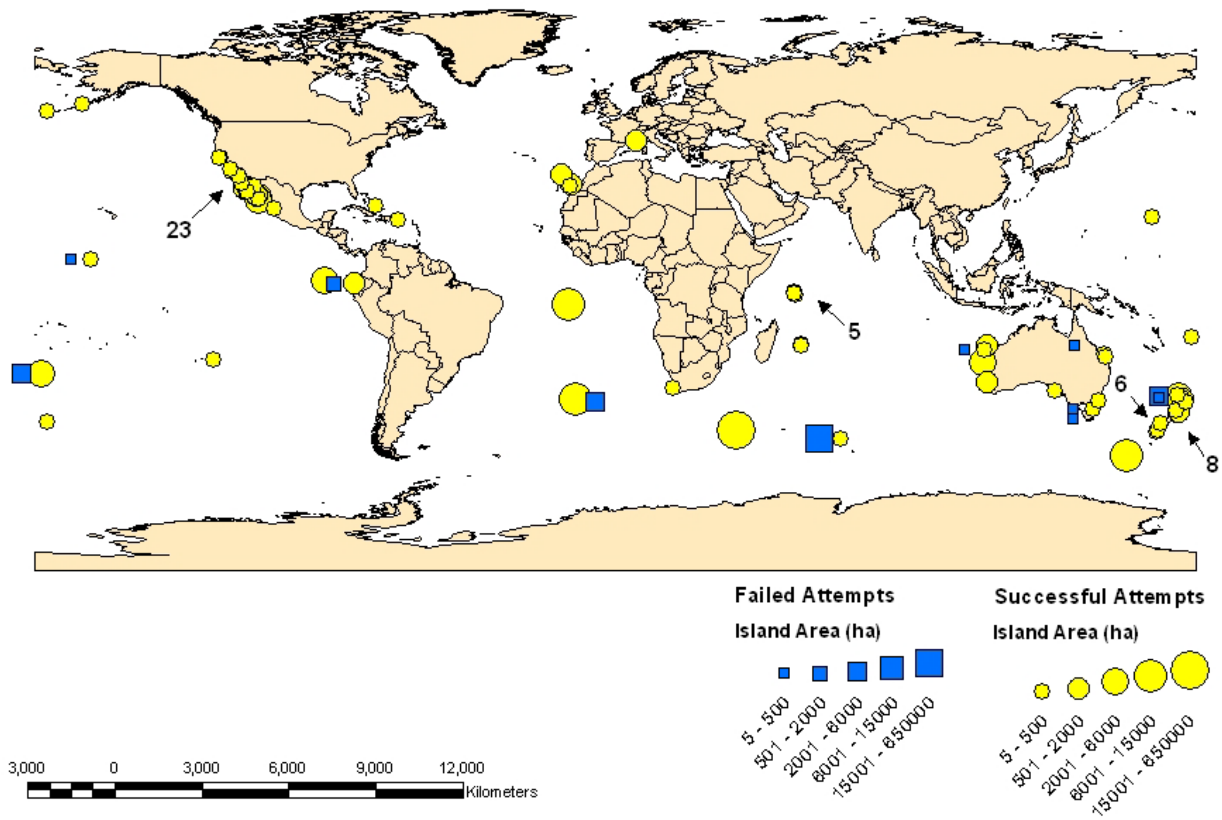

Figure 1.4.At least 83 successful and 19 failed feral cat eradication attempts have occurred on islands across the world (Campbell et al. 2011).

<u>Introduced rodents</u>

The first successful rodent eradication was in 1951 on Rouzic Island in France (Lorvelec and Pascal 2005). Through the 1970s and 1980s, New Zealand biologists developed the methodology for systematic rodent eradication techniques and successfully eradicated rats from several small islands (Moors 1985, Thomas and Taylor 2002). Building on these successes, and with the application of new strategies and research to monitor the campaigns, rats were eradicated from increasingly larger islands culminating in Macquarie Island in 2014 (12,780 ha), the largest island to date from which rats have been eradicated.

As of 2014, 446 rodent eradications have been implemented or are planned and awaiting implementation (DIISE 2014). The fundamental methodology that all but four of these eradications used was the delivery of bait containing a rodenticide into every potential rodent territory on the island. Bait was typically delivered during a time of year when food resources were scarce for rodents, as indicated by annual resource-dependent population declines. Depending on island topography and size, climate, native species assemblages, operational logistics and other factors, these eradication projects applied bait using either bait stations, broadcast, or both. Bait stations were typically laid out on a grid pattern. Bait broadcast could be delivered by hand or by using specially designed hoppers suspended under a helicopter (Howald et al. 2007).

Benefits of Eradicating Feral Cats and Introduced Rodents from Islands

The global conservation benefits of feral cat and rat eradications include increases in abundance and population parameters of a variety of taxa including seabirds, landbirds, reptiles, mammals, and plants, as well as overall ecosystem recovery. Owing to the well-documented impact of introduced rodents and cats on seabirds (Jones et al. 2008, Nogales et al. 2013), removal of feral cats and introduced rodents almost automatically provides protection for existing seabird colonies.

In Hawaiʻi there are several successful examples of natural areas that have benefited from the removal of invasive mammals. In 2008, Polynesian rats were eradicated from Mōkapu island, a 15 acre islet off the coast of Molokaʻi by an aerial application of diphacinone. This benefitted in the natural regeneration of Loulu palm (*Pritchardia hillebrandii*) and Lama (*Diospyros sandwicensis*). There were also new records of Bulwer's petrels (*Bulweria bulwerii*) nesting on the islet (MOPEP, Ane Bakutis, personal communication). At Kaʻena point on the western tip of Oahu, a predator proof fence was constructed to keep out feral cats and rodents. This resulted in 59 acres of protected area in prime seabird habitat. Since the installation of the fence Laysan Albatross Wedge-tailed Shearwater presence and native plant regeneration have all increased (VanderWerf et al. 2014).

At Midway Atoll National Wildlife Refuge, Bonin Petrel (*Pterodroma hypoleuca*)populations increased from fewer than 5,000 nesting pairs in the 1980s to over 135,000 pairs in 2008 subsequent to eradication of rats in 1997 (Pyle and Pyle 2009, FWS 2010a).

Control efforts in Hawaii have also yielded favorable results. On Molokaʻi, at Moʻomomi Preserve nesting wedge-tail shearwater nests increased from only one nest in 1999 to 399 by 2010 after the removal and control of feral cats (TNC 2011). On Maui at Hawea Point, wedge-tail shearwater fledglings experienced a survival rate increase from less than an estimated 30 to 350-400+ fledglings after predator control efforts (F. Duvall, personal communication).

Anacapa Island off the coast of California was the first island in the U.S. to use the aerial broadcast method for rodenticide application. A robust monitoring program pre and post project has documented the remarkable recovery of a rare nesting seabird, the Scripps's Murrelet. Overall hatching success post-eradication in 2003-2014 (82%; n = 304 clutches) was nearly 3 times that observed pre-eradication in 2001-2002 (30%; n = 20 clutches). The annual number of occupied nests increased nearly 6-fold from 11 in 2001 to 60 in 2014, while the number of clutches increased over 6-fold from 11 in 2001 to 67 in 2014. Slopes of the time series regression lines (2003-2014) for the log-transformed number of occupied murrelet nests indicated a per annum growth rate of 11.1% in sea caves and 18.6% in non-cave plots. Another success story is that another rare seabird, the Ashy Storm-Petrel, was documented nesting for the first time on Anacapa Island in 2012 (Whitworth et al. 2015).

Change in productivity was the most commonly reported demographic response in bird populations after rat eradication in a review by Lavers et al. (2010). They found that productivity increased by 25.3 percent in 112 studies of 87 species. Increases in native land birds after rat eradication have also been reported. In New Zealand, the abundance of 4 species of native landbirds increased between 10 and 178 percent during the 3 years after rat eradication (Graham and Veitch 2002), and endemic species have even recolonized islands after local extirpation by rats (Barker et al. 2005, Ortiz-Catedral et al. 2009). Also in New Zealand, rodent eradication has been used to restore endemic and native reptile populations. By

1998, rodents had been removed from 25 islands providing measurable or potential benefits for Tuatara (*Sphenodon sp*.), 2 species of *Naultinus* geckos, 6 species of *Hoplodactylus* geckos, 5 species of *Cyclodina* skinks, and 7 species of *Oligosoma* skinks (Towns 1994, Cree et al. 1995, Towns et al. 2007). Island-dwelling mammals have also benefited from rodent eradication, including an endemic deer mouse in California (Howald et al. 2010) and 2 species of shrew in France (Pascal et al. 2005).At the ecosystem-level, indigenous forest restoration has been documented as a result of substantial increase in the number of shrub and tree seedlings after Norway rat eradication (Allen et al. 1994). In addition to direct biological diversity benefits, feral cat and introduced rodent eradications have been carried out to create predator-free refuges for native and endemic fauna and flora that are at risk from predators elsewhere in their range.

On Natividad Island, feral cats were documented to have killed more than 1,000 Black-vented Shearwaters per month (Keitt et al. 2002). Following removal of the feral cat population, mortality was reduced to less than 100 birds per month, a result of natural mortality from native avian predators such as peregrine falcons (*Falco peregrinus*; Keitt and Tershy 2003). On Asuncion Island, feral cats were eradicated in 1994, and the Mexican endemic subspecies of Cassin's Auklet (*Ptychoramphus aleuticusaustrale*) extirpated in the 1970s, was re-discovered on the island in 2004 (B. Keitt personal communication).

Fig. 1.5. Colonies of Wedge-tailed Shearwaters and Red-tailed Tropicbirds can only be found on the remote cliffs and offshore islets of Kahoʻolawe due to threats from feral cats and rodents.

Summary of expected benefits to Kahoʻolawe's ecosystem from the eradication of feral cats and introduced rodents

Removal of cats and other introduced mammalian predators from the island of Kaho`olawe would increase the potential of becoming suitable habitat for endangered birds and other native Hawaiian animals. Combined with appropriate management of wetland habitats, Kahoʻolawe could serve as release sites for nēnē and Laysanducks (Henry 2006) and coastal habitat for endangered turtles and seals would be enhanced. In fact there are many federally listed endangered endemic species that have been identified in several recovery plans that could return to a restored coastal, wetland, marine and dryland forest habitat of Kahoʻolawe (Table 1.1). After the removal of invasive mammals these and other endangered species would benefit from restoration actions in a way that is unparalleled on the other main Hawaiian Islands.

Table 1.1 Endangered species expected to benefit from the project. *Regular wildlife surveys needed to determine current status on Kahoʻolawe.

Common name	Scientific name	Project benefits
Hawaiian Stilt or aeʻo	*Himantopus mexicanus knudseni*	Habitat restoration, potential future nesting site
Hawaiian Duck or koloa maoli	*Anas wyvilliana*	Habitat restoration, potential future nesting site*
Laysan Duck	*Anas laysanensis*	Habitat restoration, potential future nesting site
Hawaiian Goose or nēnē	*Branta sandvicensis*	Habitat restoration, potential future nesting site
Hawaiian Petrel or ʻuaʻu	*Pterodroma sandwichensis*	Habitat restoration, potential future nesting site*
Newell's Shearwater or ʻaʻo	*Puffinus auricularis newelli*	Habitat restoration, potential future nesting site*
Nihoa Millerbird	*Acrocephalus familiaris kingi*	Habitat restoration, potential future nesting site
Blackburn's Sphinx Moth	*Manduca blackburni*	Habitat restoration*
Hawaiian Hoary Bat or ʻōpeʻapeʻa	*Lasiurus cinereus semotus*	Habitat restoration*

In addition to threats from predation many of these species are identified as at risk from renewable energy development (wind farms) elsewhere in the state. On Maui wind turbines are known to "take" endangered and threatened shearwaters, petrels, nēnē and Hawaiian hoary bats and new wind energy projects must obtain an incidental take permit from the U.S. Fish and Wildlife Service under the Endangered Species Act. Kaho'olawe would represent a refuge from predation from invasive mammals, a healthier ecosystem and if managed correctly, renewable energy that is safe for Hawaiian species at risk. In total, 16 endangered species and 27 species of concern listed in various conservation and recovery plans could return to Kahoʻolawe. (Appendix B).

Lindsey et al. (1997) estimated that at least 16–20 species of seabirds once nested on Kaho`olawe, while Harrison (1990) listed only six species (Brown Booby, White- and Red-tailed Tropic Birds, Black Noddy, Bulwer's Petrel and Wedge-tailed Shearwater) recorded in recent decades and then only as relict populations of less than 300 birds heavily preyed on by cats. Removal of cats and rodents would allow natural recolonization by at least these species from the adjacent islets of Puʻu koaʻe and ʻAleʻale (as well as the other Hawaiian Islands), and perhaps by others still present in the region. It would also allow surrogates for extinct species to be translocated, and open up opportunities to use the island as a refuge for other Hawaiian birds threatened on their own islands (VanderWerf 2012, e.g. see Hutton et al. 2007). Apart from the direct benefits of having these birds back in their own right, nesting seabirds are ecosystem engineers because of the huge amounts of marine nutrients they can deposit on islands and, for the burrowing species, by driving above- and below-ground ecosystem processes (Fukami et al. 2006).

There are on-going efforts in other parts of the world to restore highly degraded islands bearing similar issues to Kahoʻolawe. On all islands the first step has been to eradicate the key introduced species that contribute to the ongoing degradation or stop any successional recovery. On some islands (e.g. Phillip

Island off Norfolk Island) there has been no active restoration since the removal of the pests – rabbits and goats – and the ecosystems have been left to recover by natural succession and recolonization (Coyle 2009). On others (e.g. Mana Island in New Zealand) the introduced mammals – domestic stock and mice – were removed and a huge active restoration scheme begun to replant the islands with their original forest trees and to reintroduce extirpated animals back to the new habitats thus created (Timmins et al. 1987). On others (e.g. Guadalupe Island in Mexico) the main herbivores (goats) have been removed, but although this has suited the native plants, it has also suited the mice and cats still present so seabird restoration is not yet possible (A. Aguirre, personal communication) (*In* Parkes 2009).

There is some uncertainty to what effect a complete eradication of introduced rodents and feral cats will have on the dryland forest and coastal ecosystem of Kahoʻolawe. In limited data from Mōkapu Island, the eradication has resulted in the restoration of the native ecosystem but also increased the presence of non-native plants and reptiles (MOPEP, unpublished data). There will be a likely be a significant increase in invertebrates and reptiles after the proposed eradication. It is also uncertain what will happen to the raptor presence on Kahoʻolawe. The native owl could turn to hunting small birds. If only feral cats are removed then the terrestrial apex predator will most likely be the Hawaiian Short Eared and Barn Owls. There is a possibility of an increase and/or a sustained bloom of rodents and an increased presence of Polynesian rats. Even if less desirable species becomes more abundant the overall benefit is expected to exceed the negative impacts.

Archeological Evidence of Native Hawaiian Birds on Kahoʻolawe

During the extensive archeological surveys conducted on Kahoʻolawe, fire pit excavations revealed the presence of native birds. Compared however to other archeological records in Hawaiʻi the information still leaves questions about the nature of the pre-human avifauna or the environment of the island. There are only six species listed in the record (Fig.1.6) Four of the species are seabirds that all still occur in the Reserve. Only one species, the Nēnē or Hawaiian goose, is an endemic Hawaiian land bird that has become extinct on the island. This species was widespread in the archipelago, and has larger derivatives, possibly separate species, at least on Kauaʻi, Oʻahu, and Maui (Olson and James 1991). Considering that all forms of the genus were exterminated in the prehistoric period everywhere in the archipelago except Hawaiʻi, it is hardly surprising that these geese were extirpated from the small island of Kahoʻolawe. This is at least one small indication of the level of prehistoric human disturbance with the environment of the island. The complete absence in the historic period of any flightless birds, especially rails, of any native passerines, or of any endemic form of predatory bird, is a strong indication of pervasive human intervention in the ecology of Kahoʻolawe (Gon et al.1992).

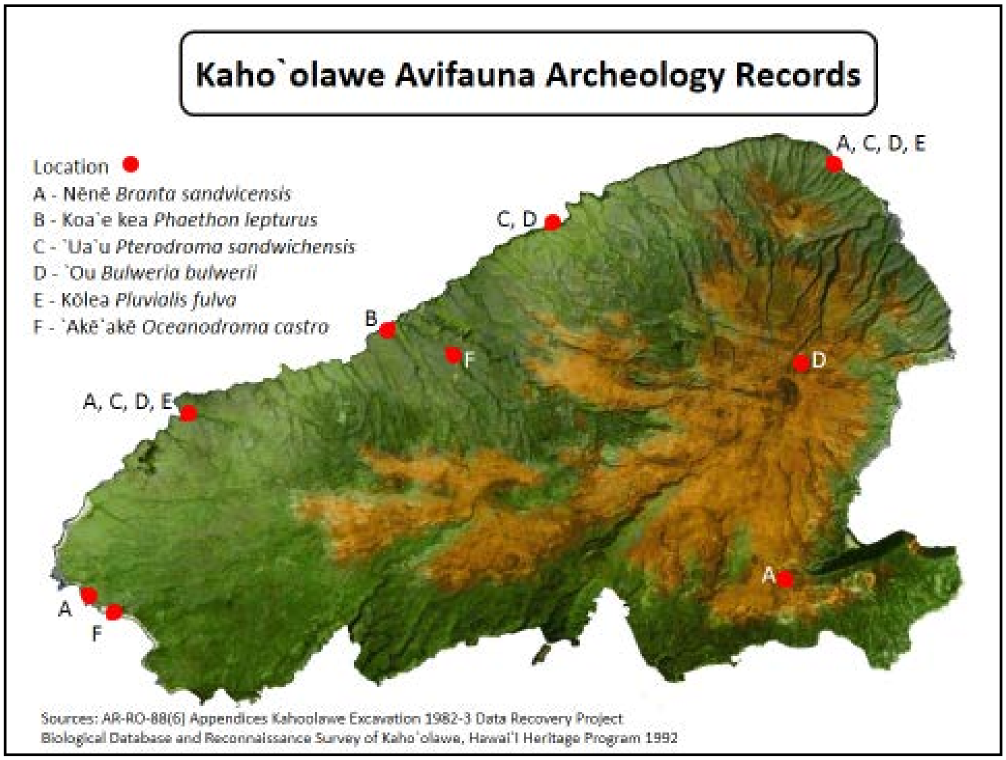

Figure 1.6. Hawaiian avifauna archeological records from Kaho‘olawe

Offering bundles from a cave in Kamohio contained only a few of the red and yellow feathers, so highly prized by the Hawaiians, and used in making their elaborate cloaks, helmets, and images. The yellow feathers were obtained from the mamo (*Drepanis pacifica*) and the `ō `ō (*Acrulocerus nobilis*) and the red feathers from the ‘apapane (*Himatione sanguine*) and ‘i‘iwi (*Vestiaria coccinea*). In addition, some of the offering bundles had common chicken feathers distributed among the other materials (McAllister 1933). It is interesting to note an‘apapane carcass was discovered on Kaho‘olawe in 2013, which supports the theory thatnative Hawaiian Honeycreepers (*Drepanidinae*) naturally occurred on Kaho‘olawe.

<u>Hawaiian Avifauna Species from Archeological Excavations</u>

- **Hawaiian Petrel**, *Pterdroma phaeopygia*: Individuals, including some juveniles, have been reported from seven archaeological sites (Collins 1987). This seabird is known historically from Kaho‘olawe and could still occur there.
- **Bulwer’s Petrel**, *Bulweria bulwerii*: Reported from four archaeological sites (Collins 1987). This seabird is known historically from Kaho‘olawe.
- **Band-rumped Storm Petrel**, *Oceanodroma castro*: Two humeri were recovered in 1984 from the sand dunes immediately west of Smuggler’s Cove (Honokanai‘a), and the distal end of a humerus was found in the small lava tube in Ahupu Gulch in 1992. This species is known to breed on Kaua‘i, Maui and on the island of Hawai‘i. Deceased specimens were discovered on ‘Ale‘ale during an opportunistic survey (Wood et al. 2003) so it cannot necessarily be assumed

that the species is extinct on Kahoʻolawe, although the great number of cats on the island would certainly preclude its survival in any but the most inaccessible places.

- **White-tailed Tropicbird**, *Phaethon lepturus*: Reported from two archaeological sites (Collins 1987). This seabird still occurs on Kahoʻolawe.
- **Nēnē**, *Branta sandvicensis*: Reported from seven archaeological sites (Hommon 1983; Collins 1987). The nēnē is known historically only from Hawaiʻi, although fossil finds indicate that it certainly or probably occurred on all the main islands (Olson and James 1991).
- **Pacific Golden Plover**, *Pluvialis fulva*: A common migrant to Kahoʻolawe reported from a single archaeological site.

Authority and Responsibility to Act

In 1993, Act 340 was passed by the Hawaiʻi State Legislature which established the KIRC under the Hawaiʻi Revised Statutes, Chapter 6K. Today, the KIRC's mandate is to manage Kahoʻolawe, its surrounding waters, and its resources, in trust for the general public and for the future Native Hawaiian sovereign entity. This is outlined in more detail in Chapter 2.

Scope of the Proposed Action

This Business Plan identifies, documents, and evaluates the effects of the proposed action: Aid the protection and restoration of the native species and habitats of Kahoʻolawe Island, Hawaii, by removing feral cats and invasive mice and rats from the Island that harm populations of native plants, nesting seabirds, and native invertebrates, and to establish predator-free habitat for native Hawaiian species that are threatened by the effects of climate change. Four approaches are discussed in Chapter 3.

An interdisciplinary team of natural resource managers, cultural experts, and environmental scientists has analyzed the proposed action in light of existing conditions and has identified relevant effects associated with implementing the proposed action compared to the "no action" alternative.

Chapter 2 - Compliance

Summary

- This Chapter is broken down in to two categories, cultural compliance through traditional Hawaiian protocol and regulatory environmental compliance which outline the laws, rules, and regulations for an eradication project of this scale.

Cultural Protocol

KIRC Vision Statement

> The kino of Kanaloa is restored. Forests and shrublands of native plants and other biota clothe its slopes and valleys. Pristine ocean waters and healthy reef ecosystems are the foundation that supports and surrounds the island.
>
> Na poʻe Hawaiʻi care for the land in a manner which recognizes the island and the ocean of Kanaloa as a living spiritual entity. Kanaloa is a *puʻuhonua* and *wahi pana* where Native Hawaiian cultural practices flourish.
>
> The piko of Kanaloa is the crossroads of past and future generations from which the Native Hawaiian lifestyle spreads throughout the islands.

As stated in the KIRCs vision statement, cultural integration is emphasized in all facets of Kahoʻolawe's restoration "Kahoʻolawe serves as a cultural resource, particularly for Native Hawaiians, because it links the past traditions with contemporary practices. It is a place where cultural practices continue to be observed" (KICC 1993). The KIRC staff maintains the cultural essence of Kahoʻolawe by adhering to the cultural protocols outlined by theEdith Kanakaʻole Foundation's *ʻAha Pāwalu, A Cultural Protocol for Kanaloa-Kahoʻolawe*. "Protocol re-establishes an awareness of relationship between people and place. It provides a pervading attitude toward ecological sensitivity tantamount to 'mālama" and "aloha āina'. It communicates a code of behavior in respect to places, peoples and things. It is a unifying mechanism giving strength to purpose" (KIRC 1995).

The Kahoʻolawe Island Seabird Restoration Project will adhere to the vision of the two entities to seek out appropriate cultural protocols, rituals and ceremonies. The *ʻAha Pāwalu* was written with protocols specific to Kahoʻolawe, and any new ceremonies or chants will be developed following this precedent. In addition, the stewardship agreement between the KIRC and the Protect Kahoʻolawe ʻOhana (PKO) allows the two organizations to develop project specific protocols appropriate for the island.

Significance of Hawaiian seabirds to Kahoʻolawe's indigenous inhabitants

To understand the significance of Hawaiian seabirds on Kahoʻolawe's Hawaiian inhabitants, it is helpful to investigate the historic and archeological records in addition to oral history (*moʻolelo*). Kahoʻolawe's (Kanaloa) unique legends and traditions offer important insights into the Hawaiian culture and the role the island played within that culture. Numerous unique and significant features include well-preserved remains of settlements, religious and burial sites, petroglyphs, numerous fishing shrines, and the State’s second largest Hawaiian adze quarry.

Stone carvings or petroglyphs offer insight into the cultural significance of important symbols to the inhabitants of Kaho‘olawe. The Petroglyph Recording Project was conducted from 1976-1980 and discovered various references of birds. The most striking is a bird man image (Fig. 2.1) found at prominent archeological sites across the island. This petroglyph is described as “a single phallic figure that has a triangular body and may represent a “bird man” in that it has very wide spread arms with a wing like appearance.”

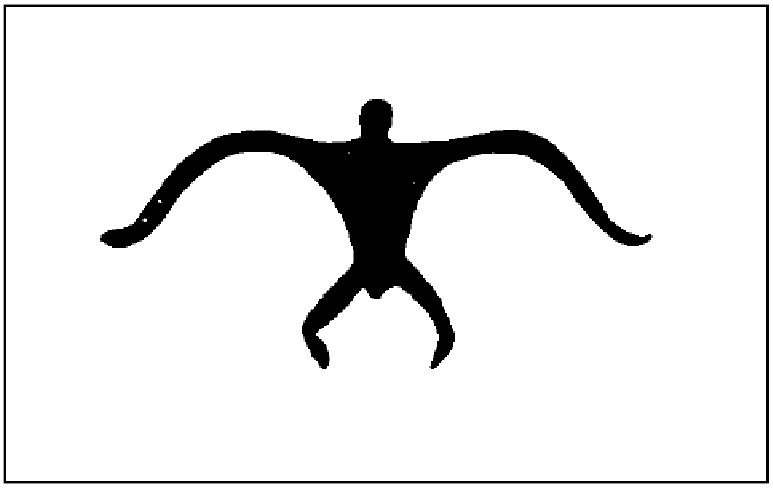

Figure 2.1. Bird Man symbol

According to the authors of “The Petroglyph Project”, the bird-like images were one of the conventions that stand out on Kaho‘olawe (and Maui Nui) compared to that of other main Hawaiian Islands (Lee and Stasack 1993).

Early historical records of birds are scant butinclude records of seabirds. Accounts include “Larks, pigeons, plovers and various sea birds were seen over different parts of the island and may have been a means of new plant arrivals” (Forbes 1913) and the captain of the Russian Ship, *Kamatchka* reports Tahoorowa (Kaho‘olawe) that “countless number of sea birds dwell on it” (Golovnin 1979). Other archeological records include various species of Hawaiian bird bones from excavation sites (Gon et al. 1992).

The translation of *wahi pana* can be defined as literally a “celebrated, noted, or legendary place” (Pukui &Elbert 1971). Kaho‘olawe in itself is a *wahi pana* but *wahi pana* can be found on all parts of the island.

Fornander (1919) translates a story that relates Honua‘ula (Hanaula), Kaho‘olawe, and bird-men. An excerpt follows:

"...When the prophet arrived, these two flew on to the parents-in-law; when the prophet arrived there, they flew to Kaho‘olawe, and from there they returned to Hanaula, and at that place the prophet met them and offered his sacrifice; and that was how the rain was restored. While these sons lived at Hanaula, they thought a great deal of Puuoinaina, their wife, but they did not know what she was doing. Because after that, Puuoinaina took for her the husband of Pele, Lohiau, and forgot her own husbands..."

This legend refers to Puʻuoinaina, a *moʻo* (lizard) that lived on Kahoʻolawe.She had two husbands that were bird-men. They lived on Maui at Honuaʻula and became farmers.The birdmen fed their parents-in-law and also flew to Kahoʻolawe to give their wife food.Once Pele found the giant moʻostretching from Kahoʻolawe to Makena she became so enraged she cut Puʻuoinaina in two. The islet of Molokini is said to be the head of Puʻuoinaina and tail is Puʻu olaʻi. (Fornander 1919). The complete version is included as Appendix C of this document.

Another unique feature of Kahoʻolawe is that no other island has a comparable array of intact fishing shrines (*koʻa*). During archeological surveys these were identified as "a number of enclosures and terraces distributed along the coast" (Hommon and Streck, 1981). It is interesting to note that there are also many type of *koʻa* and there are also *koʻa manu* or bird shrines. Hawaiian historian Samuel Kamakau, writing in the 1860s, provided detailed descriptions of various *koʻa*. "on islets inhabited by birds, the bird catchers who caught birds by imitating their calls and then snaring them (*kono manu*), or who smoked them out of their nesting holes (*puhi manu*), or who drew them out from their holes (*pu manu*) also set up *ko'a* to give life to the land by an abundance of birds" (Kamakau 1976, Reeve 1993, Spoehr 1993) With the abundance of *koʻa* on Kahoʻolawe it is possible some were dedicated to birds. On Puʻu koaʻe there are manmade structures presumably built to attract seabirds (Wood et al. 2003) (Fig 2.2).

Figure 2.2. Hawaiian Rock Structure on Puʻu koaʻe islet

There are extensive studies and research material compiled for Kahoʻolawe to gain further insight into island specific Hawaiian protocol for the Seabird Restoration Project. By combining different fields of

Hawaiian study and utilizing Hawaiian cultural practitioners, appropriate cultural protocol will be developed accordingly.

A commonly sighted bird on Kahoʻolawe especially after mouse irruptions is the pueo (Hawaiian short-eared owl -*Asio flammeus sandwichensis)*. Pueo are among the oldest and well known ʻaumākua(family protectors). In a legend from Maui, Pueo-nui-akea is an owl god who brings back to life souls who are wandering on the plains. Additionally, the universal guardianship of the owl is expressed in the saying attached to it, "A no lani, a no honua" (Belonging to heaven and earth). Careful consideration from a Hawaiian cultural perspective must be taken into account as pueo would be considered a non-target during a rodent eradication.

Recommendations for Cultural Compliance
A "before and after" or "pre and post" approach is recommended. The recommendation is that the KIRC Cultural and Restoration Programs coordinate with the Protect Kahoʻolawe ʻOhana to develop the appropriate protocols in accordance to existing precedent set forth from the *ʻAha Pawalu*. A blessing and ceremony will be conducted before eradication efforts begin to ensure it is carried out properly from a Hawaiian cultural perspective. As the project is implemented cultural protocol would be adhered to and compliment the success of the project.

After confirmation of eradication of at least the largest threat to seabirds (feral cats), a *ko'a manu*or *heiau koʻa*will be constructed on island to help call the seabirds back to island. The *heiau koʻa* or *koʻamanu* will not be constructed until the stewards of the island can ensure safety from predators. The construction would be conducted by Hawaiian cultural practitioners and using traditional stone working techniques.

Environmental Regulatory Compliance
The techniques employed for full-island eradication projects in the U.S. are nearly always categorized as "major federal actions," which makes them subject to the environmental analysis guidelines set forth in the National Environmental Protection Act (NEPA, Figure 2.3) and Hawaiʻi Environmental Protection Act (HEPA) compliance processes. NEPA and HEPA require Federal or State agencies to consider environmental effects that include impacts on social, cultural, and economic resources, as well as natural resources.

KIRC Legal Authority:
Activities within the Reserve are restricted and permitted only for the purposes allowed under State law. The relevant provisions of Chapter 6K, Hawaiʻi Revised Statutes (HRS) and Section 13-261, Hawaiʻi Administrative Rules (HAR) read as follows:

> **§6K-3 Reservation of uses.** (a) The Kahoʻolawe island reserve shall be used solely and exclusively for the following purposes:
>
> - Rehabilitation, revegetation, habitat restoration, and preservation….
>
> §**13-261-14 Prohibited activities** (b) Except as authorized by the commission or its authorized representative, activities not provided for in §13-261-13 shall be prohibited, including, but not limited to, the following activities:

- To take, disturb, injure, kill, alter or deface, or possess any form of plant or wildlife or aquatic life;
- To remove, damage, or disturb any natural feature or natural resource;
- To possess or use or discharge any firearm, bow and arrow, spear gun, or any other weapon, trap, snare, poison, or any device designed to take, capture, or kill wildlife on or into the reserve;
- To remove or attempt to remove, from the reserve any aquatic life or wildlife… or other naturally-occurring object or resource….

Therefore, the Commission can authorize the four above-listed actions because they are for habitat restoration and preservation purposes.

Additionally, Hawaiʻi's Comprehensive Wildlife Conservation Strategy and KIRC's Kahoʻolawe Environmental Restoration Plan *Hoʻōla Hou I Ke Kino O Kanaloa* fall within the provisions of Chapter 195D, HRS, relating to Conservation of Aquatic Life, Wildlife, and Land Plants, and Chapter 183D, HRS, relating to Wildlife. The relevant sections are as follows:

> **§195D-5 Conservation programs.** (a) The department shall conduct research on indigenous aquatic life, wildlife, and land plants, and on endangered species and their associated ecosystems, and shall utilize the land acquisition and other authority vested in the department to carry out programs for the conservation, management, and protection of such species and their associated ecosystems….
>
> **§183D-65 Posting; destruction of predators.** (a) On any game management area, public hunting area, or forest reserve or other lands under the jurisdiction of the department, predators deemed harmful to wildlife by the department may be destroyed by any means deemed necessary by the department.
>
> **§183D-1 "Predators"** means animals destructive of wildlife by nature of their predatory habits, including mongooses, cats, dogs, and rats.

Finally, conducting an eradication of introduced rodents and feral cats from Kahoʻolawe fits within existing state and federal legislation designed to promote and protect native and/or listed species through the removal of invasive species and/or habitat restoration, including:

- Presidential Executive Order 13112 on Invasive Species (February 3, 1999): Section 2
- U.S. Federal Statute: The Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Stat. 884), as amended.
- Hawaiʻi Administrative Rules, Title 13-12-261 The purpose of these rules is to manage, preserve, restore, and protect the natural and cultural resources of the reserve; regulate activities within the reserve; and to protect public health and safety
- Hawaiʻi Department of Land and Natural Resources (DLNR) Statutes:
    - Hawaiʻi Revised Statutes, Chapter 26-15. To manage and administer public lands, including wildlife resources and coastal areas.

    - Hawaiʻi Revised Statutes, Chapter 195D-5 To conserve, manage and protect indigenous species
- Hawaiʻi Administrative Rules, Title 13-12-261 The purpose of these rules is to manage, preserve, restore, and protect the natural and cultural resources of the reserve; regulate activities within the reserve; and to protect public health and safety

In addition to completing the NEPA process, a number of different permits would need to be sought in order to implement the rodent eradication:

- Hawaiʻi State laws HRS 195D and HAR 13-124 concerning the Conservation of Aquatic Life, Wildlife, and Land Plants (endangered species) for all species impacted by the eradication.
- DLNR-State Historic Preservation Division will require an assessment of the impacts to cultural artifacts on Kahoʻolawe, in the form of stone platforms and rock cairns (HRS Chapter 6E).
- ESA Section 7 Consultation with the National Marine Fisheries Service and United States Fish and Wildlife Service (USFWS) to address impacts to federally protected species.
- Marine Mammal Protection Act (MMPA)- Letter of Confirmation (LOC) for Level B Harassment under the MMPA General Authorization to address potential effects of the eradication on monk seals hauled out on, or foraging near, Kahoʻolawe.
- USFWS Migratory Bird Treaty Act Special Purpose Permit for disturbance or mortality caused to bird species protected under the Migratory Bird Treaty Act.
- Clean Water Act National Pollutant Discharge Elimination System (NPDES) permit for aerial applications of pesticides over waters of the U.S. through the Hawaiʻi Department of Health, Clean Water Branch (DOH-CWB).
- Coastal Zone Management Act Consistency Determination to ensure compliance with State Coastal Zone Management Plan.
- State of Hawaiʻi Department of Agriculture permit to aerially apply a Restricted Use Pesticide (RUP) (HI P-23).

<u>NEPA</u>

The NEPA process would require the completion of either an Environmental Assessment (EA) or Environmental Impact Statement (EIS). It is possible that the Kahoʻolawe eradication project could be tiered from the state-wide Programmatic EIS (PEIS) for conservation-based rodent control and eradication which is currently under development by USFWS and DLNR (Figure 2.3).

<u>HEPA</u>

The HEPA process would require the completion of either an EA or EIS. However, the KIRC, as an agency operating under the Hawaiʻi Department of Land and Natural Resources (DLNR), may qualify for an exemption with the Hawaiʻi Office of Environmental Quality (OEQC). If an exemption is possible, the KIRC would complete and provide an Exemption Declaration form to the OEQC for approval.

<u>NPDES</u>

Additional permitting would be required to adhere to the Individual NPDES. Either a Pesticide General Permit or an Individual Permit would be required based on the status of the KIRC as a Hawaiʻi State agency. If a PGP is required the application for the permit is submitted to the Hawaiʻi Department of Health, Clean Water Branch (DOH-CWB) and processing is expected to not exceed one month (A. Wong, Hawai‘i CWB Program Manager pers. comm.). If an Individual Permit is required, then application for the permit is processed through the EPA Region 9 office.

FIFRA and HDOA

The use of a rodenticide, by any delivery method, would require additional permitting from the Hawai‘i State Department of Agriculture (HDOA) Pesticides Branch and Hawai‘i Department of Health (DOH). In addition to federal pesticide registration, Hawai‘i State requires the registration of pesticides and the certification of applicators and pilots flying aircraft involved in the application of rodenticides. Finally, if the proposed bait type is not currently registered for use in the United States, a registration dossier would need to be submitted by the registrant with the U.S. Environmental Protection Agency and again to the HDOA Pesticides Branch.

Currently, four rodenticide based products are registered under the Federal Insecticides, Fungicides, and Rodenticides Act (FIFRA) for use in the United States and in U.S. territories for conservation purposes:

- Pelletized bait
    - Diphacinone-50 Conservation (USDA/APHIS, EPA Reg. No. 56228-35; SLN No. HI-8600.1)
    - Brodifacoum-25W Conservation (USDA/APHIS, EPA Reg. No. 56228-36)
    - Brodifacoum-25D Conservation (USDA/APHIS, EPA Reg. No. 56228-37)
- Bait blocks
    - Ramik® Mini Bars All-Weather Rat & Mouse Killer (USFWS, EPA Reg. No. 61282-26; SLN no. HI-980005)

In the state of Hawai‘i, rodenticide products that are to be used for conservation purposes are administered by the Hawai‘i Department of Agriculture (HRS Chapter 149A, HAR 4-66, 2006) and require licensing and labeling in addition to the FIFRA registration and labeling requirements. Diphacinone-50 Conservation and Ramik® Mini Bars All-Weather Rat & Mouse Killer are the only rodenticide bait products currently registered and labeled by the Hawai‘i Department of Agriculture for conservation use in the state of Hawai‘i. It is possible that the two FIFRA registered brodifacoum bait products could be registered for conservation use in the state of Hawai‘i, or, if warranted, a novel bait product could be developed and registered under FIFRA and within the state of Hawai‘i for conservation purposes (Figure 2.4).

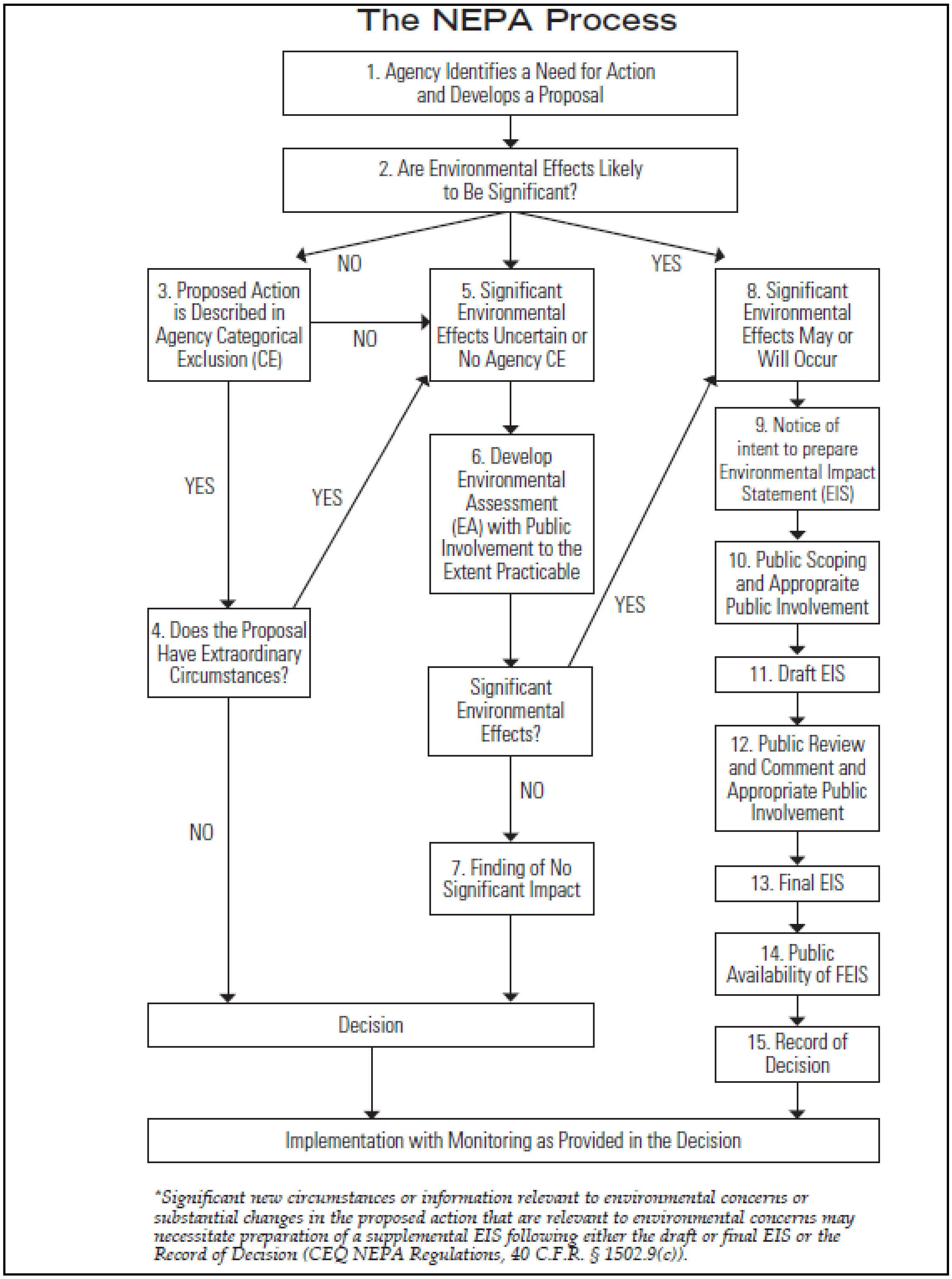

Figure 2.3. The NEPA process from CEQ (2007).

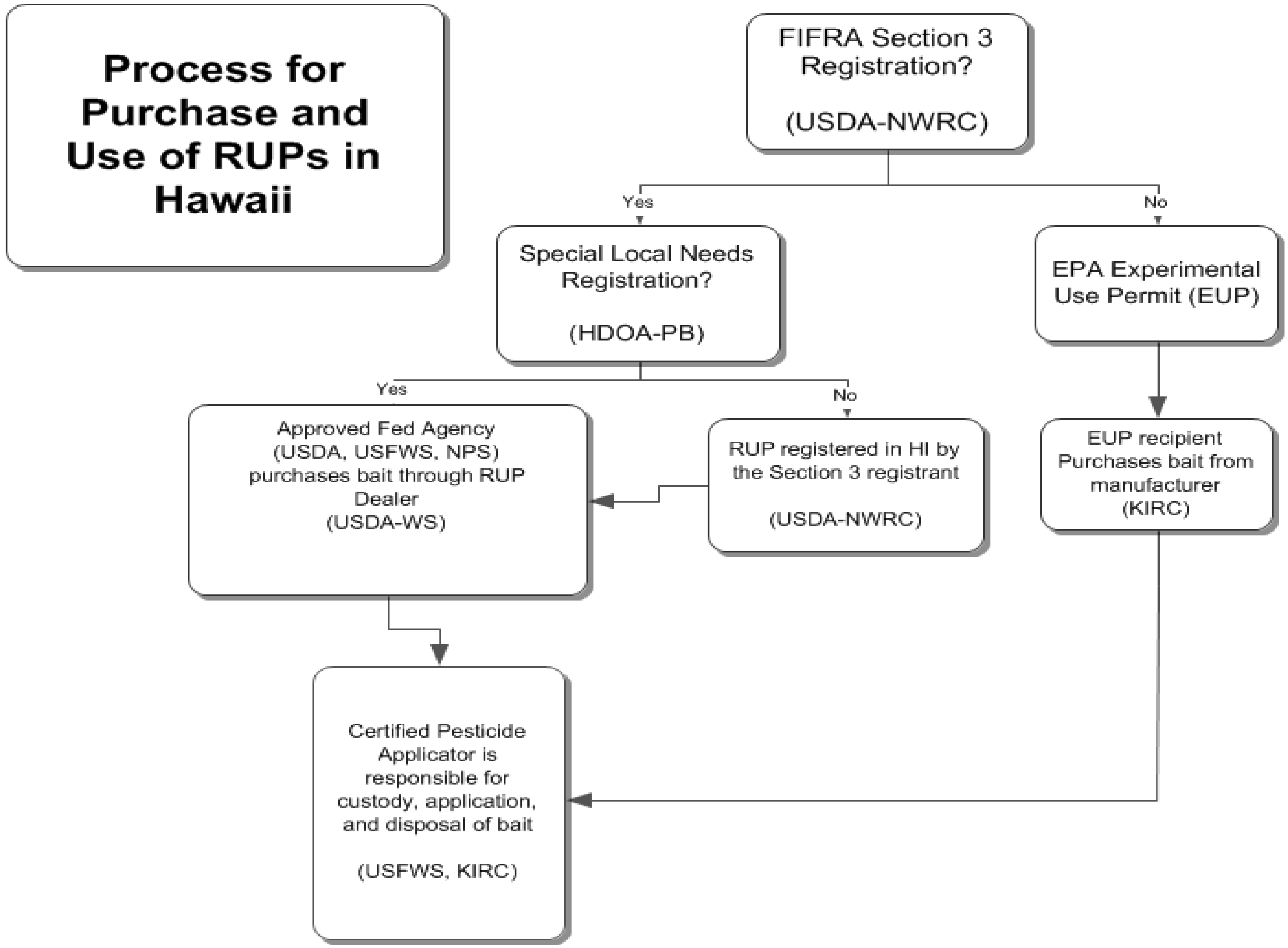

Figure 2.4. Process for the purchase of and use of Restricted Use Pesticides (RUPs) for conservation purposes in Hawaiʻi.

Chapter 3- Possible Approaches

Summary

- A successful eradication project would permanently remove all individuals within the target populations from Kahoʻolawe while minimizing impacts from the project and facilitate the protection and restoration of native species and habitats.
- The eradication of feral cats and rodents from Kahoʻolawe is achievable given that other feral cat, mouse, and rat eradication projects have been successful on islands of similar or greater scale and complexity.
- Due to the size (11,520 ha), complex topography areas inaccessible by personnel due to unexploded ordinance (UXO), and regulatory requirements the options for implementation of the eradication project are limited.
- Possible approaches consist of single-taxa eradication, feral cat and rodent eradication conducted concurrently or cat and rodent eradication conducted at different times.
- Techniques such as trapping, hunting, and pesticides have been developed to remove cats and rodents and would be used for the eradication project on Kaho'olawe.
- The strategy for eradicating feral cats and rodents from Kahoʻolawe should balance the need to maximize efficacy while minimizing risk to both personnel and non-target species (native and non-native), while maintaining efficiency (costs) from the implementation of the project.
- The preferred approach would remove both feral cats and invasive rodents concurrently, recognizing that there will be a need to employ multiple eradication methods (pesticides, trapping, and hunting) to achieve this goal.

Eradication is not an intensified version of control, it must remove the last individual within the target population, which means taking individual behavior into account from the very beginning (Broome et al. 2014). Every step in the design and implementation of an eradication project must strive to minimize the risk of failure with robust and meticulous planning (Cromarty et al. 2002). Multiple techniques are often needed, and rarely can one technique alone achieve eradication. Additional or modified techniques are often needed to remove the last few individuals and to confirm that eradication is complete. To under-achieve eradication, even though this result could still be considered a high level of control, means failure. As defined here, a successful eradication project removes all individuals within the target population from the treatment area while incurring minimal and accepted impact to native non-target species.

The basic guidelines for achieving eradication of an invasive species population are:

- All individuals within the target population must be put at risk by the methods used.
- All individuals within the target population must be removed at a rate faster than they can reproduce.
- Risk of reinvasion must be zero or as close to zero as possible, and this risk must be managed effectively.
- The long-term benefits from the eradication must outweigh the potential short-term risk to populations of non-target native species.

- The eradication strategy must be known by, and accepted by project partners, stakeholders, and local communities.

When assessing an eradication method, there are four aspects that must be kept in mind:

1) Efficacy of the chosen method(s)—can the combination be used to reach and successfully remove every individual in the target population?
2) Non-target risks associated with the chosen method—would the chosen methods negatively impact individuals of a non-target species (either through direct action or disturbance), both terrestrial and marine? Are the risks acceptable? Can they be mitigated?
3) Safety of personnel—can the project be completed without putting the health and safety of project personnel at high and persistent risk?
4) Regulatory – is the eradication strategy legal, or with appropriate and adequate investment, be made legal?

No Action - Maintain Existing Control

Analysis of the No Action approach provides a benchmark for comparing action-based approaches to the management of introduced rodents and feral cats on Kahoʻolawe. Mice, rats, and feral cats would not be eradicated under this approach; however, other ongoing natural resource restoration programs on Kahoʻolawe would continue based on the KIRC's mission and restoration goals. At Honokanaiʻa basecamp, the KIRC currently manages introduce rodents (primarily mice) through trapping and limited use of rodenticide in bait stations and manages feral cats by trapping. When the need arises, feral cat and rodent control is conducted at remote sites to protect native plants and animals (e.g., trapping near active sea turtle or seabird nesting sites, or near the single remaining *Kanaloa kahoolawensis* plant growing on the cliffs of ʻAleʻale off the coast of the Kahoʻolawe). Additionally, native seeds and seedlings are planted in areas of the island that are designated for habitat restoration. These efforts would continue under the No Action approach. However, it is considered that the continued presence and impacts of mice, rats, and feral cats would compromise the effectiveness of current and future ecosystem restoration efforts and greatly extend the effort and time required to achieve only a partial restoration of the island. Prospecting seabirds are at constant risk of predation and nesting covers a wide expanse at unpredictable sites to maintain any type of strategic control program. Current biosecurity measures to stop the introduction of new invasive species, such as Norway rats, plants, and insects would continue under the No Action alternative.

The No Action approach to the management of introduced mice, rats and feral cats would be contrary to the KIRC's goals of conservation and restoration of natural biodiversity and management of culturally important natural resources. In addition, this alternative would not allow Kahoʻolawe to become a future site for native and endemic species translocations (Reynolds et al. 2010).

Single-Population Eradication

<u>Feral cat eradication only</u>

Kahoʻolawe is a large island (11,550 ha / 28,800 acres) compared to feral cat eradication efforts undertaken elsewhere. The large size and rugged terrain of Kahoʻolawe, combined with restrictions on access to much of the island due to the presence of UXO, suggest that eradication would be a complicated process. However, advances in the development of techniques to safely and efficaciously remove feral cats from islands make eradication technically feasible (Island Conservation 2011). If completed Kaho‘olawe would be the third largest island from which cats have been eradicated (Campbell et al. 2011).

Multiple lethal and non-lethal methods have been used on successful cat eradications worldwide, including trapping, hunting, dogs, pesticides and diseases. Of these, the tools most frequently applied are foot-hold trapping, ground-based hunting, and the ground-based application of pesticide baits. Eradication projects on large islands require a suite of methods, because no one method is effective for all cats in all situations. On large islands, the initial reduction (“knock-down” phase) is usually accomplished using toxic baits or a cat-specific pathogen. The rapid reduction in cat numbers is necessary to overcome recruitment that can occur with density reduction (Parkes et al. 2014). Unfortunately, no pesticides are registered in the US for the control or the eradication of feral cats (the use of disease on Kaho’olawe is excluded for other reasons [see below]). However, procedures such as experimental use permits exist which provide a mechanism to use pesticides for conservation work prior to the pesticide being registered.

Based on past projects where there was unlimited access to the islands by cat removal specialists (Campbell et al. 2011), a combination of trapping using remotely monitored padded leg-hold live traps, kill traps, and hunting with the use of specialist detection dogs proved most efficacious. Feral cat eradication on Kaho‘olawe is believed feasible by using a helicopter to support trapping and hunting, however UXO land access restrictions would require teams be supported by an Explosive Ordnance Disposal (EOD) specialist. It is anticipated that to increase the probability of success, the project would require specialized tools such as padded leg-hold traps fitted with remote trap-monitoring systems. Other techniques, such as spotlight hunting have been used successfully to eradicate feral cats and should not be discounted as this tool may be valuable in certain situations. A network of infrared cameras used in combination with spotlighting would be the primary methods for detecting cats throughout the project and determining when the eradication is successful.A detection probability model based on a running measure of the probability of detecting cats as the eradication progresses would determine the optimal amount of effort required to confirm the eradication of cats from the island (Ramsey et al. 2011).

On Kaho‘olawe, feral cats likely have higher densities along the coastal fringes, near refuse sources, and in the watershed drainages where prey items are more plentiful (KIRC unpublished data). Enhancing cat foraging opportunities with strategically placed food items in the vicinity of trap sites could facilitate the removal of the feral cats. It is unknown exactly how many feral cats are on Kaho‘olawe, and numbers appear to fluctuate over time in relation to food resources. Feral cat population indices could be derived from trapping rates and other detection methods (Forsyth et al. 2005). These methods, along with dog team encounter rates, sentinel cats, detections on camera traps, baiting and trap success, visual sightings, and presence/abundance of fresh activity would be used by managers throughout the campaign to gauge efficacy of methods and monitor progress towards the goal of eradication (IC 2011).

Feral cat eradication approaches considered and dismissed

Trap and transport

This method would involve trapping all feral cats on Kahoʻolawe Island and transporting them to another island, or the mainland to be kept in captivity for the remainder of their lives. This alternative is inappropriate for use on Kahoʻolawe for several reasons. First, live trapping as a sole method for removal is unlikely to capture all individuals within the island's feral cat population due to the inability to trap in restricted areas because of the presence of UXO. Second, Kahoʻolawe's cats are not suitable as adoptive pets given their feral nature and they could not be released into the wild without having the same invasive impact to native fauna wherever released. Finally, Maui Island would be the likely candidate location to receive trapped cats from Kahoʻolawe. However, Maui is overburdened with feral cats that are likewise threatening native bird populations http://www.salon.com/2014/10/22/mauis_feral_cats_are_taking_over_the_island/ accessed 7 Dec 2014) and there are currently no indoor facilities with adequate resources to care for the cats for the remainder of their lives. This option will not be further evaluated.

Disease

Three diseases have been considered as a tool in cat eradication projects: retroviruses feline immunodeficiency virus (FIV) and feline leukemia (FeLV), and feline panleukopenia virus (FPLV), also known as feline enteritis. Disease is most effective on islands where feral cats have existed for a many generations without multiple introductions; it is typically these populations that have no immunity to the disease. Disease has been used in three cat eradications (Rauzon and Woodroffe 1985, Bester et al. 2000, Veitch 2001) using FPLV. FPLV (as well as FIV and FeLV) is transmitted primarily through bodily fluids, which can occur through social interactions (e.g., biting, grooming) or by fleas. For disease transfer to be effective a considerable portion of the population must be inoculated. For FPLV, it is estimated that 5% of the population must be inoculated (Veitch 1980). This would require capturing, inoculating and then releasing cats across Kaho'olawe, and considering the apparent low density of cats on the island, it is likely disease transmission via encounters of infected individuals with un-infected individuals would be low. On Little Barrier Island, a mesic, densely forested island, FPLV was estimated to have reduced the population by 80% (Veitch 2001). In contrast, on the xeric sparsely vegetated Jarvis Island (similar to Kaho'olawe), it was estimated the disease would only remove around 41% of the population (Rauzon and Woodroffe 1985). On islands where endemic carnivores or carnivore populations of concern are present, disease is likely an inappropriate removal method due to the potential risk of infected cats facilitating disease transfer to native carnivores. On Kahoʻolawe Island, disease is not a viable option because the anticipated ineffectiveness relative to other safer methods and the risk of immunocompromised cats potentially facilitating disease transfer to Hawaiian monk seals. Finally, introduction of disease as a method in cat eradications is less humane than other methods. Infected cats require days to weeks to die, much of that time in distress. In contrast, the pesticide Para-aminopropiophenone (PAPP) usually kills cats in less than three hours and animals show few signs of distress (Murphy et al. 2007).

Immunocontraception

Immunocontraception is a process by which the immune system of an individual is made to attack its own reproductive cells, leading to sterility. This is achieved by infecting individuals using a gamete protein that triggers an immune response; the resulting antibodies bind to these proteins and block fertilization (Bradley et al. 1997). Infection occurs by injection, bait, or living vectors (Courchamp and Cornell 2000 and references therein). Immunocontraceptive agents that have been successfully used in other species have been ineffective with feral cats. Furthermore, searches for other agents for feral cats have not revealed any effective candidates (Levy et al. 2005). Even if agents were developed, delivery to the target species remains problematic. Bait delivery may be effective, but immunocontraceptive agents are not species specific (Levy et al. 2005). Finally, virus-vectored immunocontraception, which utilizes a species-specific virus to disseminate the vaccine through a pest population by placing the gene encoding the reproductive protein into the genome of the virus (Tyndale-Biscoe 1994), has not been developed for cats and is still a theoretical science (Courchamp and Cornell 2000). Immunocontraception, therefore, is an inappropriate method for removing feral cats from Kahoʻolawe Island.

Trap-Neuter-Release

Trap-neuter-release (TNR, also known as Trap-Neuter-Return and Trap-Neuter-Re-abandon), involves capturing feral cats using, neutering the animals, and returning them to where they were captured (Jessup 2004) and is contrary to the goals of conservation efforts. The presence of neutered and re-abandoned feral cats on Kahoʻolawe Island would greatly decrease the ability to trap the remaining un-neutered feral cats because of an inability to distinguish between feral cats that had already been neutered and released and new or not previously trapped feral cats through traditional methods (sign, dog tracking, etc.). In addition, releasing neutered cats back onto Kahoʻolawe is contrary to the conservation goals of the KIRC as neutered cats are still capable of killing and maiming native birds and continue to pose a threat of transmitting toxoplasmosis to Hawaiian monk seals.

TNR has been used in efforts to manage feral cat populations, but the legality, ethics, and effectiveness of the practice have been widely questioned (Barrows 2004, Jessup 2004, Winter 2004, Foley et al. 2005). Federal law may limit or prohibit abandoning / releasing non-native wildlife, including feral cats. For example, the release of feral cats may result in mortality of listed species or migratory birds, resulting in a potential violation of the ESA and/or the Migratory Bird Treaty Act (Barrows 2004). The ethics of TNR have been a concern because of questions surrounding: 1) the humaneness for other wildlife of releasing cats in the wild knowing they will kill and maim other wildlife, and 2) the quality of life for the cats themselves. Many feral cats live unnaturally short lives. The average lifespan of feral cats is only two years, compared to 10 for owned cats (AVMA 2003). Accurately assessing the effectiveness of TNR programs is difficult, and many of the programs that have claimed success at reducing feral cat populations did not use sufficiently rigorous monitoring protocols to substantiate their claims (Winter 2004). Two studies of TNR programs that did use relatively rigorous monitoring are reported in Foley et al. (2005). These programs, despite a “substantial expenditure of resources,” resulted in no measurable decrease in feral cat populations. Foley et al. (2005) used mathematical modeling to determine that 75 percent of animals in a population would need to be neutered annually to reduce the population. This level of effort was recognized as unrealistic by the authors. In addition, their model did not account for density dependence in the feral cat population. Given a cat’s ability to reproduce rapidly (Stoskopf and Nutter 2004), if TNR is successful in reducing a population, the increase in cat reproduction as a function of newly available territory and food could possibly offset this decrease, and a much greater effort would be required to maintain a decreasing population. For these reasons, TNR is inappropriate for removing feral cats from Kahoʻolawe Island and would not meet the purpose and need of the project.

Introduced rodent eradication only

To date, successful rodent eradications have been achieved on at least478 islands in over 43 countries/territories (DIISE 2014). Only two tools are currently available for the eradication of introduced rodents from islands, trapping and pesticides. In order to eradicate a rodent population, one or both of these tools must be deployed across the entirety of the island and must be widely attractive (through the use of palatable lures in traps or palatable rodenticide formulations) to the rodent population in order for all individuals to be removed.

Trapping

Trapping as the sole means of eliminating a rodent population has only been successfully implemented on a few small, low-lying, islands with easily accessible terrain (<15 ha; DIISE 2014). Trapping is not a feasible method of eradicating mice and rats from Kahoʻolawe; traps would need to be deployed at a minimum density of 25 stations per hectare spaced at 20 m apart) to ensure that all mice are at risk of capture within their home ranges – almost 300,000 traps.

Rodenticides

Rodenticides have been used in the vast majority of rodent eradication campaigns worldwide (99.5%), with a 90-95% success rate, depending on the target species (Holmes et al. 2015).Historically, rodent eradication projects targeting mice on islands have had a higher failure rate than eradication projects targeting rats (Howald et al. 2007, MacKay and Russell 2007, DIISE 2014), and mice show a higher tolerance of anticoagulant rodenticides than do rats (Fisher 2005). In tropical environments, the success rate of rodenticide based rodent eradications is lower (81%) compared to non-tropical environments (Holmes et al. 2015). The reduced success rate on tropical islands reflects more variable rodent reproductive cycles tied to weak seasonality in food resources compared to temperate systems with distinct rodent breeding seasons tied to seasonally available food resources. In addition, on tropical islands non-target bait consumers (e.g., land crabs) often make it difficult to ensure that bait remains available for a period of time that ensures that every individual rodent within the target population consumes a lethal dose of rodenticide.

Rodenticides employed in bait products that are registered for the control or eradication of rodents in the U.S. fall into four categories (Table 3.1). The main differences between each class of rodenticides are the mode and speed of action of the pesticide, and the related risks each poses to non-target consumers. In the case of Kahoʻolawe, the terrestrial non-target species of concern are primarily birds. However, few species of native birds are currently found on Kahoʻolawe and a fraction of these would be at risk of being exposed to rodenticide.

Table 3.1. A list of the nine rodenticides that are included in bait products registered with the U.S. EPA for control of rodents. Each pesticide is grouped into one of four categories and rated for its toxicity to bird species (low to high).

Category	**Description**	**Rodenticide**	**Toxicity to Birds**[4]
Acute	A pesticide that acts rapidly and causes death within 24-36 hours after ingestion.	Bromethalin	High
		Zinc phosphide	High

Category	Description	Rodenticide	Toxicity to Birds[4]
Subacute	A pesticide that causes death between 24 and 48 hours after ingestion.	Cholecalciferol	Low, no secondary poisoning
1st generation anticoagulant	A pesticide that prevents coagulation (clotting) of the blood and requires multiple doses to induce mortality.[1] It takes 3-7 days for the anticoagulant effect to develop.[2]	Chlorophacinone	High
		Diphacinone	Moderate
		Warfarin	Moderate
2nd generation anticoagulant	A pesticide that prevents coagulation (clotting) of the blood and may require just a single dose to induce mortality.[1] It takes an average of 4 days for the anticoagulant effect to develop.[3]	Brodifacoum	High
		Bromadiolone	High
		Difethialone	High
		Difenacoum	High

[1] (Parkes et al. 2011)
[2](Eason and Ogilvie 2009)
[3](Broome et al. 2012)
[4](US Environmental Protection Agency 1991, 1998, Erickson and Urban 2004, US Environmental Protection Agency 2007)

The main impediments to an effective rodenticide application stems from four sources: low toxicity, resistance to rodenticides, conditioned aversion to bait or "bait shyness," and low acceptance (palatability) of the bait. It is essential to consider these factors along with the island-specific conditions and human health risks, when selecting a rodenticide for an eradication campaign to optimize the probability of success.

1. In an equal-dosing scenario, first generation anticoagulant rodenticides (FGARs) are less toxic to rodents than second generation anticoagulant rodenticides (SGARs) (US EPA 2004). In general, this means rodents must eat more of this rodenticide and they must eat it over an extended period of time without interruption to achieve mortality. The two classes of rodenticides differ in how the compounds bind to the vitamin-K reductase enzyme (VKOR), a process by which they impair the liver's production of active clotting factors resulting in death from internal hemorrhaging. SGARs bind tightly to the enzyme and are typically more resistant to metabolism, giving them the ability to kill a rodent after a single feeding if an adequate dose is consumed, while FGARs have a weaker bond with the enzyme and hence are more subject to metabolism (Buckle and Smith 1994). For example, rodents must feed on bait containing the SGAR diphacinone multiple times over a several day period before the anticoagulant effect takes hold (U.S. EPA 2004) – the ingestion rate must exceed the rate of metabolism for the rodent to succumb to the rodenticide and sustained exposure to an adequate concentration over multiple days is required.
2. Resistance to or tolerance of an anticoagulant rodenticide by a population of rodents occurs after sustained use of anticoagulant pesticides for rodent control. Rodent resistance to anticoagulants was first observed after prolonged use of warfarin (FGIR) in Scotland and has subsequently been observed with other first- and second-generation anticoagulants (Lund 1984,Bailey and Eason 2000, Howald et al. 2004). Animals that are resistant to anticoagulant rodenticide carry a

"resistance" allele that weakens the ability of the anticoagulant molecule to bind to VKOR (Buckle and Prescott 2012). Resistance becomes prevalent within a rodent population when carriers of the resistance allele are selected for during a prolonged period of exposure to anticoagulant rodenticide; resistance typically manifests within 10 generations of chronic exposure to the anticoagulant rodenticide (Brunton et al. 1993, Bailey and Eason 2000). Additionally, populations that are resistant to one pesticide are often resistant to others of the same category, termed cross-resistance (Hadler and Buckle 1992). It is very unlikely that resistance to anticoagulant rodenticide has developed within Kaho‘olawe's population of *R. exulans* as the population has not experienced chronic exposure to anticoagulant rodenticides except possibly in areas around buildings where historically diphacinone baits (J.T. Eaton block baits with peanut butter) and more recently bromadiolone bait (ContracBlox ®) has been used (Parkes 2009).

3. Bait shyness often results from an individual consuming a sub-lethal dose of pesticide and associating the symptoms of exposure with the bait, i.e. a learned aversion, and thereafter avoiding the bait and never consuming a fatal dose of rodenticide. Bait shyness is found typically with the acute rodenticides and is attributable to both the specific activity of certain rodenticides and bait formulations (Marsh 1987, Buckle and Smith 1994). For conservation purposes, acute rodenticides have typically been avoided by rodent eradication campaigns due to bait shyness concerns. The delayed onset of symptoms associated with exposure (typically after a lethal dose has been consumed) to anticoagulant rodenticides is believed to minimize the risk of bait shyness occurring with this group of rodenticides (U.S. EPA 2004). One of the reasons that SGARs have been so effective at eradicating populations of rats is that they are not known to cause bait-shyness because of their "chronic" mode of action (Buckle and Fenn 1992).
4. Low acceptance speaks to the palatability or relative "attractiveness" of the bait to rats—especially in the presence of competing food sources. Palatability is primarily dictated by the bait matrix and the bait form (pellets, blocks, inert ingredients, etc.) (Buckle and Kaukeinen 1988, Mason et al. 1991, Schmolz 2011). However, some research suggests that certain rodenticides can impart palatability issues, related to the concentration of the rodenticide in the product (Buckle and Smith 1994, Pitt et al. 2011)

Currently, three anticoagulant rodenticide based products are registered under the Federal Insecticides, Fungicides, and Rodenticides Act (FIFRA) for use in the United States and in U.S. territories for conservation purposes:

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

Each bait product is designed to be attractive and palatable to rodents, such that rodents are more likely to choose the bait product over natural food sources. The predominant ingredients in these bait products are inactive, non-germinating grains (either sterile or crushed). Brodifacoum-25W Conservation was designed for use in wet environments where a lot of rainfall is expected, whereas Brodifacoum-25D Conservation was developed for drier conditions. Diphacinone-50 Conservation and Ramik® Mini Bars All-Weather Rat & Mouse Killerare the only rodenticide currently registered and labeled by the Hawai‘i Department of Agriculture for conservation use in the state of Hawai‘i.

It is possible that the two FIFRA registered brodifacoum bait products could be registered for conservation use in the state of Hawaiʻi, or, if warranted, a novel bait product could be developed and registered under FIFRA and within the state of Hawaiʻi for conservation purposes. A new product for conservation use would require registration under Section 3 of FIFRA, requiring first laboratory then field testing to ensure efficacy and risks are well understood. For Kahoʻolawe, the project implementation could be structured under alternative registrations with a vetted monitoring program to collect data to support the Section 3 registration of a future conservation rodenticide bait product. The registration would include an Experimental Use Permit and/or covered by FIFRA Section 18. The costs associated with a new registration are directly dependent on the amount of data that currently exists relative to the amount of new data required for registration along with considerations of capacity of the registrant. In addition there are costs of project implementation and environmental monitoring.

Rodenticide Delivery

Not only are there different rodenticides available for eradications, but there are also different bait delivery methods. Determining which method(s) to use on a specific island is based on a suite of factors, including island size and non-target species. Some islands because of variation in terrain or land-use practices may require multiple methods.

Bait stations

Within the US, bait stations are the oldest method of bait delivery and involve enclosing bait in a container with small entrances in order to protect the bait from the elements and to limit access to bait for non-target consumers (O'Connor and Eason 2000, Howald et al. 2007, Broome and Brown 2010). Bait stations must be regularly serviced by project personnel in order to ensure that sufficient bait is available to rodents. The largest island where bait stations have been successfully implemented for rodent eradication occurred on temperate Langara Island, Canada (3,105 ha) (Taylor et al. 2000). Bait stations are not a feasible primary method of eradicating mice and rats from Kahoʻolawe; stations would need to be deployed at a minimum density of 25 stations per hectare about 20m apart to ensure that all mice have access to bait within their home ranges. A total of 288,750 bait stations would need to be installed and frequently maintained for many months to provide the level of bait coverage required to eradicate mice from Kahoʻolawe. Bait stations would be effective at removing rodents from areas that cannot be treated by broadcasting bait, e.g., inside inhabited buildings.

Hand broadcasting

Hand broadcasting bait was developed as an alternative way of distributing a lethal dose of bait into the home territory of every rodent. In order to comprehensively cover the island, project personnel would hand broadcast measured amounts of bait uniformly along pre-determined transects covering the island. The largest island where hand broadcasting bait has successfully eradicated rodents occurred on Tea Island in the Falklands (360 ha) (DIISE 2015). Because of the presence of UXO on Kahoʻolawe, the size of the island (11,550 ha), and the prevalence of steep cliffs, it is not feasible to apply bait by hand across the entire island but could be used as a supplemental approach to treat areas that cannot be treated by aerial broadcast.

Aerial broadcast

Since the early 1990s, when the aerial broadcast of pelletized bait was first introduced it has been extensively employed in rodent eradications, particularly on large islands with inaccessible terrain

(Howald et al. 2007). This method uses a commercial-grade fertilizer bucket slung from the underside of a helicopter using GPS technology to accurately and uniformly apply bait to the entirety of the island. The goal is to deliver a lethal dose of bait into every potential rodent territory. Typically, two applications of bait are made, 7-10 days apart; however, a longer period between applications (21+ days) is desired if breeding is suspected in the target rodent population.

These aerial application methods were employed successfully during recent rat eradication operations undertaken on Hawadax Island (Alaska Maritime National Wildlife Refuge), on Mokapu Island, Hawaiʻi (Hess and Jacobi 2011) and on Palmyra Atoll National Wildlife Refuge (Wegmann et al. 2012), and have been used to implement 34% of rodent eradications globally and 100% of rodent eradications on islands larger than 11,000 ha. Targeted application rates for Kahoʻolawe would be determined with pre-eradication baiting trials.

Pre-eradication non-toxic bait application trials would assist in determining the recommended application rate specific for Kahoʻolawe (Pott et al. 2014). Trials would also help determine the number of applications required. Most projects use two applications, however, because there are two species of rodents on Kahoʻolawe, it is possible that additional applications may be required to address bait competition between the mice and rats. Exact application dates would be weather dependent, but it is anticipated that all of the aerial bait broadcast applications would be completed in the spring to summer and would follow the peak in mouse abundance that results from a wintertime precipitation-driven increase in primary productivity on the island. The best window for implementing the rodent eradication on Kahoʻolawe would depend on several environmental factors (Table 3.2; Figures 3.2-3.5) including the peak of rodent populations, the presence of non-target species considered at risk and climatic factors such as precipitation and wind. Figures 3.2 and 3.5 indicate there is annual variation with respect to relative abundance of rodents and though there is a trend toward increasing abundance from mid-winter to spring, the peak population is not consistent each year (Figure 3.5) making selecting a window for implementation challenging based on rodent abundance alone. Planners would need to decide which factors are most important when selecting the implementation season (i.e., efficacy and non-target risks).

Figure 3.1 Multiple-catch mouse traps are deployed on a regular basis to monitor rodent abundance in three habitats on the island. Pueo (Hawaiian short eared owl) are also surveyed at the same time to monitor abundance. The pueo are considered *ʻaumākua* or family gods and spiritual protectors to Native Hawaiians.

Table 3.2. The seasonality of environmental factors that would influence the timing of bait trials, and ultimately a rodent eradication, on Kahoʻolawe Island. Mouse population values based on monthly capture survey data.

Environmental factor	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mouse population increase	X	X	X	X								
Mouse population peak				X	X	X						
Mouse population decline					X	X	X	X	X			
Pueo population peak				X	X	X	X	X				
Shorebirds present	X	X	X	X				X	X	X	X	X
Monk seal pupping					X	X	X					

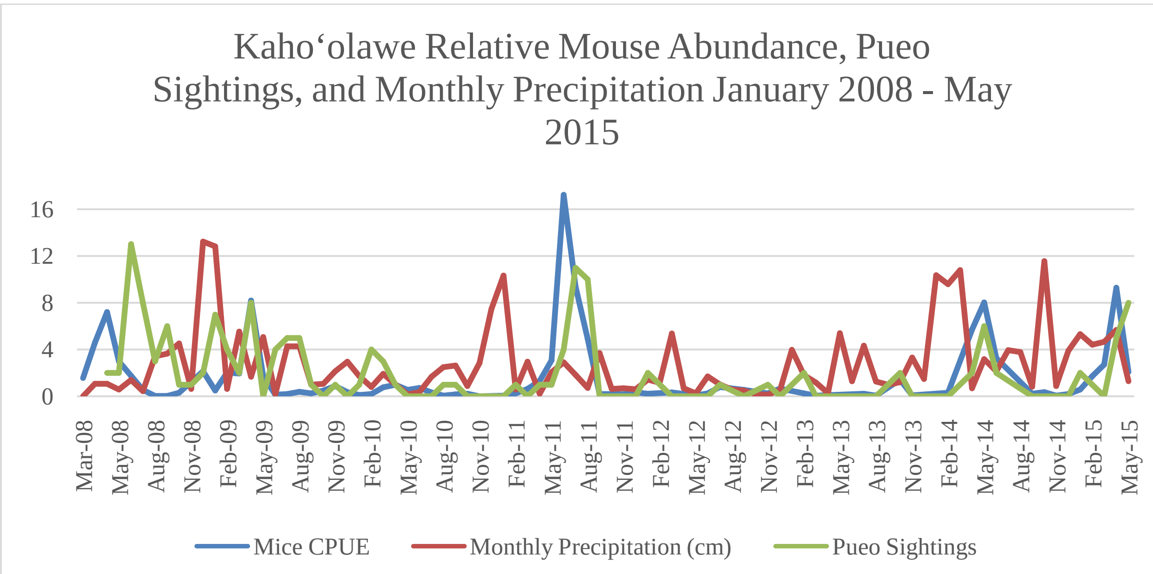

Figure 3.2. Relative average mouse abundance from monthly one-day trapping surveys (presented as catch per unit effort [CPUE\), monthly pueo sightings, and cumulative average monthly precipitation for Kahoʻolawe Island January 2008 – May 2015. Incomplete data lines for mice and pueo denote months when surveys were not undertaken: July 2008, Dec 2010, Feb/Apr/Aug/Oct 2012, Jan/Apr/May/Jun/Sep/Dec 2013, and Jan/Mar/Jul/Aug 2014.

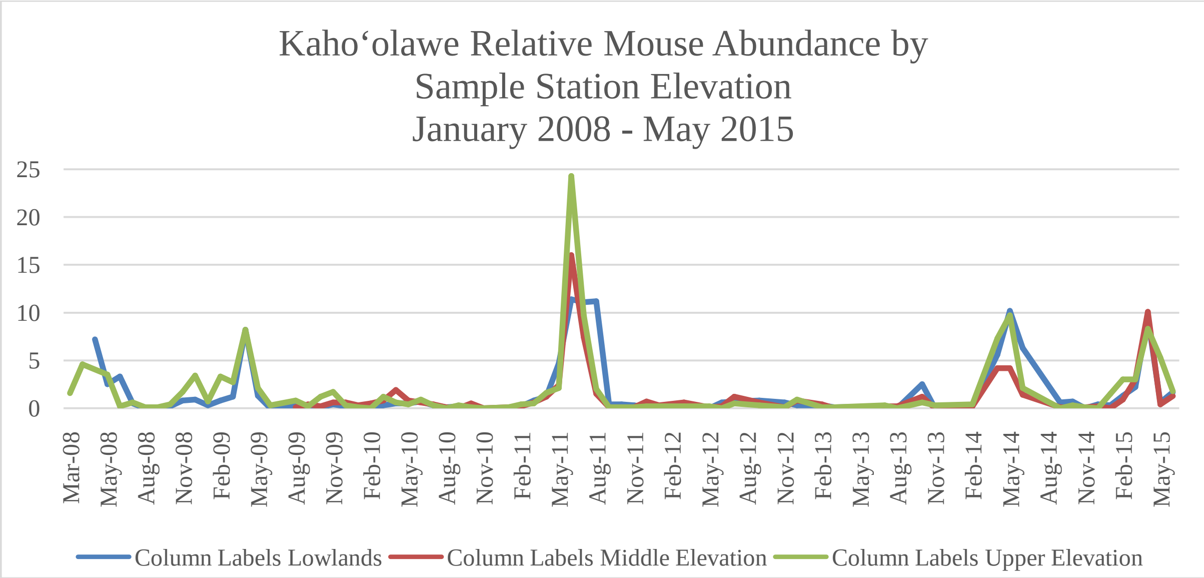

Figure 3.3 Relative average mouse abundance from monthly one-day trapping surveys in each of three habitat/elevation types on Kahoʻolawe Island. Not all months were sampled equally with data missing for July 2008 Dec 2010, Feb/Apr/Aug/Oct 2012, Jan/Apr/May/Jun/Sep/Dec 2013, and Jan/Mar/Jul/Aug 2014.

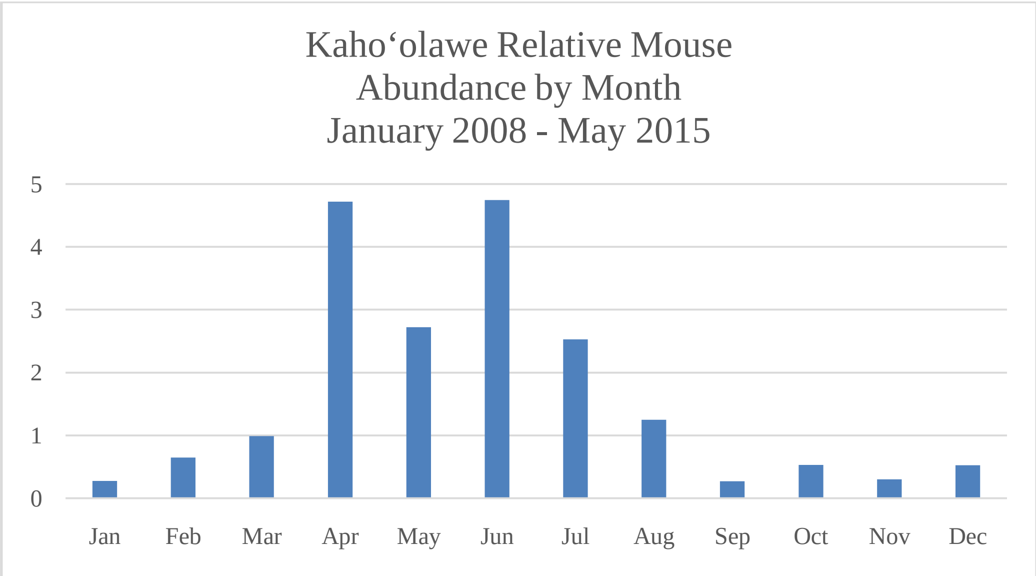

Figure 3.4 Relative average mouse abundance combined for all months from one-day surveys conducted January 2008 – May 2015 on Kahoʻolawe Island. Not all months were sampled equally with data missing for July 2008, Dec 2010, Feb/Apr/Aug/Oct 2012, Jan/Apr/May/Jun/Sep/Dec 2013, and Jan/Mar/Jul/Aug 2014.

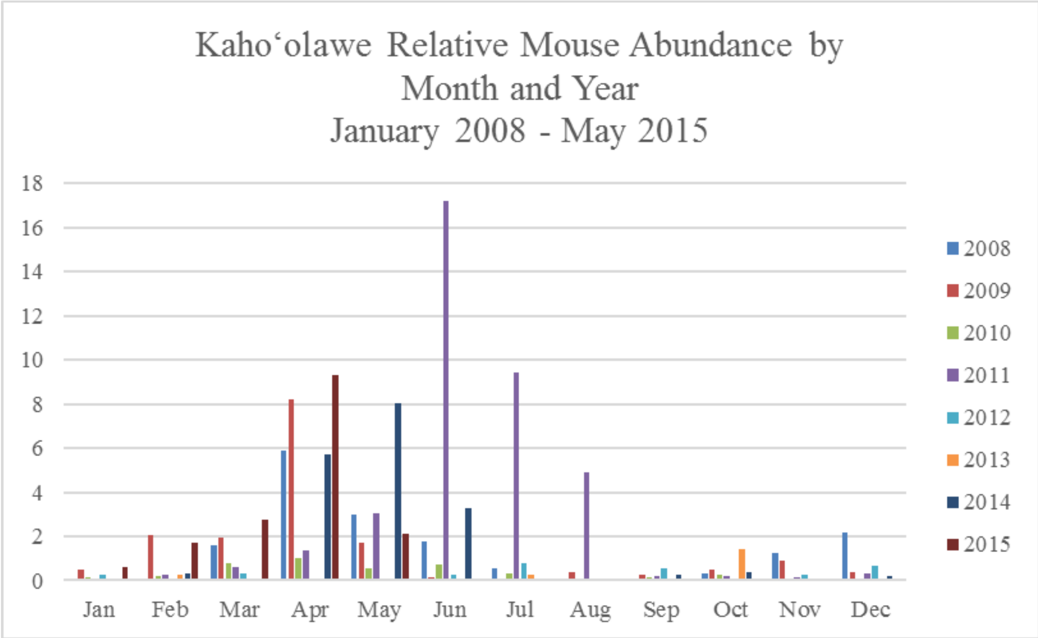

Figure 3.5 Relative average mouse abundance by month and year from one-day surveys conducted January 2008 – May 2015 on Kahoʻolawe Island. Not all months were sampled equally with data missing for July 2008, Dec 2010, Feb/Apr/Aug/Oct 2012, Jan/Apr/May/Jun/Sep/Dec 2013, and Jan/Mar/Jul/Aug 2014.

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

- The need to apply bait as evenly as possible to prevent gaps in coverage or excessive overlap;
- Island topography;
- The need to minimize bait drift into the marine environment;
- The need to minimize disturbance to pinnipeds (Hawaiian monk seal) hauled out on land;
- The need to avoid bait broadcast into areas of human habitation; and
- Weather conditions.

The baiting regime would follow common practices that are based on successful island rodent eradications elsewhere in the U.S. and globally (Howald et al. 2007). Flight swaths are flown across the interior island area accompanied by overlapping swaths flown with a bucket that is configured to spread bait in a specified direction (to minimize bait drift into the marine environment) flown around the coastal perimeter. Each flight swath would overlap the previous by approximately 25-50 percent to ensure no gaps in bait coverage. During each application, most points on Kahoʻolawe would likely be subject to up to two helicopter passes.

Bait would be applied in strict accordance with FIFRA, the EPA's pesticide regulation. The precise bait application rate after all applications would be up to but not in excess of the label rate set by the EPA. Prior to bait application, the pilot would calibrate the helicopter and hopper combination to ensure consistent and accurate bait application using a placebo bait product. The calibration would occur at a test site in conditions similar to those on Kahoʻolawe.

To ensure complete and uniform application of rodenticide:

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

- During the operation the application rate would be calculated from the quantity of bait applied and the area covered as recorded by the helicopter's onboard global positioning system (GPS). More in depth analysis of application rates across the island would be undertaken periodically during the operation using Geographic Information System (GIS) software.

- Adjustments in bait flow rates, helicopter speed, and flight lines would be made as needed to meet the optimal application rate, staying within the legal limits set by the EPA.

While US regulations prohibit the spread of rodenticide into the marine environment, if a rodent eradication using rodenticide were undertaken on Kahoʻolawe it would be impossible to avoid some drift of bait into the marine environment. Given this, fish and other marine organisms in the near-shore environment could be at risk of exposure to rodenticide. Risks to the organisms in the marine environment are specific to each rodenticide – see Chapter 4 for further discussion of risk posed to non-target species by rodenticides used in rodent eradication projects.

Tracking the bait application with GPS and GIS programs allows project managers to accurately monitor the application of bait across the island and to react in real-time to deficiencies in bait coverage. The ability to aerially apply bait is constrained by weather. Winds greater than 35 mph greatly reduce the accuracy of the bait application, and persistent precipitation can cause the bait to become sticky and foul the spreading mechanism in the applicator bucket. With aerial bait applications, bait is spread during a shorter time duration compared to other application methods (e.g., hand and bait station) (Broome et al. 2014) and more easily applied to all habitats except those with subterranean complexity (e.g., caves).

As a result of the need for caution near the marine environment, the coastlines and offshore islets, which are potential mouse and rat habitat, may not receive the optimal bait coverage with helicopter broadcast alone. In cases where it is evident or suspected that any land area did not receive full coverage, supplemental, systematic broadcast either by hand, boat, spot-baiting by helicopter, or any combination of the above would need to be undertaken. These areas would be identified during analysis with the helicopter tracking data using GIS. Helicopters may hover for brief periods over land during bait application to bait offshore islets using a method that is in compliance with the bait product use label.

Helicopters may be staged from Kahoʻolawe, the island of Maui, or from a boat or barge offshore of Kahoʻolawe. During the bait application phase, helicopters would land at the designated staging areas, where staff would re-fill the bait bucket, and re-fuel. The staging areas would be adequately stocked with fuel and other supplies and equipment to support the helicopter for the entire bait application process.

After each bucket broadcast, the helicopter would fly to a designated staging area where personnel would refill the bait hopper, refuel the helicopters, and conduct other necessary equipment maintenance. The secure staging area would be adequately stocked with bait, fuel, personal protective equipment (PPE), and other supplies and equipment to support the helicopters and project personnel during the bait application process.

All personnel participating in supplemental hand broadcasts would be trained in systematic bait application at the target application rates. In coastal areas with irregular shorelines, aerial broadcast may be replaced by hand baiting or other techniques to minimize bait drift into the marine environment, as well as to minimize any areas of coastal habitat that could otherwise be subject to bait densities below or above the targeted application rate.

All personnel that handle bait or monitor bait application in the field would be equipped with PPE that meet or exceed all requirements by the EPA. All bait application activities (aerial broadcast, hand broadcast, and bait station filling) would be conducted by or under the supervision of one or more pesticide applicators licensed by the State of Hawai‘i.

Rodent eradication approaches considered and dismissed

Use of other pesticides
The following rodenticides that are available, but are either registered with the EPA for any purpose other than conservation on islands (cholecalciferol, difethialone, bromadiolone, wafarin, zinc phosphide, bromethaline, chlorophacinone, and strychnine) or are not registered with EPA for any purpose (pindone, 1080, flocoumafen, and Coumatetralyl) were dismissed from further consideration for one or more of the following reasons: 1) the time to trial and register (if successful) the product for conservation purposes was a minimum of two to five years; 2) use of the pesticide could have increased the potential for bait shyness to develop in the targeted mouse and rat populations which would result in operational failure; 3) there is a potential for mice to develop resistance to the product, which can develop within a population that has alleles for tolerance to the pesticide; 4) the product lacks an effective antidote in case of human exposure; 5) the product has been untested in an eradication environment. Chlorophacinone is a potential exception. There is currently no FIFRA Section 3 or Special Local Needs label for a chlorophacinone bait product for eradicating rodents from islands for conservation purposes. However, a recent study by Pitt et al. (2010) suggests that chlorophacinone may be effective at eradicating rats and possibly mice from island; chlorophacinone may be assessed as a candidate rodenticide for the eradication of mice and rats from Kaho‘olawe Island.

Use of disease
While there is ongoing research focused on the development of taxon-specific diseases that can control populations of invasive species (CSIRO, www.cse.csiro.au/research/rodents/publications.htm), there are no pathogens with proven efficacy at eradicating rodents (Howald et al. 2007). Even a highly lethal mouse- or rat-specific pathogen would be ineffective at eradicating mice or rats from Kaho‘olawe, because the rodent populations would most likely rapidly decline, causing the introduced disease to disappear before fully infecting all individuals within the population. Therefore, the use of disease will not be pursued as an approach to eradicating rodents from Kaho‘olawe Island.

Biological control

The alternative to introduce natural predators of rats and mice, such as snakes, was dismissed because biological control most often only reduces, rather than fully eradicates the target species failing to achieve the desired ecological benefit gained through complete rat and mouse removal. There is no known effective biological control agent for rats or mice on islands, and some forms of biological control would result in unacceptable damage to the environment. Alien predators (e.g., small Indian mongoose [*Herpestes auropunctatus*], cane toads [*Rhinella marina*]) have been introduced to islands in an attempt to control other species (native and alien) (Lever 2001, Hays and Conant 2007). These introductions have impacted native species and failed to control the target species causing harm. Therefore, this approach was eliminated from further consideration as an approach to the eradication of rodents from Kahoʻolawe Island.

Fertility Control (Immunocontraception and Genetic Mutation)

Fertility control has been used with limited success as a method of pest management for a few invasive species (Ji 2009, Campbell 2007). Experimental sterilization methods have included chemicals and proteins delivered by vaccine, genetically-modified viral pathogens, and genetically modified mice (Chambers et al. 1999). However, the effectiveness of these experimental techniques in the wild, as well as their potential impacts to non-target animals, is unknown. The current lack of information on fertility control as an eradication method (Tobin and Fall 2005) eliminates this approach from the list of viable options for eradicating rodents from Kahoʻolawe Island.

Combined feral cat and introduced rodent eradication

The eradication of feral cats and introduced rodents could occur as a multi-step conservation action targeting feral cats and rodents separately or as a single conservation action targeting cats and rodents simultaneously. It is beyond the scope of this document to evaluate every possible approach. Consideration and details outlining all possible approaches would be required and included in the regulatory compliance phase of eradication project planning (see Chapter 5).

A multi-species eradication strategy for Kahoʻolawe would follow the guidelines for feral cat and rodent eradication presented in the above sections. As a component of multi-species eradication campaigns, cats have been eradicated or their numbers reduced in at least seven projects (Table 3.3). In these projects, rodents were targeted using brodifacoum. Non-target mortality of feral cats occurred primarily through secondary poisoning when feral cats consumed rodents containing rodenticide. On Tuhua Island, New Zealand, all feral cats were removed as non-targets (Towns and Broome 2003). In the other six projects, cats were not eradicated during the rodent baiting campaign. Follow-up trapping and hunting were used to remove the remaining cats.

As previously mentioned, there is no pesticide product that is registered under FIFRA that can be used to eradicate or control feral cats in the US. Furthermore, it is not clear whether an eradication strategy that endeavors to eradicate invasive rodents with rodenticide while cats are present on a US island would require a separate pesticide label to regulate the associated removal of feral cats, or if the indirect take of feral cats would be considered “non-target” or “incidental” take and managed according to the standards set through the environmental compliance process that would precede the eradication. This point would need to be clarified prior to developing a combined strategy for eradicating introduced rodents and feral cats from Kahoʻolawe.

Table 3.3.Multi-species eradication projects where the application of rodenticide to eradicate one or more populations of invasive rodents was also used as a strategy to eradicate or decrease the abundance of feral cats within the project area.

Island Name	**Country**	**Area (ha)**	**Year**	**Rodent baiting method**	**Reference**
Rangitoto / Motutapu	New Zealand	3,854	2009	Aerial	Griffiths, 2011
Raoul	New Zealand	2,943	2005	Aerial	Broome, 2009
Tuhua	New Zealand	1,277	2000	Aerial	Towns and Broome, 2003
Pitcairn	UK Overseas Territory	500	1997	Ground	Nogales et al., 2004
Curieuse	Seychelles	286	2001	Aerial	Merton et al., 2002
Flat	Mauritius	253	1998	Ground	Bell, 2002
Isabela	Mexico	194	1996	Aerial	Rodriguez et al., 2006
Viwa	Fiji	60	2006	Ground	Campbell et al., 2011

Preferred approach

While it would be possible to eradicate either rodents or feral cats from Kahoʻolawe while leaving one or the other of the invasive mammal populations on the island, doing so would fall short of the KIRC's ecosystem and cultural restoration goals. If either feral cats or rodents were left on Kahoʻolawe, the benefit to extant populations of native species would be less than that achieved by removing both rodents and feral cats. Furthermore, with either feral cats or rodents on Kahoʻolawe, the island will not provide suitable, predator-free habitat for native Hawaiian species that are at risk of extinction from sea level rise due to climate change throughout their current ranges, e.g., the Nihoa Millerbird (*Acrocephalus familiaris kingi*) and the Laysan Duck (*Anus laysanensis*). An eradication strategy that targets both rodents and feral cats would provide over 11,000 hectares of predator-free habitat for native Hawaiian species, ensure that culturally-important natural resources (e.g., plants, seabirds) are safeguarded on the island, and would benefit from strategic use of project funds through all phases of the project. The preferred approach will also contain a biosecurity program for Kahoʻolawe that is developed, implemented, and assessed for weaknesses in advance of the implementation of the eradication project. The biosecurity program will ensure that the conservation benefits achieved by eradicating feral cats and introduced rodents from the island will be maintained in perpetuity, and it will minimize the risk of subsequent introductions of other invasive species.

Chapter4 - Monitoring

Summary

- An important component to the planning and implementation of any invasive animal eradication project is monitoring the environment, including physical and biological factors, prior to, during and following the eradication. A thorough understanding of ecosystem relationships prior to the eradication assists management decisions by identifying potential consequences and providing a basis for proactive or adaptive management of the eradication project. Monitoring following the eradication provides information to managers on expected and unexpected impacts, both positive and negative, and provides lessons that can facilitate future eradication projects (Zavaleta et al. 2001).
- The goal of the environmental monitoring would be to document the presence, fate, and persistence of the rodenticides in the environment, to identify pathways of exposure to non-target species, and to identify mortality of non-target animals caused by the eradication. Ecosystem response monitoring identifies ecosystem changes in response to the eradication. The monitoring of target species is necessary in order to plan for the operational implementation of the eradication and to determine success of the operation. Post-eradication monitoring of target species would be necessary to document eradication success or to identify the need to implement contingency operations in the event of the continued detection of individuals of the targeted populations.
- Numerous factors are considered when planning the monitoring phase of an eradication project and several are considered here. The size and complexity of the island would dictate the amount and intensity of monitoring that would be required to adequately capture ecosystem changes. The variety and distribution of different habitats again would inform sampling strategies to ensure target and non-target species are sufficiently monitored. An evaluation of potential rodenticide movement through the ecosystem and food web interactions identifies potential secondary impacts to non-target species and further identify those species that should be sampled for rodenticide residue. Finally, if the eradication strategy removes cats or rodents in a step-wise approach (i.e., the order of first removing either cats or rodents), those removal effects to the species that remain would be captured.
- Environmental monitoring would include sampling of both sea and fresh water, soil and a suite of terrestrial and marine vertebrates and invertebrates. Ecosystem response monitoring would be implemented to determine how different components of the terrestrial ecosystems respond to the eradication. The operational success of the eradication would be confirmed with sampling methods focused on the detection of the target species.
- For the eradication of feral cats and introduced rodents from Kahoʻolawe, multiple methods and protocols would be developed and implemented in order to provide information on the status of the target species populations, the potential environmental impacts, and the ecosystem response to the eradication. Three types of monitoring plans would be developed and implemented: environmental impacts monitoring, ecosystem response monitoring, and target species monitoring.

Environmental Monitoring

An important component to planning and implementing a rodent eradication utilizing rodenticides is to evaluate the impacts to the environment from the rodenticide bait application. Developing and implementing a monitoring program that includes the collection and analyses of physical and biological samples for rodenticide residue is recommended to understand the impact to non-target animals (Dunlevy and Swift 2010, Fisher et al. 2011, Pitt et al. 2015). More importantly, rodenticide-based eradication of rodents fromislands is a growing field of applied conservation and each new attempt, if properly documented, will inform subsequent projects on ways to increase safeguards for humans and minimize harm to non-target animals.

For the overall success of the project, the importance of creating an environmental monitoring program that both meets regulatory and cultural compliance as well as social approval cannot be understatedand has been suggested as a requirement to meet minimum standards for both state and federal regulations as well as public acceptance of eradication projects in Hawaiʻi (Dunlevy and Swift 2010). Recommendations by the Hawaiʻi Toxicant Working Group recommend environmental monitoring should be implemented "until a track record of environmental safety is established that is acceptable to regulators and the public" (Dunlevy and Swift 2010). Eradication leaders involved with seminal invasive species eradication projects in New Zealand advised monitoring, though costly and time consuming, will provide data thatassists with the development of environmental risk assessments and mitigation planning for future projects (Fisher et al. 2011). Each new project, through success or failure, adds to the growing field of eradication science and provides critical data toward developing new best practices.

<u>Chapter limitations</u>

Several limitations exist in providing detail in this chapter namely the exact methods of eradication are yet to be defined for each target species and the order of the eradication process is unknown (e.g., cats and rodents treated simultaneously or each separately). In addition, the rodenticide bait product that would be used for the rodent eradication has not been identified thus laboratory testing procedures specific to the toxicant cannot be fully addressed though historic examples are given. The monitoring methods would be more fully developed and defined during the operational planning stages of the eradication thus this chapter will lack specific details of how exactly to monitor and instead presents examples of what has been conducted elsewhere along with recommendations of what may be incorporated into a monitoring program specific to Kahoʻolawe.

Methods of sampling and rodenticide residue analyses would be best developed and conducted by aqualified entitythat is not otherwise involved in the eradication planning and implementation and to reduce perception of bias in the results. Three labs have been used previously for rodent eradication environmental sample analyses using diphacinone in Hawaiʻi and for diphacinone and brodifacoum at Palmyra: the University of California Animal Health and Food Safety Laboratory, Davis California; the U.S. Geological Survey Columbia Environmental Research Center, Columbia, Missouri; and the USDA/APHIS National Wildlife Research Center, Fort Collins, Colorado (Gale et al. 2008, Orazio et al. 2009, Alifano et al. 2012, Pitt et al. 2015).

The environmental monitoring section of this chapter applies to the use of rodenticides for the rodent eradication portion of the project. If toxicants are incorporated into the cat eradication an environmental monitoring program specific to the chosen toxicant would be developed.

Though this chapter discusses and evaluates some potential risk to non-target species, this chapter does not include a formal risk assessment which would be completed as part of environmental compliance requirements. Such analyses would consider individual, island-wide, and global population mortality impacts and is beyond the scope of this business plan. Similar to designing and implementing environmental monitoring efforts, a risk assessment is best conducted by a qualified entity otherwise not involved with the eradication operational planning so the analyses are independent.

Given the limitations listed above, we present the results from eradication projects and published literature that utilizedbrodifacoum, the most widely used rodenticide in global operations to date, anddiphacinone, the rodenticide used in two aerial broadcast eradication operations within Hawaiʻi as examples of methods that could be employed and applied to the environmental monitoring surrounding the eradication of rodents from Kahoʻolawe. Further, noteworthy findings from these historical studies emphasizing unexpected outcomes from the projects and their recommendations for improvements to other similar and future island eradication efforts with an end goal of increasing efficacy and eliminating or greatly reducing non-target mortality.

In recent years there has been a growing body of literature measuring rodenticide residues and non-target mortality associated with island rodent eradications globally, especially for the rodenticide brodifacoum (e.g., Morgan et al. 1996, Ogilvie et al. 1997, Dowding et al. 1999, Howald et al. 1999, Pitt et al. 2005, Fisher et al. 2007, Howald et al. 2009, Fisher et al. 2011, Masuda et al. 2014, Masuda et al. 2015, Pitt et al. 2015). Within Hawaiʻi, the Mokapu Island and Lehua Island rodent eradication projects both incorporated environmental monitoring programs to analyze the use of diphacinone (e.g., Gale et al. 2008, Orazio et al. 2009, Dunlevy and Swift 2010).

<u>Criteria for developing an environmental monitoring sampling protocol</u>

Several considerations would be evaluated in designing an environmental monitoring program specific for Kahoʻolawe. Planners must decide what to sample, where to collect those samples, and the time duration sampling should continue until a point is reached that satisfies the established monitoring criteria. Other important components that inform the sampling strategy include conducting studies to determine an appropriate bait application rate specific for Kahoʻolawe (Pott et al. 2014) in conjunction with a bait degradation study (Craddock 2003). A bait degradation study would inform planners on the duration, on average and under specific weather conditions, pelletized rodenticide bait would remain intact and available for primary consumption.

A robust evaluation of potential environmental impacts includes estimating how the rodenticide could travel through the environment by considering all of the physical parameters and pathways open to the rodenticide and then designing a monitoring plan that directly samples those pathways. Rodenticide movement can be estimated based on the physical characteristics of the compound specifically the mobility, including leaching and adsorption, degradation and dissipation in soil and water, and the metabolic processing after consumption by target and non-target consumers (Ramney et al. 1994).

Recent island rodent eradication projects stress the need to more fully understand rodenticide movement through the physical and biological environment during the planning phase of projects in order to minimize the probability of unexpected non-target mortality (Pitt et al. 2015).A tool that would assist in understanding potential rodenticide movement on Kahoʻolawe is a conceptual compartment ecotoxicology diagram of potential exposure pathways and to identify risks to non-target species (Figure 4.1, adapted from Cox and Smith 1990, Smith et al. 1990, U.S. EPA 2011). Smith et al. (1990) developed theoretical models that combine rodenticide exposure and toxicity while distinguishing rodenticide transfer processes from the accumulation of residues which are important to consider identifying risk to target and non-target animals. Although this model was developed for control applications, the basis of the model has applications to island eradications and is used here to provide a framework to evaluate a sampling strategy for Kahoʻolawe.

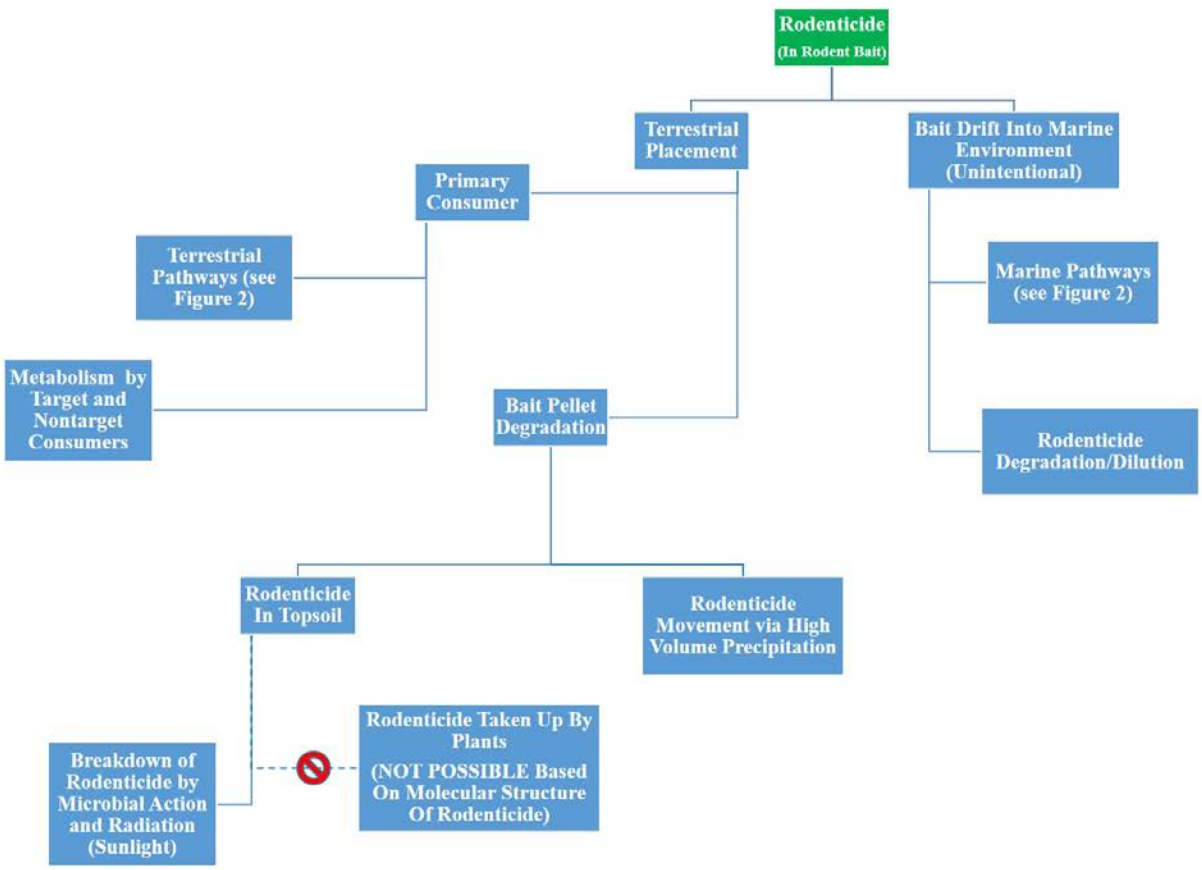

Figure 4.1. Conceptual diagram of potential rodenticide bait exposure pathways.

Exposure of organisms to rodenticide would occur through one of two pathways: primary exposure due to direct consumption of bait pellets, or secondary exposure through the predation/consumption or scavenging of organisms that consumed the bait. An exposure pathway model (Figure 4.2) allows for the identification of potentially significant consumers as vectors of rodenticide movement through the environment which informs the prioritization of organisms to be collected for residue analyses (Hoare and Hare 2006a). The diagram includes all possible vectors; however, some of these vectors may be more probable than others and the ability to understand those relationships depends directly on having data for each relationship. The diagram is constructed so that all pathways may be considered regardless of probability and in some cases species appear within the diagram that may not be present or are only seasonally present on Kaho'olawe (e.g., migratory shorebirds, bats have not been confirmed as present). This all-inclusive approach is needed to anticipate the unexpected and to plan accordingly.

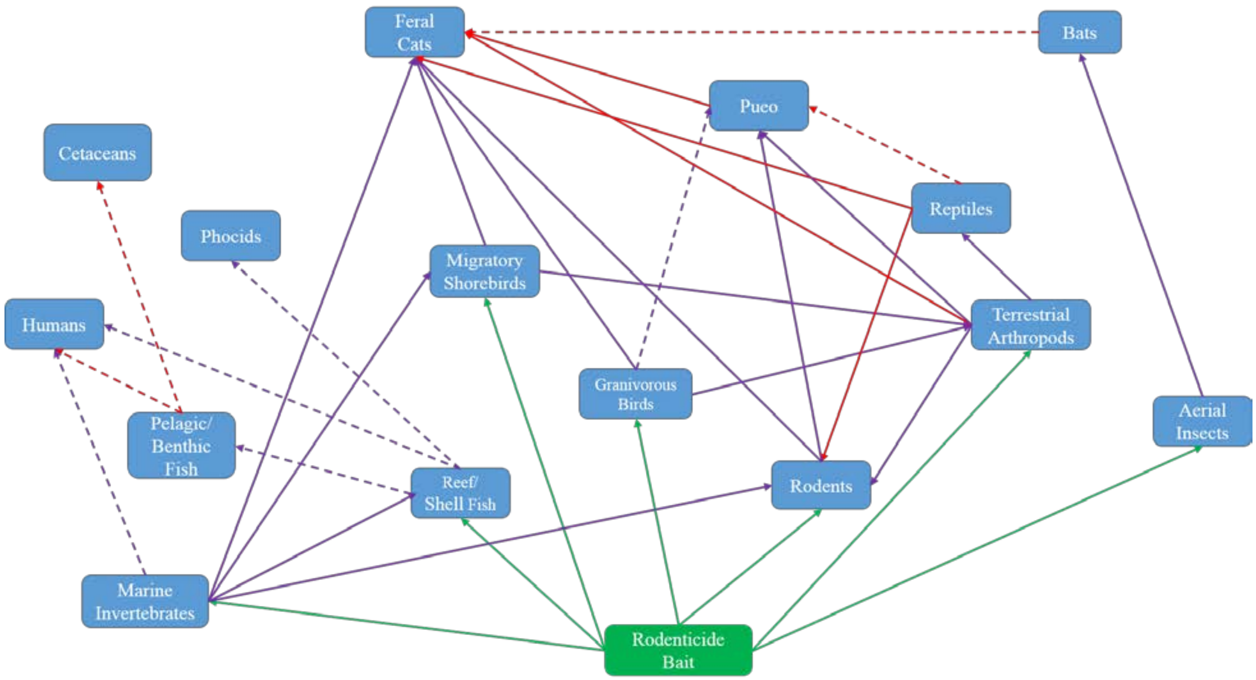

Figure 4. 2. Conceptual diagram of rodenticide bait terrestrial and marine exposure pathways for Kaho'olawe Island, Hawai'i. Solid lines indicate pathways documented from other rodent eradication projects and dashed lines indicate hypothetical pathways not previously reported. Line colors are representative of exposure as follows: green = primary, purple = secondary, and red = tertiary.

The conceptual model diagram should be interpreted as a dynamic system that changes with time even over the course of a few days for some variables (e.g., water testing) due to degradation of the bait and the rodenticide, changes in weather, the decrease in rodenticide bait availability over time, and other natural processes that would alter the amount of rodenticide bait in the environment. For example, an initial reduction in rodents due to mortality could increase the number of invertebrates, through decreased predationby rodents, which could become primary bait consumers if bait were still available (Hoare and Hare 2006a).

In this model, the rodenticide bait used for rodent eradication would be applied via aerial methods with the majority of pellets contacting the terrestrial surface of Kaho'olawe, but some small portion may enter the marine environment via drift caused by wind or inconsistencies in the topography of the coastline relative to the flight path of the helicopter during aerial application. Terrestrial pellets have two initial pathways for consideration: primary consumption by both target and non-target species (Figures 1 and 2) or pellet degradation in place leading to mixing with the topsoil or movement downslope caused by a significant precipitation or wind event. There is no indication that anticoagulant rodenticides are taken up by plants (terrestrial or marine) due to low water solubility and the inability of the large rodenticide molecules to transfer across plant membranes (Askham 1986, Salmon 1987, U.S. EPA 2011). For bait pellets that drift into the marine environment, the diagram identifies two potential pathways of rodenticide movement: direct consumption of bait pellets by marine organisms or bait pellet degradation and dilutioninto sea water.

The rodenticide exposure diagrams identify where rodenticides may travel within the terrestrial and marine environment, but they do not indicate impact related to exposure or dosing (i.e., the amount needed to be lethal). Several important physical principles of how the rodenticide is processed (either physical or physiological) for each system needs to be clarified to understand potential risk to non-target animals and assist with prioritization of sampling strategies.

<u>Anticoagulant rodenticides</u>

Anticoagulant rodenticides (hereafter rodenticides) are largely water insoluble (Eason and Wickstrom 2001, U.S. EPA 2011), generally immobile in soil (U.S. EPA 2004) and have limited leaching capability (World Health Organization 1995). When rodenticide bait pellets disintegrate in soils, the rodenticideis degraded by a combination of soil microorganisms and exposure to solar radiation. This process will vary based on local soil fauna, climactic factors, and temperatures (Eason and Wickstrom 2001). The half-life of brodifacoum in soil is reported to be 84-175 days (Eason and Wickstrom 2001) and for diphacinone in laboratory tests the half-life was 30 and 60 days under aerobic and anaerobic conditions, respectively (World Health Organization 1995). Brodifacoum is considered highly toxic and diphacinone is considered moderately toxic to aquatic organisms (U.S. EPA 1998), but low water solubility for both rodenticides limits risks of exposure to non-target organisms (Eason and Wickstrom 2001).

As was indicated in earlier chapters, anticoagulant rodenticides act by preventing blood from clotting. Brodifacoum is a 2nd generation anticoagulant and usually requires a single feeding to produce acute toxicity though mortality may be delayed for 5 to 10 days (U.S. EPA 2004). A delay in mortality means an individual may continue feeding on bait consuming greater than the minimum required dose to cause mortality. Diphacinone is a 1st generation anticoagulant and generally requires multiple feedings over several days to produce acute toxicity due to the faster rate of metabolism and excretion of the rodenticide. Diphacinone is considered to be less toxic than 2nd generation anticoagulants (U.S. EPA 2004). Brodifacoum persists in tissues for longer compared to diphacinone and as such poses greater risk of secondary exposure for non-target species (U.S. EPA 2004).

Taxa respond differently to anticoagulant rodenticides and there is considerable variation in effects in three general ways: acute (i.e., the amount of rodenticide to cause mortality) or sub-lethal toxicity, the location within the body where rodenticides concentrate, and the retention or metabolism/expulsion rate of the rodenticide. This variation means assessing secondary risks for non-target species can be difficult, especially where data is lacking but understanding these differences can assist planning for environmental monitoring.

Anticoagulant rodenticides were created for rodent control and as such the wealth of studies and available toxicity data are specific to rodents and other mammals. Birds also experience acute toxicity with exposure to specific quantities of some rodenticides and are often a primary consideration for impacts to non-target species. The U.S. EPA has used the Northern Bobwhite and the Mallard Duck as traditional test species to determine rodenticide concentrations needed to produce mortality and those results are often extrapolated to estimate risk to species that have not been thoroughly studied (i.e., average body weight comparisons at specific rodenticide concentrations consumed by Bobwhites and Mallards to cause mortality). However, more recent data are shedding light on species-specific responses to rodenticide exposure and caution is warranted when estimating secondary exposure impacts. For example, Rattner et al. (2012) tested diphacinone and found some raptors showed signs of intoxication and mortality at doses 20 to 30 times lower than the traditional test species.For other taxa, especially invertebrates, aquatic organisms, reptiles and amphibians, data are limited (Hoare and Hare 2006a) and potential impacts of secondary exposure to a rodenticide must be estimated.

Risk of non-target species exposure to rodenticide can be evaluated by estimating both exposure and toxicity to individuals (Smith et al. 1990). One benefit of using the conceptual compartment exposure model (Cox and Smith 1990), is in the ability to distinguish between the processes of rodenticide transfer from the accumulation of residues over time. The rate of retention or expulsion has direct consequences for secondary exposure considerations in understanding how long a sampling program should persist, e.g.,a fast or slow expulsion rate by a common primary bait consumer could lead to differences in secondary exposure risks.

Some species retain rodenticides for long periods and some quickly process and excrete rodenticidesthus individual toxicity and the propensity to become an exposure pathway for secondary consumers is species specific. Mammals and birds are known to accumulate rodenticides and have slow metabolic processes for expulsion whereas other species can accumulate amounts to some threshold at which point any additional consumption does not increase rodenticide accumulation, which seems be the case for at least some invertebrates (Fisher et al. 2007). Locusts fed brodifacoum showed rapid excretion of brodifacoum and long-term accumulation was deemed unlikely (Craddock 2003). Similarly, Fisher et al. (2007) found tree weta (Order Orthoptera) fed diphacinone continuously did not show whole body concentrations that were cumulative with increased quantity of the rodenticide. This result suggests a threshold saturation body burden was achieved and additionally consumed diphacinone was metabolized or excreted. However, it should be noted, the authors did not test the frass thus potential impacts to the cycling of excrement into the environment is unknown. Fisher et al. (2007) used the weta data to imply consequences in an island eradication scenario whereby a 20 g bird would need to consume >10 kg of contaminated weta to receive a lethal dose (sub-lethal impacts were not evaluated) providing context for risk to non-target species.

The majority of the examples presented above (unless specifically identified as field studies) were taken from laboratory studies where continuous feeding programs were used to evaluate, in some instances, control programs which provide rodenticides in a continuous manner. In addition, laboratory studies often represent an extreme in terms of rodenticide availability and may be specifically designed to test the limits of toxicity and mortality. These studies need to be put into context for comparison to an island eradication rodenticide application scenario where a known, discrete quantity of rodenticide bait is applied (usually 1 to 3 applications).Planners can use this information to assess risk to non-target species by estimating how long organisms may carry rodenticide residues, how long non-target species are at risk of exposure, and at what point is human safety from exposure through consumption of organisms assured through testing and analysis.

Terminology

Before describing the specific types of sampling that could be included in planning for Kahoʻolawe, we present how results of residue testing are presented which require an understanding of some basic toxicology terminology (US EPA 2004).

Analyte – substance whose chemical constituents are being identified and measured.

LC50 – Median lethal concentration estimated statistically and expected to be lethal to 50% of test animals expressed as ppm (parts per million).

LD50 – Median lethal oral dose estimated statistically and expected to be lethal to 50% of test animals expressed as mg of active ingredient per KG of body weight of the animal. Most readily reported statistic used as an index of toxicity.

RQ – Dietary Risk Quotient – Index of exposure to dietary toxicity (LC50), expressed as amount of rodenticide in food (ppm ai [active ingredient] in bait for primary exposure or in target species for secondary exposure). Useful for comparing risks among compounds (e.g., brodifacoum vs. diphacinone).

LOC – Level of Concern - Level above which an RQ is deemed an acute risk.

MDL – method detection limit - minimum concentration of a substance that can be measured and reported with 99% confidence the analyte concentration is greater than zero determined from analysis of a sample in a given matrix containing the analyte.

Considerations for creating an environmental monitoring sampling plan for Kahoʻolawe

In creating an environmental monitoring plan for Kahoʻolawe, we may utilize historic precedent as well as the conceptual diagram to create a sampling and testing strategy. We present in this section the primary findings from other island rodent eradication projects. Masuda et al. (2015) provides a literature review of island eradication projects where brodifacoum was applied aerially (11 projects) and summarizes the sampling methodology and results of residue testing. Hoare and Hare (2006a) similarly review studies evaluating nonnative mammal control projects using brodifacoum and the impacts on non-target native New Zealand fauna. Aerial application of diphacinone has only occurred on six islands and environmental monitoring results consist of three publications in Hawaiʻi (Gale et al. 2008, Orazio et al. 2009, Dunlevy and Swift 2010). Caution is needed in making direct comparisons of anticoagulant rodenticide residual residue (hereafter known as residues) concentrations among studies due to differences in the rodenticides used, the amount applied to each island, and the environments of the islands.

Sampling strategies should be island-specific, but some general guidelines for sampling have evolved from historic and seminal works. All variables tested would be sampled before the project to provide a baseline for post-eradication comparisons.This includes understanding the baseline mortality rate of species prior to the eradication when using carcass searching as a method. If systematic sampling methods (e.g., plots and transects) are to be utilized, a pre-project sweep of those sites, including the removal off all carcasses, to understand mortality of non-target animals that may be a result of the eradication project (i.e., based on analyses of tissues). These data are then compared to post eradication mortality so localized impacts can be assessed.

For all sampling involving collections, 50% of collected samples would be sent to the laboratory for analyses and the other half kept as reference samples. All collected samples would follow chain of custody protocols and sample locations would be documented. Personnel involved in collection of environmental samples would be prohibited from coming into contact with personnel, equipment, or vehicles involved in the handling or application of rodenticide bait to ensure there is no cross contamination of bait products into the samples.

General Environmental Sampling Recommendations from the Literature

- Collect more samples than will be tested so that if any questions arise as to results or if a greater resolution of residue levels is needed, the samples will be available (Fisher et al. 2011).
- Sample a large number of species, larger sample sizes for each interval and greater number of intervals increases the chances of detecting residual brodifacoum (Masuda et al. 2015).
- For species that will be harvested for consumption, set a ‘no-take’ harvest period that aligns with sampling until no residues are detected (Masuda et al. 2015).

Soil sampling and testing
The testing of soils to detect residue is directly related to the rate of individual pellet breakdown into the soil. Pellet degradation studies have been used to provide context for the duration of time soil sampling could occur as well as informing the risk of exposing non-target animals to residue, especially with regard to the release of any captive held animals following an eradication (Fisher et al. 2011). Typically, these studies consist of placing bait pellets within wire cages so as not to be consumed by large taxa (e.g., rodents, birds) but that are nonetheless exposed to the elements and invertebrates – both of which can be responsible for the degradation of pellets. A scale to score the rate of degradation was developed by Craddock (2003) and is now commonly used for field studies (Fisher et al. 2007, Fisher et al. 2011, Masuda et al. 2014).

Both the rate of degradation of the pellet and the remaining concentration of residue are important factors to understand. On Anacapa Island, brodifacoum concentration in pellets declined by > 50% in 42 days and >90% in 182 days. In a pellet degradation study on New Zealand islands, Fisher et al. (2011) found 96.5% of pellets evaluated had completely broken down by 120 days. The variability in breakdown rates is due to local factors and each will regionally likely produce unique results (Fisher et al. 2011).

Testing soils for rodenticide residues iscommonly undertaken in monitoring areas surrounding eradication projects onislands. Completely randomized sampling of soils (i.e., not associated with a bait pellet) to detect rodenticide residue, as was utilized in some early eradication projects using brodifacoum (Ogilvie et al. 1997, Howald et al. 1999) produced negative test results likely due to the physical immobility of anticoagulant rodenticides (described previously) and the variable distance between the sample locations relative to the location randomly distributed bait pellets (i.e., hand and aerial broadcasts). Likewise, testing for diphacinone residue in soils produced undetectable or negative results from Lehua Island where sampling locations were not associated with a bait pellet (Orazio et al. 2009).

The primary question with soil residue sampling is to determine how long the rodenticide residue persists after application and how far the residue migrates by sampling at specific intervals and to specific soil depths. Howald et al. (2009) detected brodifacoum residue on Anacapa Island in 1 of 48 samples 182 days after bait application up to 5 cm from an individual bait pellet. Fisher et al. (2011) reported residual concentrations of brodifacoum on New Zealand offshore islands decreased to near the MLD by approximately 100 days following bait application. Differences in duration of detectability may be attributed to different soil types and the local environment. Alifano et al. (2012) compared the persistence of brodifacoum and diphacinone in two soil types at Palmyra Atoll. Residue concentrations decreased over time and at 28 days, diphacinone residues were no longer detected and at 50 days only trace amounts (≤0.2 ppm) of brodifacoum were detected.

Based on results from previous studies, we would recommend soil residue sampling occur at known locations as opposed to random bait pellet locations following the application of bait to Kahoʻolawe. Prior to the eradication, an experimental trial could determine the potential for residue migration. Following the application of bait for the eradication, soil sampling could also include a strategy to sample soil at the bottom of topographic gullies (e.g., Orazio et al. 2009) immediately after the next known significant rain event. Soil residue sampling duration should represent the extreme values based on the published literature and sampling intervals should be determined from the results of a bait degradation study.

Water sampling

The sampling of both fresh water and seawater are commonly incorporated into eradication environmental monitoring plans associated with eradication projects. On Kahoʻolawe, fresh water is only seasonally present in the form of standing water in pools or running water in drainages as a result of periodic rainfall. Depending on the time of year when the eradication would be implemented, fresh water sources may not be available for sampling and sampling locations would be tied to the island topography. For example, water samples on Lehua Island were collected at the bottom of naturally formed drainages where bait pellets may have moved from upslope locations to the island/marine interface; however none of those samples tested positive for residue (Orazio et al. 2009). Similarly, Fisher et al. (2011) did not detect residue in samples collected in freshwater streams. Pitt and others (2015) found brodifacoum residue in one of five fresh water samples collected from a pond on Palmyra atoll.

Although bait pellets are not meant to enter the marine environment and precautions would be in place to prevent this from happening, some unintentional drift of bait pellets into the ocean could occur during the aerial application of bait. Pitt and others (2015) did not detect rodenticide residue in sea water testing during the aerial application of rodenticide bait during the eradication of rats from Palmyra Atoll and likewise in Hawaiʻi, the eradication projects on Lehua and Mokapu Island did not detect residue in salt water samples (Gale et al. 2008, Orazio et al. 2009).

To better understand the fate of brodifacoum following the drift of bait pellets into the marine environment surrounding Anacapa Island, Howald et al. (2009) placed divers in the ocean during the aerial application to observe whether pellets entered the water, to assess consumption by marine organisms, and to evaluate the amount of time pellets remained intact in the water. Divers observed pellets entering the water largely due to bounce off from cliff faces and did not directly observe the consumption of pellets though their presence in the water may have impacted natural foraging behaviors of marine consumers. Divers reported bait pellets were completely dissolved in seawater within five hours, which is similar to results reported from Kapiti Island, New Zealand (Empson and Miskelly

1999).Given this rapid rate of degradation in the water, collections of seawater should commence immediately following bait application to have the best chance of detecting residue. Sea water samples would be collected from near-shore locations and at deep water locations; sampling locations near natural drainages should be selected to maximize the probability of detecting residue. Similar to recommendations for the timing of soil sampling, ocean water testing at drainages could occur in conjunction with the next large precipitation event if personnel were available.

In contrast to the studies discussed above, we present a case study where, in 2001, a truck carrying 20 tons of brodifacoum bait (20 ppm) crashed into the ocean near Kaikura, New Zealand. This accident provided researchers with an unfortunate and unplanned occasion to assess the impacts of a large discharge of rodenticide into a marine environment. Rodenticide concentrations were detected in seawater at the crash area for the first 36 hours but levels dropped to below MLD (<0.020 ppb) between 36 hours and 9 days (Primus et al. 2005). Similarly, marine sediment collected at nine days tested below MLD.

Sampling the Terrestrial Community

Invertebrates

Invertebrates consume bait pellets directly and otherwise can play a significant role in ecosystem functions especially those taxa that act as detritivores and affect organic material cycling into soils (Kammenga et al. 2000). Rodenticides do not appear to be acutely toxic to most invertebrates studied to date due to differences in clotting mechanisms compared to vertebrates (Shirer 1992 cited in Fisher et al. 2007). The results are similar for both brodifacoum (Booth et al. 2001) and diphacinone (Fisher et al. 2007). However, little is known about invertebrate anticoagulant adsorption, metabolism, and excretion (Fisher et al. 2007).

Recent studies have revealed that invertebrates often function as secondary pathways of rodenticide exposure for non-target animals (Dowding et al. 2006, Masudaetal.2014). New Zealand Dotterels were the first recorded mortalities from secondary exposure to a rodenticide (brodifacoum) from the consumption of invertebrates that had fed on bait (Dowding et al. 2006), and Masuda et al. (2014) report rodenticide-related mortality of insectivorous nestlings in New Zealand. On Palmyra Atoll, land crabs, intertidal crabs, ants, and cockroaches also tested positive for brodifacoum (Pitt et al 2015) and on Lady Alice Island, New Zealand Ogilvie et al. (1997) detected brodifacoum residue only on invertebrates that were observed feeding directly on bait pellets but not in samples that were randomly collected. On Hawaiʻi Island, in lab and field tests, ants, slugs, and snails were observed consuming bait (Dunlevy et al. 2000) and it is assumed invertebrates will behave similarly on Kahoʻolawe.

Field sampling on Kahoʻolawe indicate 23 arthropod orders (Starr and Starr 2007) and 22 species of snails (Gon et al. 1992) as present. We assume that at least some of the species present will consume bait pellets and create a possible secondary pathway of exposure for other non-target species(Figure 4.2). On Kahoʻolawe we recommend sampling for cockroaches, ants, and any members of the Order Orthoptera. Methods include using coconut or peanut butter as bait in traps, sticky traps, light traps, pit fall traps, malaise traps, and opportunistic capture. Samples could be collected at discreet time intervals so that analyses of the residues may reveal increases or decreases in concentration over time.

Vertebrates

Sampling for residue in vertebrates during and following eradication projects generally result from the collection of carcasses of both target and non-target species, and the testing of tissues for residue. Carcass collection methods may involve using a stratified systematic survey methodology over specific time intervals where plots are repeatedly surveyed and carcasses are collected when observed. This provides planners with information about the rate at which mortality is occurring, the persistence of residue in the environment and the associated risk to non-target species.

Consumption of rodenticides can alter traditional diurnal/nocturnal activity patterns in rodents and a reduction in both seeking seclusion and thigmotactic behaviors (Cox and Smith 1992). In controlled experiments, 50% of study rodents died exterior to nest boxes (Cox and Smith 1992). In island eradication field settings, Howald et al. (1999) found 13% of test radio-collared rats (*Rattus novegicus*) died in open areas after brodifacoum bait application. As a result of these findings, diurnal, non-target scavengers and predators are at risk of secondary exposure. If present, both feral cats and pueo may be exposed to rodenticide from consumption of rodents that had consumed bait.

On Kahoʻolawe, carcass scavenging is most likely to impact feral cats. Methods to more accurately determine risk to non-target animals from carcass scavenging may include using camera traps at purposefully placed rodenticide-free carcasses (e.g., frozen mice) as part of the pre-eradication planning process. Howald et al. (1999) used a similar method to identify several species of birds that were at risk of secondary exposure during the Langara Island rat eradication project. Results from these studies can reveal candidate species that could be trapped and held in captivity until such time as there is an overall reduction in carcasses and release is deemed safe.

Several vertebrate groups previously not considered in island eradications have recently received additional attention because of documented secondary exposure to rodenticides (e.g., bats) and their role as vectors in toxicant transmission (e.g., reptiles). Insectivorous bats are likely at risk of secondary exposure from the consumption of invertebrates that have consumed bait (Dennis and Gartrell 2015). In New Zealand, the first reports of deaths of both adult and adolescent Lesser Short-tailed bats were linked to diphacinone used to control rats (Dennis and Gartrell 2015). It is unknown if bats currently occur on Kahoʻolawe Island and only a single observation is reported from 1989 (HHP 1992 cited in Gon et al. 1992). Hoary bats are known to consume invertebrates present on Kahoʻolawe (e.g., moths, cockroaches); however, to determine conclusively if bats should be considered at risk from a rodenticide-based eradication of rodents from Kahoʻolawe, acoustic bat detectors could be used to evaluate their presence.

Reptiles have also been the focus of increased scrutiny of the role they play in the movement of rodenticides in the environment. Studies of rodenticide toxicity to reptiles are few, and metabolism of toxicants, LD50 values, accumulation and expulsion rates are largely unknown (Hoare and Hare 2006a). Poisoning risk to reptiles is thought to be low due to their distinct blood clotting mechanism that is different from mammals (Merton 1987) and do not appear to experience acute toxicity from the consumption of rodenticides (Whitmer 2012). However, reptiles may act as a pathway for toxicant movement despite not individually suffering mortality.

On Kahoʻolawe, at least two species of geckos and one species of skink, all introduced to the Hawaiian Islands, are known to occur on island (Gon et al. 1992). Skinks are known to consume rodenticide bait (Merton 1987, Merton et al. 2002 Thorsen et al. 2000) and Hoare and Hare (2006b) reported the first observations of the consumption of rodenticides by common geckos (*Hoplodactylus maculatus*) based on the discovery of rodenticides in gecko feces, and Pitt et al. (2015) found brodifacoum residue in geckos following the aerial application of bait at Palmyra Atoll. Reptiles can provide a secondary or tertiary exposure pathway for higher order consumers (feral cats and owls) and need careful consideration during the risk assessment process.

Vertebrate sampling on Kahoʻolawe could include systematic stratified carcass searches before and after the bait application (Figure 4.3), collecting samples for residue analysis for up to 180 days (Pitt et al. 2015),and relative abundance estimates for indicator species (shorebirds or others) before and after the bait application. Live organism collections for those species that do not experience acute toxicity could also be conducted (e.g., reptiles) to determine if rodenticide residues are present.

Figure 4.3 Vertebrate sampling will include carcass searches and also involve baseline studies to determine the presence of Hawaiian hoary bats and other listed species.

Sampling for marine vertebrates and invertebrates

One of the primary factors to consider when monitoring the marine environment prior to and following the eradication of rodents from Kahoʻolawe is the harvest of marine organisms by humans. In a review of studies that tested marine organisms for brodifacoum residue following aerial applications, Masuda et al. (2015) found an overall detection rate of 5.6% for marine invertebrates and a 3.1% rate for fish. In their own study of brodifacoum residue testing on Ulva Island, New Zealand, the authors noted the risk of mortality to individuals appeared very low and concluded little chance of adverse effects to humans that consumed marine species containing residues.

Commonly consumed species from the waters around Kahoʻolawe are listed in Table 4.1.More sedentary marine species are generally considered better test organisms since they have the greatest probability of being exposed to toxicants compared to mobile species. Likewise species that feed within the nearshore environment and those that are likely to consume bait pellets should be considered for collection and testing.On Palmyra Atoll, non-toxic bait pellets were distributed to shallow, middle and deep water locations and observers documented species either directly consuming or mouthing pellets as a method to prioritize species collected for tissue analyses during eradication planning (Alifano and Wegmann 2011).

Table 4.1. List of species collected for human consumption on Kahoʻolawe.

Hawaiian Name	Scientific Name	Common Name
Aʻawa	*Bodianus albotaeniatus*	Hog Fish
ʻAʻama	*Grapsus tenuicrustatus*	Sally Light Foot, Black Crab
Āholehole	*Kuhlia xenura, Kuhlia sandvinensis*	Flagtail
ʻApi	*Acanthurus guttatus*	White Spotted Surgeon Fish
Enenue	*Kyphosus spp.*	Rudder Fish
Heʻe	*Octopus cyanea*	Tako/Octopus
Kala	*Naso unicornis, Naso litturatus*	Unicorn Fish
Kūmū	*Parupeneus porhyreus*	White Saddled Goat Fish
Manini	*Acanthurus triostegus*	Convict Tang
Moano Kali	*Parupeneus cyclostomus*	Blue Goatfish
Moano	*Parupeneus multifasciatus*	Double Barred Goatfish
Moi	*Polydactylus sexfilis*	Pacific Threadfish
Mullet/ʻamaʻama	*Mugil cephalus, Neomyxus leuciscus, Moolgarda engeli*	Mullet
Naʻenaʻe	*Acanthurus olivaceus*	Orange Band Surgeon Fish
ʻOpihi	*Cellana exerata, Cellena talcosa, Cellana sandwicensis*	Limpet
Pākuikuʻi	*Acanthurus achillies*	Achilles Tang
Papio/Ulua	*Caranx spp.*	Jack Fish/ Blue Trevally
Pipipi	*Nerita picea*	Sergeant major/Nerita
Uhu	*Chlorurus and Scarus spp.*	Parrot Fish
Ula	*Panulirus marginatus, Panulirus pencillatus*	Lobster/Bug
ʻŪʻū	*Myripristis spp.*	Soldier Fish

Hawaiian Name	Scientific Name	Common Name
Weke	*Parupeneus spp., Mulloidichthys spp.*	Goatfish

Another factor that will require consideration is the selection of tissues to sample for rodenticide residues in marine organisms. If the purpose of residue testing is to prevent the unhealthy consumption of fish by humans, then it should be noted during the design phase of the monitoring program whether whole fish, muscle or fish livers are likely to be consumed. Masuda et al. (2015) noted muscle and homogenate whole fish samples less frequently detectedbrodifacoum residue compared to testing liver tissue alone. Fish homogenate and fish muscle (filets) were tested in previous eradication studies conducted in Hawaiʻi and results did not detect diphacinone residue (Gale et al. 2008, Orazio et al. 2009).

Evaluating how long to sample may be driven by the selection of the specific rodenticide used in the eradication. Detection residues of brodifacoum in marine organisms declined to below detectable concentrations after 176 and before 274 days (Masuda et al. 2015) and sampling was suspended when residue was no longer detected. In Hawaiʻi, no marine organisms tested positive for diphacinone residues following the eradication projects on Mokapu and Lehua Islands (Gale et al. 2008, Orazio et al. 2009).

Decisions on risk associated with consumption of marine species would be more fully evaluated during the compliance and planning phase of the eradication project development and the development of the risk assessment at which point agencies, organizations or individuals could be identified that are able to determine applicable 'no-take' periods (e.g., Hawaiʻi Department of Health). On Kahoʻolawe, it is recommend to conduct sampling at predefined regular intervals. To reduce risks to humans, a 'no-take' period of harvest of all marine organisms from near-shore waters could be maintained until residues are no longer detected (Masuda et al. 2015, Fisher et al. 2011).

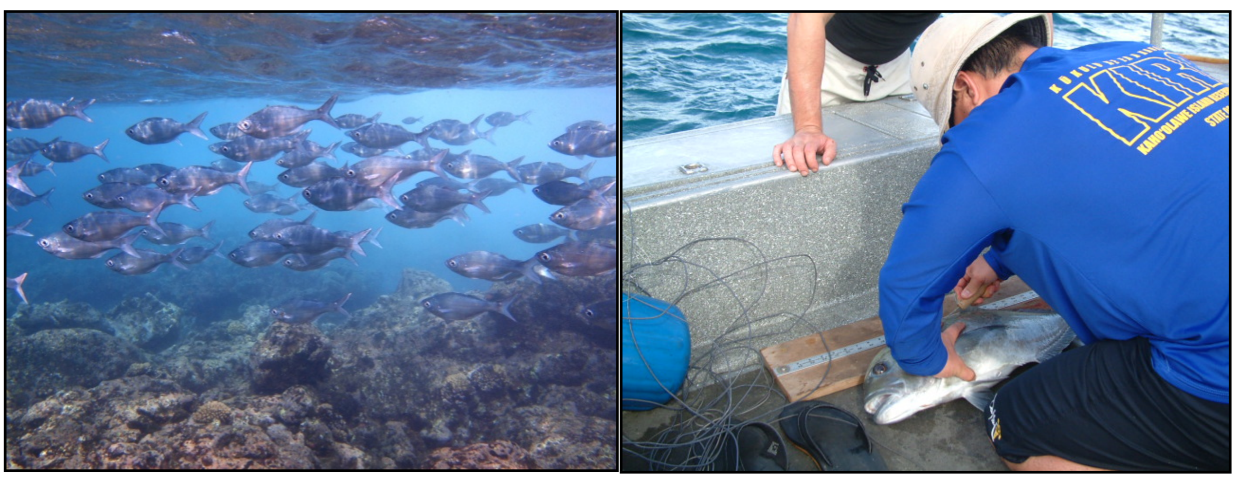

Figure 4.4 Various marine components would need to sampled pre and post rodenticide drop. *Left*: Hawaiian Flagtail or *āholehole*, and other "silverfish" are common in the nearshore waters of Kahoʻolawe. *Right*: A Giant Trevally or *ulua* is measured by KIRC Staff for a catch and release study.

Ecosystem Response to Rodent and Cat Eradication

Vertebrate and Botanical Monitoring

Outcome monitoring focuses on components of island ecosystems, habitats and native species response to island restoration techniques, and evaluates how well the primary goal of the restoration is being achieved. Such monitoring can inform future adaptive management for Kahoʻolawe following cat and rat eradication, and also contributes to our global understanding of how native species respond to invasive vertebrate eradication on islands.

Following the removal of invasive species, passive recovery of seabird populations will be a function of life history (age of first breeding, fecundity), proximity to source populations (likelihood of prospecting), and overall species status (declining, stable or increasing) (Jones 2010a, Jones 2010b, Buxton et al. 2014). Recovery can be aided by active techniques including social attraction and assisted colonization (Kappes and Jones 2014). Recovery of populations can take decades (Jones 2010b), however short-term responses indicative of long-term change may be present in the first few years after eradication(e.g., Xantus now Scripps' Murrelet on Anacapa Island see - Jones et al. 2005, Whitworth et al. 2012). Indicators of habitat changes conducive to seabird breeding can also be monitored, such as seedling abundance (Townset al. 2006).

Outcome monitoring requires standardized effort before and after the removal of invasive species and where possible,comparison to conditions on control islands where no invasive vertebrates are being removed, or where they have never been present, to provide a measure for recovery expectations. For example in Hawaiʻi, island and area specific (fenced) rodent eradicationshave resulted in dramatic increases in seabird breeding as well as increased recruitment of native plant species (Marie et al. 2014, VanderWerf et al. 2014, J. Penniman pers. comm., H. Oppenheimer pers. comm). In addition to observational studies, experimental studies provide an opportunity to identify a robust inference on observed changes (Jones et al. 2005). Outcome monitoring should ideally capitalize on existing data to build a longer time series, and build upon the local expertise of partners to guide site selection and monitoring protocols.

Several methods are available to monitor seabird presence and to detect changes in abundance including the use of remotely deployed acoustic data loggers or "song meters" and visual surveys. Song meters can be deployed in areas where seabird presence is suspected then collected at a later time for subsequent analyses (Table 1). From 2004-2011 coastal surveys were conducted via helicopter on a monthly basis documenting sea bird presence and guano/whitewash on the cliff faces. Guano detections were followed up with visual surveys by land and/or sea to detect seabird colonies. In 2008, the Offshore Islet Project conducted by Bishop Museum in collaboration with the State of Hawaiʻi DLNR made baseline biological surveys on both Puʻu Koaʻe and ʻAleʻale (Hebshi 2008, Eijzenga and Preston 2008, Wood et al. 2003). Due to the remote and hazardous terrain of the current seabird colonies regular surveys are prohibitive and song meters are recommended.

In addition to employing surveys for seabird presence, we recommend monitoring for the recovery of seabird habitat. The collection of photographs at specific monitoring plots (photo points) overtime would document landscape changes in the absence of invasive rodents (Table 4.1). Selected monitoring sites would be photographed at specific intervals in time to document vegetative and other landscape changes.

On Kahoʻolawe regular vegetation monitoring has occurred using point and line intercept transects as well as photo points for various re-vegetation and restoration projects. (KIRC 2005, 2010, 2013, 2015) and can be replicated after an invasive mammal eradication takes place. These transects can be used to document changes in vegetation after rodents are removed.

Table 4.1. Data collection methods, outcomes, indicators and timing recommendations to monitor ecosystem response to the removal of invasive rodents and cats from Kahoʻolawe Island, Hawaiʻi.

Outcome	**Indicator**	**Data Collection Method**	**Baseline Data**	**Timing**
1. Contribute to the recovery of listed seabirds Newell's Shearwater and Hawaiian Petrel.	Presence of vocalizations of conservation targets.	Automated Recording Units (song meters).	Baseline data to be collected, including habitat assessment and song meter deployment.	Ideally three years of baseline data collection to capture inter-annual variation, then 3-5 years post-eradication. Peak calling periods of June-August for detection.
2. Contribute to the re-establishment / expansion of smaller ground nesting Hawaiian seabirds – e.g., Bulwwar's Petrel, Band-rumped Storm-petrel, Red-tailed Tropicbird, Wedge-tailed Shearwater.	Presence and increased vocalizations of conservation targets.	Automated Recording Units (song meters), colony mapping.	Baseline to be collected, including habitat assessment and song meter deployment.	Ideally three years of baseline data collection to capture inter-annual variation, then 3-5 years post-eradication. Peak calling periods of June-August for detection.
3. Contribute to the establishment / expansion of suitable seabird breeding habitat.	Increased vegetation cover at potential seabird colony establishment.	Photo points.	Baseline data to be collected.	Pre-eradication then 3-5 years post-eradication.

Monitoring of Target Species

Two phases of monitoring are recommended for target species on Kahoʻolawe. Pre-eradication monitoring would greatly inform the eradication tools and strategies applied to both rodents and feral cats. Baseline monitoring provides metrics which would be compared to post-eradication monitoring data informing both operational success or relating to contingency planning if individuals from the target species remain.

Pre-eradication monitoring for rodents

Methods to detect rodents include observations of rodent sign (e.g., foot prints, chew marks, feces, husking stations, and visible nests), the direct sampling of individuals (e.g., trapping, Trailmaster® cameras) and several measures of relative abundance (e.g., non-toxic chew blocks/sticks/boards and tracking tunnels). Criteria for the selection of sampling methods should be based on efficiency, and effectiveness in detecting rodents at low density. It would be important to record locations of rodent sign prior to the eradication (i.e., GPS recordings) so that locations could be compared to post-implementation monitoring to confirm the rodent sign is new (i.e., feces could persist from the pre-eradication rodents). Trapping would be necessary to collect DNA data if rodents were detected post-eradication.

Other considerations when selecting a sampling method should include an understanding of how the presence of more than one rodent species may impact the behavior of the individuals and their ability to contact the sampling devices. For example, it was suggested the presence and subsequent removal of ship rats negatively influenced researchers' ability to determine abundance estimates for mice during an experiment in New Zealand (Brown et al. 1996). Other important considerations would be to stratify the sampling across habitat types, including human inhabited areas as rodent densities are expected to vary with habitat and locations relative to consistent sources of food (e.g., high production seed areas, refuse dump areas).

DNA tissue samples from rodents would be collected and archived according to standard protocols (Ross 2009) in the event rodents are detected following the eradication. It would be important to identify whether rodents detected following the eradication are rodents that reinvaded (i.e., from another island due to biosecurity breaches) or from the pre-eradication population on the island. Rodent DNA should also be collected from potential source populations to determine if the rodent population on Kahoʻolawe is distinct from populations from Maui or any other island that is deemed a potential source population.

Other considerations for pre-eradication monitoring include an evaluation of bait exposure in rodents and non-target animals. During suggested preliminary bait application and degradation trials, bait may be infused with a biomarker. Rodents (Wanless et al. 2008) and non-target animals could be captured and screened during the trials to determine bait consumption.

Monitoring to confirm eradication for rodents

Following the implementation of the eradication a recommended waiting period of two complete breeding cycles would be observed before reinitiating sampling for remaining rodents (Broome et al. 2014). Polynesian rats may breed up to four times annually with a combined gestation and weaning of pups lasting up to seven weeks. Mice breed throughout the year and show a combined gestation and weaning period lasting six weeks. On tropical islands where rodents breed year-round, monitoring for rodents following an eradication attempt can occur at one year after the operation is concluded (Keitt et al.

2015).The island should be sampled systematically with priority given to areas perceived to be at high risk of harbouring rodents (e.g., human inhabited areas, locations of refuse). Based on the results of the pre-eradication monitoring, locations may be selected for sampling similar to where the greatest density of rodents were detected/observed. Given the difficulty with using standard rodent sampling methods to detect rodents at low densities, the use of trained dogs to locate rodents may be employed (Gsell et al. 2010). However, the limitations of accessing parts of the island restricted by UXO would require hunting teams to be accompanied by a trained UXO expert capable of providing clearance to the restricted areas.

Multiple rodent detection methods should be utilized to maximize the probability of detecting residual rodents, or rodent incursions, following the implementation of a rodent eradication. The methods and locations that were most successful at detecting rodents prior to the eradication should provide a reliable comparison for post-eradication monitoring.

Monitoring for Feral Cats

As outlined in Chapter 3, multiple methods and adaptive management would largely guide both the pre-eradication sampling and the post-eradication monitoring for feral cats. Exact methods and the schedule for implementation would depend upon the decision to treat the target populations of rodents and cats simultaneously or independently, and restricted access to areas that have not been cleared of UXO. Regardless of approach, systematic monitoring of the cat population pre-eradication would be necessary to inform the eradication strategy.

Detection methods for feral cats typically include: trail cameras (including use of an olfactory or audio lure to attract cats), searches for cat sign (e.g., scat, paw prints), traps, and detection dogs. The order of use of these methods will be specific to the overall eradication strategy for all target species. Outlined are general recommendations for how pre-eradication monitoring could occur.

Locations of cat activity would be determined and catalogued by experienced cat trappers capable of identifying cat sign (e.g., scat, latrine sites, and travel routes). From this information a baseline estimate of cat abundance would be acquired using strategically placed motion-sensing camera traps (Reconyx™ Professional Series) which would inform the hunting or trapping strategy. During the eradication operation, all activities and data should be recorded including GPS recording of all trap and hunting locations, date of cat capture, age, animal sex, details of cat sign, any cat mortality or escapes. It will be important to have a system in place capable of real-time data entry and analyses to assist in making decisions critical to the operation (Will et al. 2014).

Once animals are no longer detected, the operation would move into the confirmation monitoring phase. A probability detection model using data collected during the eradication operation could estimate the number of animals that may persist, as well as the amount of continued surveillance required to declare the eradication complete (Ramsey et al. 2011). Best practices suggest utilizing a 99% level of certainty that if a cat existed, it would be found. Once the eradication of cats is deemed successful, two annual post-eradication monitoring surveys would be recommended (Hanson and Campbell 2013).

Chapter 5- Timeline and Logistics

Summary

- In this chapter an outline is presented of major activities for five phases of operational planning and implementation for the eradication of cats and rats based on an assumed approach of starting the cat eradication one year prior to the onset of the rodent eradication.
- Activities associated with the planning of operations for the cat and rodent eradication for Kahoʻolawe fall into the following five phases:

  Phase I – Operational planning, compliance, funding acquisition, pre-eradication monitoring

  Phase II – Eradication implementation

  Phase III – Post-eradication monitoring

  Phase IV – Demobilization

  Phase V – Evaluation and Reporting

- Significant detail as to logistical planning will be largely lacking in this chapter. To fully articulate every aspect that would be needed for the eradication, specific operational plans including protocols for all activities, strategic and logistical planning, and personnel roles and responsibilities would need to be developed. An operational scoping document for the removal of cats from Kahoʻolawe was developed in 2011 (Island Conservation 2011); however, more site-specific information is needed to decide on the best strategy for the cat eradication. Similarly, site specific information about the efficacy and impact of available rodenticide bait products on Kahoʻolawe's introduced rodent population and ecosystem, respectively, is needed before a rodent eradication strategy can be designed. Furthermore, compliance with NEPA and or HEPA may need to precede the selection of strategies to eradicate feral cats and rodents from the island depending on the purpose and need of the project. It is beyond the scope of the Business Plan to fully develop operational plans for both cat and rodent removal as this effort would be premature and is dependent on key information that has not been gathered – see Appendix A for the recommended action items towards the eradication of feral cats and introduced rodents from Kahoʻolawe.
- In this chapter, we present a timeline in six month intervals, that is adjusted for the start of the eradication of cats as day zero and all activities occurring prior to the implementation of the cat eradication as (-) days and times following as (+) days. The timelines for each significant phase of the project will be presented as a series of Gantt charts depicting the commencement and curtailment of each major activity. Cat eradication is estimated to take 14-28 months for completion (Hanson et al. 2011) and the rodent eradication would take two months to implement and 24 months post-implementation to confirm success (Broome et al. 2014). Five years of ecosystem response monitoring is recommended (N. Holmes pers. comm.) and environmental impact monitoring should occur at predetermined intervals until the rodenticide applied to eradicate rodents is no longer detectable or meets a pre-determined level of detectability.

Project Timeline

The estimates for the duration of each project phase are based on timelines from other similarly-sized eradication projects. It is important to caution that eradication project planning including adhering to environmental compliance regulations, partnership building and acquisition of funding (see Chapter 6) may not be completed on any specific time schedule and will require cooperation and coordination among all key stakeholders.

The estimated overall timeline from start to finish for all phases spans 8.5 years including 5 years of post-eradication ecosystem response monitoring (Figure 5.1).

Activity	Duration	- 48 months	- 36 months	- 24 months	- 18 months	- 12 months	- 6 months	- 0 months Begin Cat Eradication	+ 6 months	+ 12 months Begin Rodent Eradication	+ 18 months	+ 24 months	+ 36 months	+ 48 months	+ 60 months	+ 72 months	+ 84 months	+ 96 months	+ 108 months
Phase I	36 months																		
Phase II	14-28 months																		
	2 months																		
Phase III	60 months																		
Phase IV	3 months																		
Phase V	24 months																		

Figure 5.1. Kahoʻolawe Island cat and rodent eradication planning timeline in 5 phases occurring over 8.5 years. Phase 1- Planning, Phase 2 Implementation, Phase 3 Monitoring, Phase IV Demobilization, Phase V Reporting.

Project Phases

<u>Phase I – Operational planning and compliance/Pre-eradication monitoring (Figure 5.2)</u>

Major components of Phase I include:

- Regulatory compliance processes for the eradication of feral cats and introduced rodents from Kahoʻolawe, development of risk assessments for select non-target species, risk mitigation planning, and application for permits (see Chapter 2).
- Acquisition of funding – Partnership development, grant writing, and fundraising
- Development of Operational Plans – Development of cat and rodent eradication operational plans including all equipment, personnel needs and associated transportation and shipping, and review by independent and partner organizations. Rodent eradication planning includes all necessary laboratory and field trials to inform the development of Operational Plans.

- Contracts and agreements – Identify project elements to be completed by contracted labor or through the development of MOUs with partner agencies.
- Public information and community involvement – Development and implementation of a public information plan.
- Pre-eradication monitoring – Monitoring of both target (cats and rodents), non-target species and environmental sampling to provide baseline data for comparison to post-eradication values.
- Site specific preparations – Establish a base of operations, ensure that the island's infrastructure can support the eradication effort.

Phase I - Operational Planning, Compliance, Fundraising, Pre-eradication Monitoring								
Activity	**Duration**	**- 48 months**	**- 36 months**	**- 24 months**	**- 18 months**	**- 12 months**	**- 6 months**	**- 0 months Begin Cat Eradication**
Regulatory Compliance	18 months							
Risk Assessments	12 months							
Environmental Compliance	18 months							
Risk Mitigation Planning	12 months							
Permitting	18 months							
Fundraising	48 months							
Operational Planning	48 months							
Project Management Plan	18 months							
Cat Eradication Plan	12 months							
Rodent Eradication Plan	12 months							
Project Review	6 months							
Identify Project Management Teams	6 months							
Identify/Hire Personnel	12 months							
Equipment Acquisition	12 months							
Equipment Shipping and Storage	6 months							
Biosecurity Planning	12 months							
Safety Plan Development	12 months							
Pre-eradication Monitoring	24 months							
Operational Scoping	12 months							
Bait Availability/Degradation	6 months							
Baseline Environmental Monitoring	12 months							
Baseline Efficacy Monitoring	12 months							
Site Preparation	6 months							
Contracts	12 months							

Phase I - Operational Planning, Compliance, Fundraising, Pre-eradication Monitoring									
Activity	**Duration**	**- 48 months**	**- 36 months**	**- 24 months**	**- 18 months**	**- 12 months**	**- 6 months**	**- 0 months Begin Cat Eradication**
Public Information	24 months							
Community Meetings	24 months							

Figure 5.2. Kaho‘olawe Island cat and rodent eradication planning timeline: Phase I - Operational Planning, Compliance, Fundraising, Pre-eradication Monitoring.

Phase II – Implementation (Figure 5.3)

Major components of Phase II include:

- Implementation of cat eradication.
- Implementation of rodent eradication.
- Environmental monitoring.
- Development of formative evaluation.

Phase II - Eradication Implementation												
Activity	**Duration**	**- 12 months**	**- 6 months**	**- 0 months Begin Cat Eradication**	**+ 6 months**	**+ 12 months Begin Rodent Eradication**	**+ 18 months**	**+ 24 months**	**+ 36 months**	**+ 48 months**	**+ 60 months**	**+ 72 months**
Cat Eradication Implementation	14-36 months											
Cat Team Communications Planning	6 months											
Initial Population Monitoring	12 months											
Efficacy Monitoring	12 months											
Detection Probability Study	6 months											
Equipment Acquisition	12 months											
Cat Removal Methods	36 months											
Trapping	24 months											
Hunting	24 months											
Cat Personnel/Team Development	12 months											

Phase II - Eradication Implementation		- 12 months	- 6 months	- 0 months Begin Cat Eradication	+ 6 months	+ 12 months Begin Rodent Eradication	+ 18 months	+ 24 months	+ 36 months	+ 48 months	+ 60 months	+ 72 months
Activity	**Duration**											
Cat Personnel on Kaho`olawe	36 months		■	■	■		■		■	■		
Cat Personnel Orientation	6 months		■	■								
Rodent Eradication Implementation	2 months					■						
Rodent Team Communications Planning	6 months				■							
Equipment Acquisition	24 months			■	■							
Bait Order/Shipping/Storage	6 months				■							
Bucket Shipping/Storage	2 months				■							
Bucket Calibration	1 month					■						
Commensal Area Preparation	6 months			■								
Bait Application Strategy	6 months	■	■									
Safety Plan	6 months		■	■								
Helicopter Contracting	6 months				■							
Helicopter Orientation	1 month				■							
Rodent Personnel/Team Development	12 months			■	■							
Rodent Personnel on Kaho`olawe	12 months					■	■					
Rodent Personnel Orientation	1 month					■						
Bait Availability Monitoring	1 month					■						
Efficacy Monitoring	1 month					■						
Environmental Monitoring	36 months					■	■	■	■	■		
Ecosystem Response Monitoring	84 months					■	■	■	■	■	■	■

Figure 5.3. Kahoʻolawe Island cat and rodent eradication planning timeline Phase II - Eradication Implementation.

<u>Phase III – Post-eradication monitoring (see Chapter 4; Figure 4.4)</u>

Major components of Phase III include:

- Environmental – collection of samples, shipment to designated labs and analyses.
- Target species – efficacy monitoring.
- Non-target species – presence and abundance surveys, carcass collection for analyses.
- Ecosystem response monitoring.

Phase III - Post-eradication Monitoring Activity	Duration	- 0 months Begin Cat Eradication	+ 6 months	+ 12 months Begin Rodent Eradication	+ 18 months	+ 24 months	+ 36 months	+ 48 months	+ 60 months	+ 72 months
Environmental Monitoring	108 months									
Soil Sampling	12 months									
Water Sampling	6 months									
Terrestrial Organism Sampling	12 months									
Marine Organism Sampling	12 months									
Carcass Searching	12 months									
Sample Shipment and Analyses	24 months									
Cat Efficacy Monitoring	24 months									
Rodent Efficacy Monitoring	2 months									
Ecosystem Response Monitoring	60 months									
Seabird Monitoring	60 months									
Vegetation Monitoring	60 months									
Intertidal Monitoring	60 months									

Figure 5.4. Kahoʻolawe Island cat and rodent eradication planning timeline Phase III - Post-eradication monitoring.

<u>Phase IV – Demobilization (Figure 5.5)</u>

Major components of Phase IV include:

- Personnel debriefing – Exit interviews with all key personnel to determine successful and unsuccessful (or needing improvement) components to the operational plans.
- Public outreach and communications.
- Project personnel depart Kahoʻolawe and Maui.
- Equipment removal and shipping to point of origin.
- Disposal of contingency bait.

Phase IV - Demobilization		- 0 months Begin Cat Eradication	+ 6 months	+ 12 months Begin Rodent Eradication	+ 18 months	+ 24 months	+ 36 months	+ 48 months	+ 60 months	+ 72 months
Activity	**Duration**									
Demobilize Equipment										
Helicopters	1 month									
Bait Bucket Return Shipping	1 month									
Bait										
Disposal of Contingency Bait	1 month									
Cat Personnel Transportation	Variable									
Rodent Personnel Transportation	1 month									
Monitoring Personnel Transportation	Variable									
Personnel Debriefing										
Cat Team	1 month									
Rodent Team	1 month									

Figure 5.5. Kaho‘olawe Island cat and rodent eradication planning timeline Phase IV - Demobilization.

Phase V – Evaluation and Reporting (Figure 5.6)

Major components of Phase V include:

- Development of reporting timelines.
- Analyses of data.
- Report writing.
- Public release of reports.
- Preparation of manuscripts for publication in scientific journals.

Phase V – Evaluation and Reporting		**- 0 months Begin Cat Eradiation**	**+ 6 months**	**+ 12 months Begin Rodent Eradication**	**+ 18 months**	**+ 24 months**	**+ 36 months**	**+ 48 months**	**+ 60 months**	**+ 72 months**	**+ 84 months**	**+ 96 months**	**+ 108 months**
Activity	**Duration**												
Public Information Updates	Variable												
Development of Reporting Timelines	6 months												
Analyses of Data	Variable to 24 months												
Efficacy Monitoring Reports													
Cat Efficacy Reports	12 months												
Rodent Efficacy Reports	12 months												
Environmental Monitoring Reports	Variable to 12 months												
Ecosystem Response Reports	6 months												
Professional Presentations	Variable to 6 months												
Manuscript Preparation	Variable to 6 months												
Manuscript Publishing	Variable to 6 months												

Figure5. 6. Kahoʻolawe Island cat and rodent eradication planning timeline Phase V - Evaluation and Reporting.

Chapter 6- Financial Plan

Summary

- Development of the financial plan for the eradication of feral cats and introduced rodents from Kahoʻolawe Island includes the estimation of costs for each phase of the project defined in Chapter 5, and the development of the strategy to identify and raise funds for the eradication. The budget presented below is based on 2015 $US dollar values and overhead rates estimated at 15%. Funding would likely come from many sources including, Federal, State, Private and Corporation.
- A review of the current status of the funding to the KIRC is included.

Estimated Project Budget

Total project costs are estimated to be $9,099,528 and cost by phase were estimated for seven general categories (Figure 1):

1. Equipment/Supplies – equipment may be used in more than a single phase of the project and is recorded within the phase of purchase.
2. Personnel – includes personnel that would be responsible for planning, implementing, demobilization, and reporting on the eradication project.
3. Travel/Lodging – includes project-related travel for planning, implementation, demobilization, and reporting.
4. Consultants/Contracts – includes parties contracted for the development of risk assessments, biosecurity planning, public relations, environmental monitoring, ecosystem response monitoring, helicopter charters, and vessel charters.
5. Logistics – includes shipping of equipment, postage/freight, and bait disposal fees.
6. Outreach – includes materials for public outreach, and participation in professional conferences.
7. Overhead – estimated at 15%.

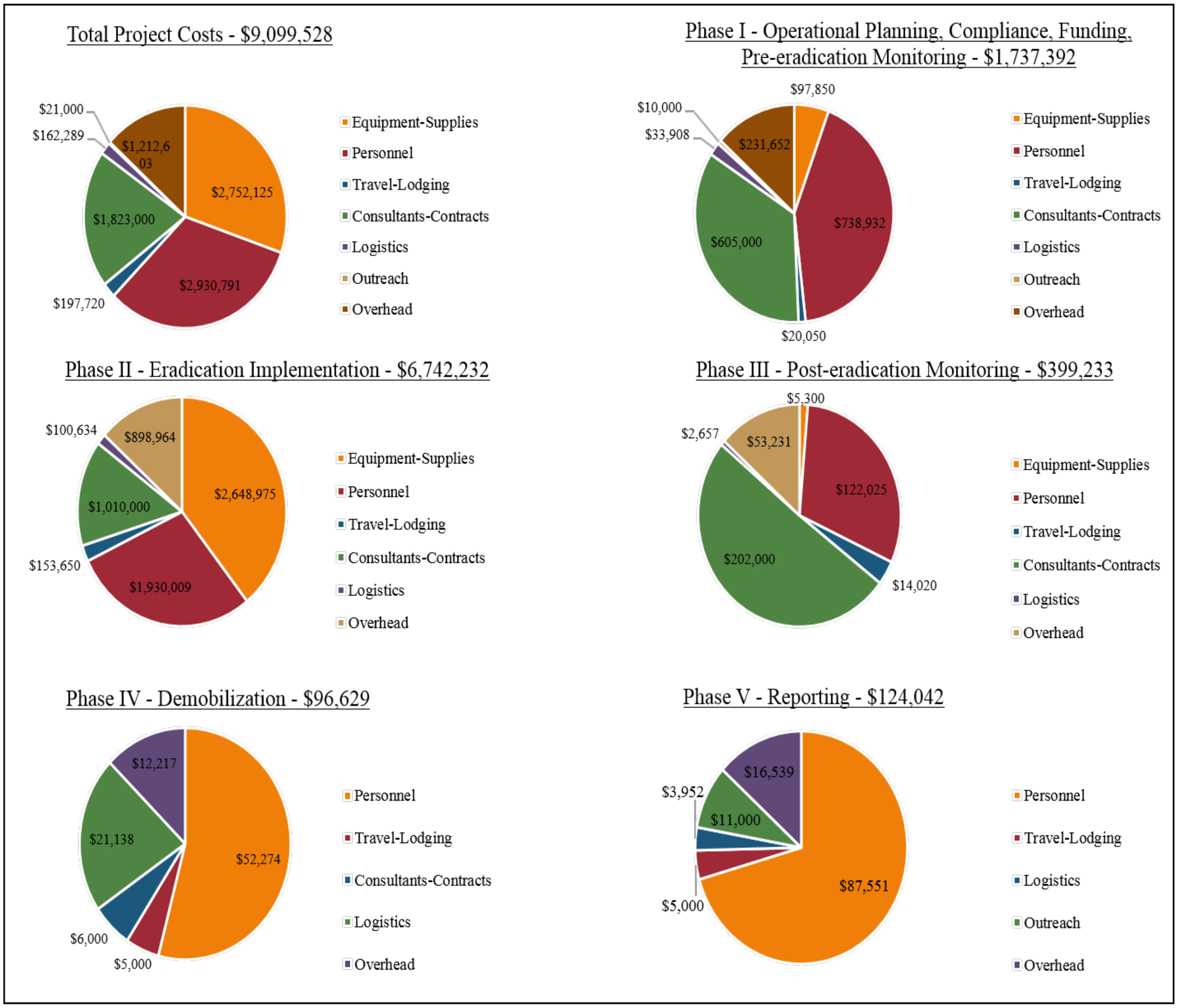

Figure 1. Estimated costs of each of the five phases of the Kahoʻolawe feral cat and introduced rodent eradication project.

KIRC Baseline Funding

In 1993, 11% of the U.S. Navy's $400M clean-up budget was allocated to the newly established Kahoʻolawe Island Reserve Commission by the Hawaiʻi State Legislature. The $44M federal fund was appropriated by congress and transferred to the Kahoʻolawe Rehabilitation Trust Fund, earmarked to initiate long-term environmental restoration, archaeological and educational activities within the Reserve. These activities were designed to carry out the terms and conditions of the MOU between the State and the Navy regarding the island's return.

Since the last appropriation to the Trust Fund in 2004, the KIRC has worked diligently to establish a permanent funding source that would allow for the continued restoration of Kahoʻolawe; until the 2015

Legislative Session, no funds had been allocated by the State to continue the work that it was tasked with. Though the KIRC has significantly extended the lifespan of program activities through grants and donor programs and redesigned the annual operating budget to a razor's-edge figure of $2.8M, it has been determined that the Reserve's critical operations costs far exceed the scope of these charitable resources. It is our contention that this continues to be a responsibility of the state.

During the 2015 Legislative Session, the State of Hawaiʻi State appropriated $1M to the KIRC from the General Fund; marking the first appropriation since the Federal Government's initial provision in 1993. While this marks a milestone in Kahoʻolawe history, it only represents about 1/3 of the minimum budget required to maintain current operations. Thus, the KIRC has dramatically scaled down the on-island volunteer program and Base Camp operations while focusing our attention on cultivating and soliciting grant partnerships that share our mission to restore, protect, preserve and provide access to Kahoʻolawe. Additionally, the KIRC have expanded the community volunteer base with revised fee-based access permit and cost-sharing arrangements with affiliated organizations. Finally, KIRC is realigning the strategy for the 2016 Legislative Session to leverage the initial investment made by the State for additional financial support.

Funding Strategy

The final meeting of the Project Steering Committee on June 24, 2015, included an open forum to identify potential sources of funding for the eradication project. Three primary sources of funding were identified by committee members: Federal, State and private funding including foundations, private donors, and mitigation funding from the business sector. The federal and State sources identified included single and multi-year grant programs, mitigation funding, conservation banking, and in-kind personnel services from the multi-agency cooperation that is anticipated for the success of the eradication. Private funding opportunities identified included foundations, private donors, public capital campaigns (e.g., crowd sourcing) and in-kind contributions fromvolunteers.

Two primary strategies for obtaining funding were identified: multi-phase implementation based on the phases outlined in Chapter 5 (Phases II, III, and IV are reliant on each other and would need to be funded at the same time) and a single-source acquisition where funding for all phases of the project is obtained at one time.

Ideally, the KIRC would acquire the funds to develop and implement the project from a single source. Single source funding would ensure the project would be completed in a reasonable time. KIRC has identified funding sources in the Federal, State, and private sector which may be a possibility. The most likely source is to introduce a line item into the State of Hawaiʻi budget to appropriate the release of funds spread over the course of the completion of the project.

One of the challenges associated with fundraising for a project of this scope andscale would be aligning different sources of funding to allow the project to progress along an ideal timeline, unless all five phases of the project are fully funded from the beginning. Requirements for matching funds and restrictions on how funding can be used would complicate a multi-source funding plan. Often, private or foundation funding provides the most flexibility. Even though it is unlikely that the total amount needed to plan and implement the project could be delivered by foundations or private sources, such funding can be used to leverage funding from state or federal sources.

The Cooperative Endangered Species Conservation Fund (Section 6 of the Endangered Species Act) provides funding to States and Territories for species and habitat conservation actions on non-Federal lands. The Section 6 conservation grants program provides financial assistance to state-led projects that conserve listed species and species at-risk. Funded activities include habitat restoration, species status surveys, public education, and outreach, captive propagation and reintroduction, nesting surveys, genetic studies, and development of management plans.

A second source of section 6 funds is through Habitat Conservation Plans. Through the development of regional Habitat Conservation Plans (HCPs), local governments incorporate species conservation into local land use planning, which streamlines the project approval process and facilitates economic development. The Habitat Conservation Planning Assistance Grants program provides funding to States to support the development of HCPs. Planning assistance grants may support planning activities such as document preparation, outreach, and baseline surveys, and inventories. The funding for the Habitat Conservation Planning Assistance Grants is competed for at the National level.

Kaua‘i has a program in place; the Kaua‘i Seabird Habitat Conservation Program (KSHCP) project is a joint effort of the State Department of Land and Natural Resources - Division of Forestry and Wildlife (DLNR-DOFAW) and the U.S. Fish and Wildlife Service (USFWS). The KSHCP provides interested businesses and agencies with a streamlined, cost-effective way to attain legal authorization and coverage for unavoidable incidental take of endangered and threatened seabirds due to light attraction (and other utilities) and to achieve net conservation benefits for Kaua'i’s endangered and threatened seabirds. The central benefit to participating businesses and agencies will be obtaining legal coverage for existing facilities and planned projects under the KSHCP through participation in a streamlined, and cost-saving permitting process. A similar HCP does not currently exist on Maui. The KIRC will investigate this option through identifying endangered species through the action items identified in Appendix A.

It is unlikely that conservation actions in amendments to existing HCPs or new HCPs will identify the eradication of feral cats and/or invasive rodents from Kaho‘olawe as mitigation actions unlessit is demonstrated that conservation targets (endangered species impacted by renewable energy projects or federal development programs) have extant populations on Kaho‘olawe; priority is typically given to protecting extant populations over creating new populations. HCPs are applicant-driven processes and the applicant (i.e. a renewable energy company) typically only proposes mitigation activities that carry a high probability of meeting quotas and timelines set by USFWS and DLNR.The action items identified in Appendix 5include the installation of acoustic recording devices on the small islets offshore of Kaho‘olawe to detect the presence of Newell’s Shearwaters, Hawaiian Petrels, and Band-rumped Storm-petrels and bat detectors to document use of Kaho‘olawe by Hawaiian hoary bats – all of these species are conservation targets for current and pending HCPs.

Another potential avenue for securing mitigation funding to support the eradication of cats and invasive rodents from Kaho‘olawe is conservation banking. Kaho‘olawe could be identified as a conservation bank where mitigation funding could be directed to affect a future, desired conservation outcome, e.g., invasive mammalian predator-free habitat for native Hawaiian species threatened with extinction.

The USFWS Migratory Bird Office recently published a Notice of Intent for the development of a Programmatic Environmental Impact Statement for an incidental take permit process for migratory birds:

https://www.federalregister.gov/articles/2015/05/26/2015-12666/migratory-bird-permits-programmatic-environmental-impact-statement. The process could be similar to the HCP process, but should apply to all species protected under the Migratory Bird Treaty Act (MBTA) and will not be restricted to ESA listed spices. A conservation mitigation funding process centered on the MBTA could be a funding source for the eradication of feral cats and introduced rodents from Kaho‘olawe; however, it is unknown how long it will be until such a process is established, or if the process will apply to conservation actions on Kaho‘olawe.

Climate change is another factor to consider in Hawai‘i and impacts to low lying islands due to sea level rise. Kaho‘olawe has the potential to be a reintroduction site for many species in the Northwest Hawaiian Islands. Federal funds available to mitigate climate change impacts will also be targeted.

While a single source of funding is ideal, the scenario for the first phase of research and field studies will come through smaller funding sources with the outcome being to target larger sources and complete Phase one identified in Chapter 5. If a single source is not obtained in the first year, then a multi-phase implementation would be carried out and decided on by priority through the KIRC and Working Group largely based on this Business Plan (Completion of Phase 1 in Chapter 5). KIRC has already received funding to start one action item identified in Appendix A (Improved Biosecurity Implementation).

Private funding will also be pursued with fundraising campaigns a possibility or outreach to specific donors and foundations. Sources have been identified and are preparatory of the KIRC. The KIRC is additionally currently looking into developing non-profits (501c3) to supplement programs and the formation of a specific non-profit for this project will be pursued.

Appendix A - Business Plan Action Items

Operational Scoping

Rodent Eradication Methods Development

The development of rodent eradication methods should include field studies to measure the environmental impact and performance of one or more potential rodenticide bait products that could be used for eradicating rodents from Kahoʻolawe. These field studies will use non-toxic bait and will provide information that will inform the federal (NEPA, ESA Section 7 consultations) and state (HEPA) compliance processes for the eradication project as well as the rodent eradication strategy.

Assessment of candidate rodenticide bait product toxicity to and acceptance by *Mus musculus* and *Rattus exulans*

The project partnership should conduct both laboratory and field-based bait product efficacy and acceptance trials to identify the ideal bait product for eradicating introduced rats from Kahoʻolawe.

Bait degradation

The project partnership should conduct a bait degradation study to determine the degradation rate of one or more bait products in both terrestrial and marine environments. Individual bait pellets will be housed in mesh wire cages affixed or secured to the ground so that rodents and other vertebrate consumers cannot remove or interfere with the bait. Study plots will be established in each of the three primary habitat types at three elevation gradients. Bait degradation plots will be monitored according to a prescribed schedule to measure the bait fate over time in the different habitat types.

Bait movement in bare ground (hardpan) habitat

The project partnership should establish bait movement plots in hardpan areas where topsoil has been removed by wind erosion. This study will inform the partnership about the fate of bait applied to this habitat type, which represents approximately 1/3 of Kahoʻolawe's surface area.

Cat Eradication Methods Development

The project partnership should test various methods for trapping feral cats, including an automated trap monitoring system and body grip traps.

Automated trap monitoring

The project partnership should test several candidate automated trap monitoring systems (ATMS) to determine which modality (radio telemetry, GSM, Bluetooth-enabled drone, or satellite) will allow the implementation team to maximize the efficiency and humaneness of trapping while minimizing the risk of encountering unexploded ordnance. For an island-wide eradication, there will be hundreds of traps set at the same time making daily visual checks impractical. Furthermore, traps must be placed within all potential cat home-ranges to successfully eradicate feral cats from the island. Access to traps within areas that require specially trained Explosive Ordnance Disposal Technician (EOD) escorts will be reduced with an ATMS, thus minimizing risk to the field team without reducing the efficacy of the eradication operation.

Feral cat traps

The project partnership should assess the efficacy of several feral cat trap types in removing cats from Kahoʻolawe. The trap types that we will assess include: body grip traps, leg-hold traps, cage traps, and, if available during this grant period, repeat-kill traps. Technological advances in the Goodnature A-24, stoat trap have extended this technology to the control of feral cats. If a prototype repeat-kill cat trap is available during this grant period, it will be tested under a partnership with the USFWS. All trap types will be tested and assessed for humaneness and efficacy using a standard protocol that includes monitoring by remote camera.

Non-target Species Assessment and Conservation Measures

Bait consumer food web

The project partnerhship should monitor how bait interacts within the terrestrial food web on Kahoʻolawe by applying inactive bait containing a non-toxic biomarker to coastal and inland plots. Observers will use UV lights to conduct searches for the biomarker within the study plots starting the day after bait application then nightly for a minimum of 3 days. Both vertebrates and invertebrates that show sign of consuming bait (glow green under UV light) will be noted. Prior to the bait application, we will establish baseline fluorescence values for the organisms that we anticipate to encounter in the study plots.

Marine bait consumers

The project partnership should place inert bait pellets in the marine environment - intertidal and nearshore habitats - where pellets could drift during an aerial application of bait to eradicate rodents from Kahoʻolawe. Snorkelers will observe the interaction between marine organisms and bait pellets that are dropped from the water surface.

Hawaiian Short-eared Owl (Pueo)

To investigate the population-level risk posed to Pueo by a rodent eradication on Kahoʻolawe – risk of exposure to rodenticide through secondary pathways - satellite transmitters whould befitted to captured Pueo to monitor the ranging behavior of birds captured on Kahoʻolawe. With this study, we hope to determine if Pueo are resident on Kahoʻolawe (remain on island year round, or breed on the island and make short trips to neighboring islands) or transient (short visits to Kahoʻolawe from neighboring islands). Due to the expense of the transmitters, rarity of pueo, and time it will take to trap on Kahoʻolawe, five transmitters will be purchased and deployed for this study. This study will be conducted in partnership with the Maui Nui Seabird Recovery Project and USGS for data acquisition and data processing.

Hawaiian hoary bat (ʻōpeʻapeʻa)

To investigate the population-level risk posed to ʻōpeʻapeʻa by a rodent eradication on Kahoʻolawe – risk of exposure to rodenticide through secondary pathways – the partnership should deploy up to six bat detector recorders to record presence and relative abundance.

Threatened Seabird Species Assessment

Acoustic and remote-camera monitoring should be conducted to look for evidence of seabird [Newell's Shearwater (Puffinus newelli, ʻAʻo, IUCN EN), Hawaiian Petrel (Pterodroma sandwichensis, ʻUaʻu, IUCN EN), and the Band-rumped Storm-petrel (*Oceanodroma castro*, ʻAkē ʻakē, HI EN)] visitation or breeding on Kaho'olawe's offshore islets, ʻAleʻale and Puʻu koaʻe. For two breeding seasons, we will deploy up to eight acoustic recorders via helicopter on both of the islets and nearby cliffs. The analysis will be conducted by Conservation Metrics who has developed specific biometrics to identify these targeted species.

Biosecurity Planning

The project partnership should develop a biosecurity plan for the island of Kahoʻolawe. This comprehensive written plan will outline the protocols necessary in preventing the introduction of invasive species. Additional objectives will include updating the "open waters" permitting process to include a declaration form for all vessels entering the reserve, updating the volunteer orientations, installing signage at the ports of departure and entry, related public outreach, and improving quarantine and shipping procedures for materials transported to island. We will also solicit an external review of the biosecurity plan by a recognized biosecurity expert.

Public Outreach

Outreach is needed to develop project understanding and support and engage with the community. Outreach will be focused on the benefits of restoring Kahoʻolawe's native biota and will include a holistic approach that combines traditional Hawaiian cultural practice along with modern science and technology. Outreach activities may include presentations, regular KIRC commission meetings, KIRC newsletters, mailings and annual reports, informal meetings, project brochures, statewide and Maui specific articles, and outreach and education to Kahoʻolawe access volunteers.

Appendix B –Benefits of eradicating feral cats and introduced rodents from Kaho‘olawe to native Hawaiian species

Federally listed species, candidates, or recently delisted speciesEndangered (E), Threatened (T)

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
Hawaiian Coot or ‘alae ke‘oke‘o	*Fulica americana alai*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision 2005 -Restore multiple self-sustaining populations of Hawaiian waterbirds, in part by establishing network of managed wetlands
Hawaiian Common Moorhen or ‘alae ‘ula	*Gallinula chloropus sandvicensis*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision 2005 - Restore multiple self-sustaining populations of Hawaiian waterbirds, in part by establishing network of managed wetlands
Hawaiian Stilt or ae‘o	*Himantopus mexicanus knudseni*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision 2005 -Restore multiple self-sustaining populations of Hawaiian waterbirds, in part by establishing network of managed wetlands
Hawaiian Duck or koloa maoli	*Anas wyvilliana*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision 2005 -Restore multiple self-sustaining populations of Hawaiian waterbirds, in part by establishing network of managed wetlands
Laysan Duck	*Anas laysanensis*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for the Laysan Duck 2004 -Restore multiple self-sustaining populations in NWHI and MHI, in part through protection, enhancement of suitable habitat

Common name	Scientific name	Status	Project benefits	Does the project support goals of a Recovery Plan? List plan and goal.
Hawaiian Goose or nēnē	*Branta sandvicensis*	E	Habitat restoration, potential future nesting site	Draft Revised Recovery Plan for the Nēnē or Hawaiian Goose 2004 - Restore multiple self-sustaining populations in MHI, in part through protection, management of suitable habitat
Hawaiian Petrel or ‘ua‘u	*Pterodroma sandwichensis*	E	Habitat restoration, potential future (or current) nesting site, regular wildlife surveys to determine distribution on Kaho`olawe	Hawaiian Dark-rumped Petrel and Newell’s Manx Shearwater Recovery Plan 1983 - Establish additional nesting colonies, preserve and maintain habitat
Newell’s Shearwater or ‘a‘o	*Puffinus auricularis newelli*	E	Habitat restoration, potential future (or current) nesting site, regular wildlife surveys to determine distribution on Kaho‘olawe	Hawaiian Dark-rumped Petrel and Newell’s Manx Shearwater Recovery Plan 1983 - Establish additional nesting colonies, preserve and maintain habitat
Hawaiian Monk Seal or īlio holo i ka uaua	*Monachus schauinslandi*	E	Habitat restoration	Recovery Plan for the Hawaiian Monk Seal Revision 2007 - Protect haul-out habitat in MHI
Green Sea Turtle or honu	*Chelonia mydas*	T	Habitat restoration, potential future nesting site	Recovery Plan for the U.S. Pacific Populations of the Green Turtle 1998 - Identify and protect nesting and foraging habitat

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
Hawksbill Sea Turtle or honu ‘ea	*Eretmochelys imbricata*	E	Habitat restoration, potential future nesting site	Recovery Plan for Hawksbill Turtle in the U.S. Carribean, Atlantic, and Gulf of Mexico 1993 - Provide long-term protection to important nesting beaches
Nihoa Finch	*Telespyza ultima*	E	Habitat restoration, potential future nesting site	Summary of Scoping, Evaluation,and Recommendations for Northwestern Hawaiian Islands Passerines’ Translocation Sites 2007- Recommended translocation sites Kaho`olawe
Nihoa Millerbird	*Acrocephalus familiaris kingi*	E	Habitat restoration, potential future nesting site	Summary of Scoping, Evaluation,and Recommendations for Northwestern Hawaiian Islands Passerines’ Translocation Sites 2007- Recommended translocation sites Kaho`olawe
Laysan Finch	*Telespyza cantans*	E	Habitat restoration, potential future nesting site	Summary of Scoping, Evaluation,and Recommendations for Northwestern Hawaiian Islands Passerines’Translocation Sites 2007- Recommended translocation sites Kaho`olawe
Blackburn’s Sphinx Moth	*Manduca blackburni*	E	Habitat restoration	Recovery Plan for the Blackburn’s Sphinx Moth 2005 - Protect, manage, and restore habitat to support populations on Maui, Kaho`olawe, and Hawai`i
Hawaiian Hoary Bat or	*Lasiurus cinereus semotus*	E	Habitat restoration, regular wildlife surveys to determine	Recovery Plan for the Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) – Conduct research on other islands

Common name	Scientific name	Status	Project benefits	Does the project support goals of a Recovery Plan? List plan and goal.
ʻōpeʻapeʻa			distribution on Kahoʻolawe	

Benefits to State of Hawaiʻi species of concern

Common name	Scientific name	Status	Project benefits	Does the project support goals of a Recovery Plan? List plan and goal.
Hawaiian Short-eared Owl or pueo	*Asio flammeus sandwichensis*	State-listed - E on Oʻahu	Habitat restoration	Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 - Continue protection, management of wildlife sanctuaries and refuges
Bristle-thighed Curlew or kioea	*Numenius tahitiensis*	High concern - U.S. Shorebird Conservation Plan	Habitat restoration	Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat, protection, restoration of additional wetland habitat U.S. Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region
Pacific Golden Plover or kōlea	*Pluvialis fulva*	High concern - U.S. Shorebird Conservation Plan	Habitat restoration	Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat U.S. Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region
Band-rumped Storm-petrel or	*Oceanodroma*	State-listed - E, federal	Habitat	Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former

Common name	Scientific name	Status	Project benefits	Does the project support goals of a Recovery Plan? List plan and goal.
‘akē‘akē	*castro*	candidate for listing, Highly imperiled - North American Waterbird Conservation Plan	restoration	colonies, in part by maintaining, protecting, enhancing habitat
Laysan Albatross or moli	*Phoebastria immutabilis*	Bird of conservation concern at regional level, High concern - North American Waterbird Conservation Plan	Habitat restoration, potential future nesting site	Hawai‘i's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat
Black-footed Albatross or ka‘upu	*Phoebastria nigripes*	State-listed - T, Bird of conservation concern at the national level, Highly imperiled -	Habitat restoration, potential future nesting site	Hawai‘i's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
		North American Waterbird Conservation Plan		enhance seabird habitat
Christmas Shearwater	*Puffinus nativitatus*	High concern - North American Waterbird Conservation Plan	Habitat restoration, potential future nesting site	Hawai‘i's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitatNorth American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Tristram's Storm-petrel	*Oceanodroma tristrami*	Moderate concern - North American Waterbird Conservation Plan	Habitat restoration, potential future nesting site	Hawai‘i's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
White-tailed Tropicbird or	*Phaethon lepturus*	Species and coastal-dependent or	Habitat restoration, potential future	Hawai‘i's Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
koa‘e kea		migratory birds listed as State of Hawai‘i Species of Greatest Conservation Need (SGCN)	or current nesting site	habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Red-tailed Tropicbird or koa‘e ‘ula	*Phaethon rubricauda*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, current nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Bulwer’s Petrel or `ou	*Bulweria bulwerii*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i	Habitat restoration, current nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect,

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
		SGCN		restore, manage sufficient high quality habitat
Wedge-tailed Shearwater or ‘ua‘u kani	*Puffinus pacificus*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, current nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Black Noddy or noio	*Anous minutus*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, current nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Brown Noddy or noio kōhā	*Anous stolidus*	Species and coastal-dependent or migratory birds listed as State of	Habitat restoration, potential future nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
		Hawai‘i SGCN		enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Brown Booby or ‘ā	*Sula leucogaster*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, current nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Masked Booby or ‘ā	*Sula dactylatra*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, potential future nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Red-footed Booby or	*Sula sula*	Species and coastal-dependent or	Habitat restoration, potential future	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
‘ā		migratory birds listed as State of Hawai‘i SGCN	nesting site	habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Great Frigatebird or ‘iwa	*Fregata minor*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration, potential future nesting site	Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protect seabird colonies and reestablish former colonies, in part by maintaining, protecting, enhancing habitat Regional Seabird Conservation Plan 2005 - Protect and enhance seabird habitat North American Waterbird Conservation Plan 2002 - Protect, restore, manage sufficient high quality habitat
Northern Pintail or koloa mapu	*Anas acuta*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration	North American Waterfowl Management Plan 2002 - Protect, restore, manage sufficient high quality habitat Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat, protection, restoration of additional wetland habitat
Northern Shoveler or	*Anas clypeata*	Species and coastal-	Habitat	North American Waterfowl Management Plan 2002 - Protect,

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
koloa moha		dependent or migratory birds listed as State of Hawai‘i SGCN	restoration	restore, manage sufficient high quality habitat Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat, protection, restoration of additional wetland habitat
Lesser Scaup	*Aythya affinis*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration	North American Waterfowl Management Plan 2002 - Protect, restore, manage sufficient high quality habitat Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat, protection, restoration of additional wetland habitat
American Wigeon	*Anas americana*	Species and coastal-dependent or migratory birds listed as State of Hawai‘i SGCN	Habitat restoration	North American Waterfowl Management Plan 2002 - Protect, restore, manage sufficient high quality habitat Hawai‘i’s Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat, protection, restoration of additional wetland habitat
Eurasian Wigeon	*Anas penelope*	Species and coastal-dependent or migratory	Habitat restoration	North American Waterfowl Management Plan 2002 - Protect, restore, manage sufficient high quality habitat

Common name	Scientific name	Status	Project benefits	Does the project support goals of a Recovery Plan? List plan and goal.
		birds listed as State of Hawaiʻi SGCN		
Pacific Golden Plover or kōlea	*Pluvialis fulva*	Species and coastal-dependent or migratory birds listed as State of Hawaiʻi SGCN	Habitat restoration	U.S. Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 - Protection of current habitat
Ruddy Turnstone or ʻakekeke	*Arenaria interpres*	Species and coastal-dependent or migratory birds listed as State of Hawaiʻi SGCN	Habitat restoration	United States Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 – Protection of current coastal habitat, protection, restoration of additional coastal habitat
Sanderling or huna kai	*Calidris alba*	Species and coastal-dependent or migratory birds listed as State of	Habitat restoration	United States Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 – Protection of current habitat, protection, restoration of

Common name	**Scientific name**	**Status**	**Project benefits**	**Does the project support goals of a Recovery Plan? List plan and goal.**
		Hawaiʻi SGCN		additional habitat
Wandering Tattler or ʻulili	*Heteroscelus incanus*	Species and coastal-dependent or migratory birds listed as State of Hawaiʻi SGCN	Habitat restoration	United States Shorebird Conservation Plan 2001 - Identify and maintain habitat that supports shorebirds that winter in and migrate through region Hawaiʻi's Comprehensive Wildlife Conservation Strategy 2005 – Protection of current habitat, protection, restoration of additional wetland habitat

Appendix C - “Myth Concerning Molokini"

Fornander 1919, Collection of Hawaiian Antiquities and Folk-Lore, Volume 5: 514-521

Molokini is an islet, although it is counted as one of the Hawaiian Islands; it is comparable in size to Kaula, Nihoa and Lehua, the smallest of this Hawaiian group, and is not fit for human habitation. The subject of this story is between Kahoolawe and Makena, Maui, in a southeasterly direction from Lahaina. But what is wanted is to find out the cause of its origin. I have two important matters to present concerning the origin of this islet: 1 relating to it, having been born by parents; 2. it originating from Haupu, that mountain on Molokai.

The parents of Molokini were Puuhele the father and Puuokali the mother; they were lizards, those hills standing just beyond Kamaalaea. After they became husband and wife, Puuokali became pregnant with their first child, and gave birth to a daughter, a lizard like themselves, to whom was given the name Puuoinaina. This daughter of theirs was placed on Kahoolawe; the name of Kahoolawe at that time, however, was Kohemalamalama; it was a very sacred land at that time, no chiefs or common people went there.

There lived here in Lahaina a chief named Hua, whose elder brother, Namakaahua, was living at Hawaii at that time. Hua lived along until he desired to get some ua’u squabs to eat; then he sent some men up to the mountains above Oloalu, to get some squabs to satisfy his desire. He did not wish for birds from the beach. When the birds were obtained, they were to be taken to the priest for him to ascertain where the birds came from; if he should give out the same information as the men had given to the chief as to the source of the birds, then he would be safe; if he should give a contrary answer, he would be killed. The name of this priest was Luahoomoe, and he also had children. When the men went up, they could not find any mountain birds at all so they decided to get some shore birds. When they caught some, they daubed the feathers red with dirt so that the chief would think the birds came from the mountain. When they returned and handed the birds to the chief, he was exceedingly glad because he thought the birds came from the mountain. The chief told the men to take them to the priest for his inspection. The priest perceived, however, that the birds came from the seashore, so he told the chief that they did not come from the mountain, but from the seashore. Then the chief said to the priest: “You shall not live, for you have guessed wrongly. I can very well see that these are mountain birds. ” Then and there an imu was prepared in which to bake the priest.

Before he was placed in the imu, however, he said to his children: “You two wait until the imu is lighted, and when the smoke ascends, should it break for the Oloalu mountains, that indicates the path; move along; and where the smoke becomes stationary, that indicates where you are to reside. Also, do not think of any other woman for a wife; let the daughter of Puuhele and his wife be your wife. With that wife you will live well, and your bones be cared for. Then the priest was cast into the oven and the opening closed up tightly. The smoke arose and darkened the sky; for six days did the smoke darken the sky before the fire in the imu gave out. But after the priest had been in the imu for two days, he reappeared and sat by the edge of the imu unknown to any one; the chief thinking all the time that he was dead; but it was not so.

When the smoke ascended and leaned towards the Oloalu mountains, the two sons went off in that direction; the cloud pointed towards Hanaula, and there it stood still, so the two sons ascended to the place and resided there.

Then the whole of Maui became dry; no rain, not even a cloud in the sky, and people died from lack of water. The smoke that hung over Hanaula became a cloud, and rain fell there. The two men became planters so as to furnish their wife Puuoinaina with food.

Hua, the chief, lived on, and because of the lack of water and food he sailed for Hawaii, the home of his elder brother; but because Hawaii also suffered from lack of water and food he came back and lived at Wailuku. Wailuku also did not have any water, and that caused the chief to be crazed, so he leaned against the edge of the precipice and died, and that was the origin of the saying "The bones of Hua rattle in the sun. "

These sons lived until their food was ripe, then they cooked it and carried it to their parents-in-law and their wife. These sons, however, were birds; Kaakakai was the elder and Kaanahua was the younger. A prophet living at Kauai noticed this smoke hanging right over Hanaula, so he sailed towards it with eight forties of pigs to be offered as a sacrifice to these sons, so that life might be restored to the whole of the Hawaiian Islands.

When the prophet arrived, these two flew on to the parents-in-law; when the prophet arrived there, they flew to Kahoolawe, and from there they returned to Hanaula, and at that place the prophet met them [and offered his sacrifice ; and that was how the rain was restored. While these sons lived at Hanaula, they thought a great deal of Puuoinaina, their wife, but they did not know what she was doing. Because after that Puuoinaina took for her the husband of Pele, Lohiau, and forgot her own husbands.

But when Pele heard what Puuoinaina had done she became angry, she then cursed Puuoinaina. When Puuoinaina heard this cursing from Pele she felt so ashamed that she ran into the sea. She left her home, Kohemalamalama, now called Kahoolawe. Pele, residing at Kahikinui, thought so much of her husband, Lohiau, who was living at Kealia, Kamaalaea that she started out to meet him; but she found her way blocked by Puuhele, so she went from there and waded through the sea. She saw her lizard rival, Puuoinaina, stretching from Kahoolawe to Makena, so she came along and cut the lizard in two, right in the middle, separating the tail from the head. The tail became Puuolai at Makena, and the head became Molokini. When the husbands heard that their wife was dead, they looked and beheld the head of their beloved standing in the sea, so they called the name of the islet Molokini. That is the story of how it was born of its parents and how it obtained this new name Molokini.

Appendix D: 'Ōlelo No'eau: Hawaiian proverbs & poetical sayings. Mary Kawena Pukui 1983

A Selection of 'Olelo No'eau of how Seabirds were incorporated into everyday expressions

- *Lele ka ʻiwa, mālie kai ko ʻo*. When the frigate bird flies out to sea, the rough sea will grow calm. (Pukui 1983, No. 1979)
- *`Ōlelo ke kupa o ka ʻaina ua mālie; ua au koaʻe*. The natives of the land declare that the weather is calm when the tropicbird travels afar. (Pukui 1983, No. 2498)
- *Ua hoʻi ka noio ʻau kaiiI uka, ke ʻino nei ka moana*. The seafaring noddy tern has returned to land, for a storm rages at sea. (Pukui 1983, No. 2787)
- *Ua mālie, ke au nei koa ʻe*. The weather is clear, the koaʻe (tropicbirds) are leisurely flying. (Pukui 1983, No. 2825)
- *Ka manu ka ʻupu halo ʻalo o ka moana.* The albatross that observes the ocean. Said of a careful observer. (Pukui 1983, No. 1479)
- *He noio ʻa ʻe ʻale no ke kai loa.* A noddy tern that treads over billows of the distant sea. An expression of admiration for a person outstanding in wisdom and skill. (Pukui 1983, No. 844)
- *Kikaha ka ʻiwa, he lā makani.* When the ʻiwa bird soars on high, it is going to be windy. Said of a nice-looking, well-dressed person. (Pukui 1983, No. 1795)
- *He ʻiwa ho ʻohaehae nāulu.* An ʻiwa that teases the rain clouds. Refers to a beautiful maiden or handsome youth who rouses jealousy in others. (Pukui 1983, No. 645)
- *He ʻaʻo ka manu noho i ka lua, ʻaʻole e loa ʻa i ka lima ke nao aku.* It is an ʻaʻo, a bird that lives in a burrow and cannot be caught even when the arm is thrust into the hole. Said of a person that is too smart to be caught. (Pukui 1983, No. 545)
- *He koaʻe, manu o ka pali kahakō.* It is the koaʻe bird of the sheer cliffs. An expression of admiration for an outstanding person.(Pukui 1983, No. 696)
- *I wawā no ka noio, he iʻa ko lalo*. When the noio [black noddy, *Anous minutus*] make a din, there are fish below. (Pukui 1983, No. 1267)
- *Ka iʻa ʻimiʻi ka moana, na ka manu e ha ʻi mai*. The fish sought for in the ocean, whose presence is revealed by birds. A school of aku, whose presence is signaled by the gathering of noio at sea. (Pukui 1983, No. 1344)
- *Pōhai ka manu maluna, he iʻa ko lalo.* When the birds circle above, there are fish below. (Pukui 1983, No. 2667)

Appendix F: References Cited

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Appendix F: Major Zoonoses of Rodents and Feral Cats

PATHOGEN	TRANSMISSION	ANIMAL DISEASE	HUMAN DISEASE
Streptobacillus moniliformis, Spirillum minor (rodents)	Animal bites, ingestion of contaminated food products	Usually a subclinical infection, but purulent lesions have been reported in some animals	Polyarthritis, myalgias, regional lymphadenopathy, fever
Salmonellosis (rodents and feral cats)	Fecal-oral, ingestion of contaminated products	Malaise, dehydration, bloody diarrhea	Dehydration,vomiting, abdominal pain, nausea
Leptospirosis (rodents)	Direct contact with contaminated urine	Infertility, fever, anorexia, anemia	Headache, myalgia, conjunctivitis, nausea
Lymphocytic Choriomeningitis (LCM) (rodents)	Exposure to saliva or urine from infected animals or to infected cell lines in the lab fomites may play a role	Viremia, viuria, and chronic wasting disease	Subclinical infection, mild flu-like symptoms viral meningitis and encephalitis (rare)
Hantavirus (rodents)	Exposure to aerosols, urine, and fecal material from infected animals fomites may play a role	Subclinical	Fever, myalgia, petechiation, abdominal pain, headache
Dermatophytosis (*Trichophyton mentagrophytes)* (rodents and feral cats)	Direct contact	Circular raised erythematous lesion with hyperkeratosis and hair loss	Circular raised erythematous lesions with hyperkeratosis and hair loss
Toxoplasma gondii (feral cats)	Exposure to fecal oocysts	Csymptomatic or ocular lesions (chorioretinitis and anterior uveitis). Pulmonary toxoplasmosis in kittens. Severe forms in FIV infected cats (anorexia, lethargy, weight loss)	Asymptomatic to mild infection (fever, adenopathy). Very severe in pregnant women during first trimester. Abortion, stillbirth, severe sequelae (retardation, cerebral calcifications, hydrocephalia)
Bartonella henselae (feral cats)	Infected animals scratch or bite the handler	Cutaneous vasculo-proliferative lesions (i.e. Verruga peruana), hepatis Peliosis,	Cutaneous vasculo-proliferative lesions (i.e. Verruga peruana), hepatis peliosis,

PATHOGEN	TRANSMISSION	ANIMAL DISEASE	HUMAN DISEASE
		splenic lesions, osseous lesions, lymphadenopathy, prolonged fever,endocarditis	Splenic lesions, osseous lesions, lymphadenopathy, prolonged fever,endocarditis.

Adapted from http://www.upenn.edu/regulatoryaffairs/Documents/iacuc/guidelines/zoonoses_rodent.doc, http://health.hawaii.gov/docd/dib/disease/cat-table