HFC Committee

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Aloha Council Chair Alice Lee, Vice Chair Keani Rawlins-Fernandez, Councilmembers and Healthy Families Committee,

I am Emily Drose Community Cat Coordinator at the Maui Humane Society. I am born and raised in Paia and some of you are classmates to my parents, aunties and uncles. In light of Friday's meeting I am hoping you take the time to review this important information. I want to make it clear that I am for the protection of all animals and my job at the Maui Humane Society is focused on Community Outreach and Education. I care about the welfare of all species, especially ones as precious as our native birds and monk seals.

I recently reached out to the manager of Kealia Pond (he has worked in conservation on all of our islands for the past 8 years) to offer deterrent devices to help keep cats away from their conservation in a way that will not harm the birds. We offer these devices here at the Humane Society but they can also be easily purchased online. He advised me that he does not have big issues with cats, in fact his issues are with rats, deer, pig, hunters cutting his fence, and drunk drivers destroying the fence (this actually just happened on 5/9 when a jeep drove into the pond). He advised me most of his time is spent repairing the fencing. I have gone by and evaluated their fencing and to be quite honest it can barely keep a plastic bag out. He did advise me there is a predator proof fencing that has recently been placed on Oahu and we desperately need it here at Kealia and our Olinda conservatory but funding seems to be an issue. This is when I stumbled on Pacific Rim Conservation (https://pacificrimconservation.org/conservation/predator-proof-fencing/).

They are a locally owned and operated agency. Their mission is to maintain and restore native bird diversity, populations, and ecosystems in Hawaii and the Pacific Region. They work together with local communities, government agencies, and other conservation organizations as a 'boots on the ground' operation. They design, manage and assist in building Hawaii's most effective predator proof fences. The first fence was built and studied at Kaena Point. Since then they have worked to improve the design and decrease the cost of this technology placing this fencing on multiple islands. These fences are designed to be effective against all mammalian pests in Hawaii. They are tall enough (2m) to prevent animals from jumping over, have a hood to prevent them from climbing, mesh that is small enough (6mm) that even mice can't squeeze through and has a skirt underground that prevents them from digging in. All of the materials are marine grade stainless steel to ensure longevity. I have attached those studies below which also include labor for your convenience. This fencing works by creating 'islands' within islands where predators have either been removed and excluded through fencing or are controlled on a long term basis. They then work to restore the habitat in these areas, and in some cases, bring bird species back that are no longer found there through translocation and social attraction. Throughout all of their work, they actively conduct research to understand avian biology, and the ecosystem changes and benefits to inform future conservation actions. To date, they have published more than 110 peer-reviewed papers in high-profile scientific journals and have had their work featured in media outlets such as the New York Times, National Geographic and the BBC. You can find all of this information and more on their website.

There are so many other factors contributing to the threat of our native Hawaiian birds and seals yet the time, energy and resources are not being used to address them. "Mongoose are opportunistic feeders that will eat birds, small mammals, reptiles, insects, fruits, and plants. They prey on the eggs and hatchlings of native ground nesting birds and endangered sea turtles. The small Indian mongoose has been blamed with the extinction of ground-nesting birds in Jamaica and Fiji and commonly kill birds, including 8 federally listed endangered Hawaiian birds, such as the Hawaiian crow (‘alalā), petrels (‘u‘au) and Hawaiian goose (nēnē). It was estimated in 1999 that mongoose cause $50 million in damages to Hawai`i and Puerto Rico annually". https://dlnr.hawaii.gov/hisc/info/invasive-species-profiles/mongoose/

Mosquitos are a huge issue not being discussed as they bring disease to these precious birds as they do humans. Please see the attached article " Conservationists worry mosquito-borne disease could wipe out the last of Hawaii's defenseless forest birds within decades. Some species, like the kiwikiu on Maui, have even less time. Biologists estimate only about 150 kiwikiu, or Maui parrotbills, are left in the wild, making them next in line for extinction". https://www.civilbeat.org/2019/12/deadly-mosquitoes-are-killing-off-hawaiis-rare-forest-birds/

Rats prey on nestlings as well as destroy native plants these species needs to thrive. Please see the following information from the attached study from UH Manoa:

"Predators, particularly black rats, are the single greatest threat to seabirds worldwide (Jones et. al. 2008). Black rats and Pacific rats, are known to prey on seabirds throughout the Hawaiian Islands, including Kaua‘i (Fleet 1972, Woodward 19 72, Smith et. al. 2006, Raine et. al. 2017). Rats and house mice (Mus musculus) have also been documented to consume n ative plants, their seeds, and invertebrates (Shiels 2010).

All of these things are major factors here yet does not seem to be a concern, why? I believe with the use of this innovative fencing in combination with our spay/neuter efforts to control cat population we can lead the way and accomplish something no one has ever seen before. Our island could become a pioneer in humane population control as well as conservation of a protected species. We all need to work together on these issues. If funding is truly the only thing stopping this from being successful and our island that is a small hurdle to overcome. Maui Bird Conservation is strongly supported by Good Fellows, there are many grants that can be pursued and I believe with the help of Pacific Rim Conservation this is quite possible.

As for our precious monk seals I was glad to see a recent article showing that their population is increasing! https://www.hawaiinewsnow.com/story/37674837/noaas-annual-monk-seal-population-count-has-a-promising-outlook. Prior to this article, according to the NOAA annual population update The Hawaiian monk seal population remained stable in 2017, with close to 1,400 seals estimated across the species range. Are you aware of the other huge factors playing a role in their decline?

- Habitat loss due to erosion. This affects their abilities to birth and raise pups, rest and molt.
- Interactions with shore casting gear pose a serious danger to seals, especially if the hooks are ingested. In 2017, 19 seals were observed hooked (two more with just fishing line). NOAA successfully removed seven of the hooks and cut three lines.
- Unattended nets are a grave threat to monk seals, if a seal becomes entangled in a net it could drown within minutes. In 2017, one seal was found dead in a lay gillnet and others were reported interacting with nets.
- Toxoplasmosis has emerged as a particularly harmful disease to Hawaiian monk seals. While disease may seem like a "natural" cause of mortality, toxoplasmosis can be found in mussels and shellfish which is known to be a part of their diet along with eels and various fish
- Other diseases such as Distemper, West Nile Virus, Leptospirosis (deer, pig and rats carry this disease and spread this through their urine)
- Trauma continues to be a sad threat to monk seals. There have been 9 deaths since 2017 directly related to humans. These incidents range from gunshots, spear gun wounds, beatings, stabbings, and evidence of fast food being fed to them. NOAA investigates these cases and continues to work with communities to improve coexistence with Hawaii's marine animals.

- https://oceana.org/marine-life/marine-mammals/hawaiian-monk-seal

There is no direct evidence, anywhere showing a seal infected with toxoplasmosis was infected by a cat or how infection was transmitted. I was shocked and saddened to hear of the intentional human related deaths and majority of these threats are human related. There needs to be more awareness and education on these matters so we as a community can do our part to protect this precious species.

In regards to toxoplasmosis in humans, more than 40 million men, women, and children in the U.S. carry the *Toxoplasma* parasite , but very few have symptoms because a healthy immune system usually keeps the parasite from causing illness. According to the CDC there have been 11 known cases of toxoplasmosis (T. gondii.) in humans in Hawaii and none have been linked to a feral cat. The number one cause of humans being infected with the parasite is through the consumption of undercooked meat. Lamb, pork, venison and shellfish are especially likely to be infected with T. gondii. Occasionally, unpasteurized dairy products also may contain the parasite. Water contaminated with T. gondii isn't common in the United States. Other common sources of infection have been known to be caused by:

- **Use contaminated knives, cutting boards or other utensils.** Kitchen utensils that come into contact with raw meat can harbor the parasites unless the utensils are washed thoroughly in hot, soapy water.
- **Eat unwashed fruits and vegetables.** The surface of fruits and vegetables may contain the parasite. To be safe, thoroughly wash and peel all produce, especially any you eat raw.
- **Receive an infected organ transplant or transfused blood.** In rare cases, toxoplasmosis can be transmitted through an organ transplant or blood transfusion.

I want to bring awareness to the HUGE issue our island has with people dumping cats. People will either dump cats maliciously or because they simply are not aware of the negative impacts this will bring. There is an idea that by taking a cat to an area where there are other cats present or a known feeder, that this is comparable to " a dog going to live on a farm the rest of his life". This is far from a fairy tale, although you can see colonies of cats together in one area, they will not be accepting of a new cat coming into their territory. Any intact cats that are brought into an area with a small number of other unfixed cats will quickly grow from 3 cats to many. An area that now could have been managed by fixing those 2-3 original cats has now directly defeated the purpose of population control.

Sadly hundreds of feral and people's own pet cats have been dumped. Not only this but domestic and community cats have been proven to try and back track their way home. There have been many local examples of cat's returning miles and weeks after being removed from their areas very thin and exhausted. Not all will make it back home and oftentimes they will be severely or fatally injured in the process.

Removing a cat from it's home will now allow any other cat's in the surrounding area (that the original cat was keeping away) access to come in and take over the vacant territory. This is called the Vacuum Effect. While this may temporarily reduce the number of community cats in a given area, it is simply a band aid and ultimately counterproductive. As the population of cats rebounds due to the Vacuum Effect, untrapped cats continue to breed, and other cats move into the newly available territory. It takes far less effort and has a much more positive effect if a cat is trapped to do the responsible thing and have it spayed/neutered, micro chipped, ear tipped. There are several effective humane deterrent devices that can assist with keeping cats away from certain properties rather than removing them. Bottom line is the act of taking an animal and bringing it to a new location without the intent of it being cared for is illegal and considered abandonment, a punishable offense. There is a much more effective alternative available to the public completely free of cost and I am willing to help any member of my community, no matter their view on cats or any animal in order to make a difference.

I am looking to you, my council, to do the right thing. To take the time to do the research and understand what we have been presenting to you has been shown to work! We do not want to see Maui fail like we did by introducing the mongoose to our state. That is a perfect example of making decisions on population control without the proper education. Let's all work together to bring real, effective solutions to the table. I personally have been verbally accosted in public, while in MHS uniform by members of the community because of their beliefs regarding this ban. There is no need in the year 2020 for us as a community to continue this discussion with so much hatred in our hearts and by proposing solutions that just simply do not work. Especially if those solutions are brought on by irresponsible news reporting, a misrepresentation of facts and biased opinion. This is not the Maui I know and love. Maui truly No Ka Oi, but can we continue to say and represent that motto with criminalization of residents and visitors to feed animals?

Please see the attached photos of the 4 foster kittens I was able to take into my home for foster. A member of the community placed them in a bucket when they were barely 2 weeks old and left a note on his neighbors door stating "If you do not take them I will drown them". His neighbor brought them to us where they received veterinary care and a foster home. Although born feral and to a feral mother, they are now going to be added members to loving homes and families. This member of the community who took these kittens from their mother had the opportunity to have her spayed in addition to placing her babies in our care yet he chose not to do so. This is why we need to continue the education and importance of spay/neuter.

There is value in collaboration and in finding ground for cats and wildlife
https://www.humanesociety.org/sites/default/files/docs/outdoor-cats-science-policy-global-perspective.pdf

Mahalo for your time and consideration, especially with all you have been faced with during this COVID-19 pandemic

Stay healthy and stay safe,

Emily Drose

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Technical Report 180

The use of predator proof fencing as a management tool in the Hawaiian Islands: a case study of Ka`ena Point Natural Area Reserve

March 2012

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PCSU is a cooperative program between the University of Hawai`i and U.S. National Park Service, Cooperative Ecological Studies Unit.

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Place key words:
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About this technical report series:

This technical report series began in 1973 with the formation of the Cooperative National Park Resources Studies Unit at the University of Hawai'i at Mānoa. In 2000, it continued under the Pacific Cooperative Studies Unit (PCSU). The series currently is supported by the PCSU and the Hawai'i-Pacific Islands Cooperative Ecosystem Studies Unit (HPI CESU).

The Pacific Cooperative Studies Unit at the University of Hawai'i at Mānoa works to protect cultural and natural biodiversity in the Pacific while encouraging a sustainable economy. PCSU works cooperatively with private, state and federal land management organizations, allowing them to pool and coordinate their efforts to address problems across the landscape.

The Hawaii-Pacific Islands Cooperative Ecosystem Studies Unit is a coalition of governmental agencies, non-governmental organizations and universities that promotes research, education and technical assistance to support better stewardship of imperiled natural and cultural resources within the Pacific.
The HPI CESU is one of 17 cooperative ecosystem studies units across the U.S.

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ABSTRACT

The Ka`ena Point Ecosystem Restoration Project was the result of a partnership between the Hawai`i Department of Land and Natural Resources, Divisions of Forestry and Wildlife and State Parks, the U.S. Fish and Wildlife Service, and the Hawai`i Chapter of The Wildlife Society. Ka`ena Point Natural Area Reserve (NAR) hosts one of the largest seabird colonies in the main Hawaiian islands, three species of endangered plants, and is a pupping ground for the endangered Hawaiian monk seals. Prior to fence construction, nesting seabirds and native plants were under constant threat from predatory animals; up to 15% of seabird chicks were killed each year prior to fledging and many endangered plants were unable to reproduce as a result of seed predation. The project involved the construction of predator-proof fencing (2m tall) to prevent feral predators such as dogs, cats, mongoose, rats and mice from entering into 20ha of coastal habitat within Ka`ena Point, followed by removal of these species.

The project was initiated with the hiring of a project coordinator, followed closely by hiring of a two-person public outreach team. The public outreach was extensive reaching over 2500 individuals via personal contact and tens of thousands more as a result of dozens of stories appearing on evening news channels, articles published in local newspapers and newsletters, and several mini-documentaries aired on local cable television shows. A website was also established to post educational materials and information on the project (www.restoreKa`ena.org). The vast majority of the public was supportive despite the vigorous objections of a few individuals.

Multiple federal, state and county permits were required. In total 12 permits were applied for and obtained over a four-year period. Two years were lost as a result of multiple contested cases filed against the project which prevented progress during their resolution. Final permit approvals were completed in November 2010, construction began on November 10, 2010 and was completed on March 30, 2011 after a two-month hiatus for the holidays

To document the effects of predator removal, extensive ecological monitoring was conducted on both native and non-native species prior to the predator removal. A permanent monitoring grid with points placed every 50m was established in the reserve to document micro-habitat shifts. Seabird populations in the reserve had been monitored intensively for over seven years, and a complete botanical, invertebrate and marine intertidal survey was conducted to document the vascular plant species present and their percent cover. Extensive rodent monitoring was also conducted to document the species present, their relative abundance, reproductive cycle, and home range to select the most effective eradication method. Based on monitoring results and regulatory restrictions, a combination of diphacinone in bait boxes, as well as live traps were used to eradicate rodents, and a combination of live-trapping and shooting was used to remove larger animals such as dogs, cats and mongoose. Invasive mammal eradication operations were initiated in February 2011 during the low point in the rodent reproductive cycle, using a combination of rodenticide in bait boxes spaced 25m apart and live multiple-catch traps placed 12.5m apart. Within three months, all predators, with the exception of mice were

eradicated from within the reserve. Mice took an additional six months to full remove and operations were completed in the fall of 2011.

The exclusion and removal of these predatory animals is anticipated to increase in the existing population of nesting seabirds, encourage new seabird species to nest at Ka`ena Point, enhance regeneration and recruitment of native plants, and benefit monk seals by reducing the risk of disease transmission. The Ka`ena Point Ecosystem Restoration Project is expected to have primarily positive effects on the resources protected in the NAR and provide the people of Hawai`i with an opportunity to visit a restored ecosystem. This was the first predator proof fence constructed in the United States at the time of its completion, and was the first project to successfully eliminate mice using the techniques discussed above.

INTRODUCTION

Introduction

Islands make up 1.3% of the U.S. land area yet they are home to 43% of species listed under the Endangered Species Act and 53% of extinctions. Invasive species are the primary threat to island ecosystems globally and are responsible for approximately two-thirds of all island extinctions in the past 400 years (Reaser et. al. 2007). Hawai`i not only is the state with the greatest number of threatened, endangered, and extinct species, but also the state with the highest proportion of endemic flora and fauna (Ziegler 2002). Non-native mammals – primarily rats, cats, mongoose, goats, sheep, and pigs – have had devastating impacts on listed and at-risk species and are major factors in population declines and extinctions in Hawai`i and elsewhere (Ziegler 2002, Reaser et. al. 2007).

In 1970, Hawai`i became one of the first states in the country to recognize the importance of its unique natural resources by establishing the Natural Area Reserves System (NARS) to "...preserve in perpetuity specific land and water areas which support communities, as relatively unmodified as possible, of the natural flora and fauna, as well as geological sites, of Hawai`i." (Hawai`i Revised Statutes § 195-1). The system presently consists of 19 reserves on five islands, encompassing more than 109,000 acres.

Ka`ena Point NAR was established in 1983, by State Executive Order 3162, to protect a portion of the most extensive remnant dune system on O`ahu from damage and degradation caused by off-road vehicle use, erosion, and the spread of invasive species. At the time the NAR was created, these factors had largely destroyed most of the native vegetation within the NAR, making it unsuitable for use by nesting seabirds. After the establishment of the NAR, vehicular access to most of the reserve was blocked, and recovery of native vegetation has been significant, with increasing numbers of endangered plants such as ‘ohai (*Sesbania tomentosa*) and recovery of the coastal naupaka (*Scaevola sericea*) community (D. Smith pers. obs.).

As the coastal habitat improved, and predator control was initiated, increasing numbers of ‘ua‘u kani, or Wedge-tailed shearwaters (*Puffinus pacificus*), and Laysan albatrosses, or mōlī (*Phoebastria immutabilis*), began to breed in the NAR. Wedge-tailed shearwater chicks hatching at Ka`ena increased in number from zero in 1994 to over 3,000 in 2011. Laysan albatross alone have increased from zero pairs in 1989 to approximately 61 nesting pairs in 2012. The dramatic increase of seabirds within the reserve is likely a combination of protection from off-road vehicles and predator control. The reserve also acts as refuge and pupping ground for the endangered Hawaiian monk seal or ‘īlioholoikauaua (*Monachus schauinslandi*). In addition, honu or green sea turtles (*Chelonia mydas*), koholā or humpback whales (*Megaptera novaeangliae*), and nai‘a or spinner dolphins (*Stenella longirostris*) are often seen just offshore.

Prior to fence construction, management techniques designed to protect the natural and cultural resources within Ka`ena Point included maintaining the existing boulder barricade, removal of invasive habitat-modifying weeds, and predator control. In cooperation with the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (USDA-WS), the State Division of Forestry and Wildlife (DoFAW) conducted regular predator control starting in 2000, primarily using baited traps and shooting, that reduced the size of feral predator populations within Ka`ena Point NAR. However, with unlimited opportunities for predator entry, control required constant effort and expense and did not provide a consistent level of protection for the native plants and animals within the NAR. Despite ongoing predator control, the rates of predation on nesting seabirds (up to 15% per year) were too high to allow the long-term recovery of the existing seabird populations and were likely preventing other seabird species from colonizing the area. The impacts of seed predation on endangered plants, while not as extensively documented, were also likely contributing to poor reproductive success and survival.

The devastating impacts of non-native mammals such as dogs, cats, mongoose, rats, and mice on island ecosystems are well-documented (Blackburn et. al. 2004;). Predation by invasive species is second only to habitat loss as the leading cause of avian extinctions and declines on islands, with rats and domestic cats implicated in most (72%) avian extinctions caused by invasive predators (Blackburn et. al. 2004). Despite existing predator control efforts at Ka`ena, attacks by cats and dogs continued to occur. For example, in 2006, 113 fledgling wedge-tailed shearwater chicks were killed by a pack of dogs in a single incident at Ka`ena. Other high-mortality attacks at Ka`ena include a 2005 incident in which a dog killed approximately twenty shearwaters, and a 1996 incident where forty nesting shearwaters were killed in one night.

Ungulates have already been excluded from a number of large tracts of sensitive habitat in Hawai`i using fencing. However, these fences do not exclude smaller pest species such as mongooses, cats, and rodents. Impacts of feral cats and mongooses in Hawai`i have been well documented, including the predation on many endangered species, primarily birds (Hodges and Nagata 2001, Smith et. al. 2002, Laut et. al. 2003). Invasive rodents such as rats and mice constitute a potentially even greater threat to native species by contributing to extinctions as well as ecosystem level changes (Fukami et. al. 2006). In Hawai`i, rats have been documented to prey on ground-nesting seabirds, forest birds including the endangered O`ahu ‘Elepaio (*Chasiempis ibidis)* and the Laysan Finch (*Telespiza catans;* VanderWerf and Smith, 2002). As omnivorous feeders, rats are also known to eat the seeds, fruits, leaves, and shoots of a variety of plants, including stripping the bark of koa (*Acacia koa*) saplings and eating the seeds of loulu (*Pritchardia* spp.) palms and other endangered plant species (U.S. Army 2006). These actions may kill plants outright, make them more susceptible to pathogens or insects, or prevent natural reproduction. While rats can be controlled in small areas using bait stations and traps, it is extremely labor intensive and not a permanent solution. Until recently, there was no way to effectively eradicate rats and mice from larger islands, or even to exclude them from specific areas.

Finally, the predators found at Ka`ena act as carriers of leptospirosis, morbilli virus (distemper), and toxoplasmosis. The Recovery Plan for the

Hawaiian Monk Seal identifies these diseases as threats to monk seal survival. In addition, toxoplasmosis also a dangerous disease for humans. Despite existing predator control efforts, the possibility of exposure continues as long as predators can enter the reserve.

Until 2006, DoFAW was constrained by their budget from tackling the outstanding issues at Ka`ena Point. In a series of events that included the large shearwater kill discussed above, and the cancellation of a fully funded predator proof fencing project on Hawai`i island, funding was made available from the US Fish and Wildlife Service (USFWS) to construct a predator proof fence at Ka`ena Point. The funding was provided as a grant to the Wildlife Society Hawai`i Chapter (TWS) in trust for the state under the USFWS recovery program to protect endangered plant species.

Predator-proof fencing is a relatively recent technology that was developed in New Zealand and to date over 52 fences have been constructed protecting more than 10,000 ha. The fencing excludes non-native predatory animals as small as a two-day old mouse, and prevents these animals from digging under or climbing over the fence. The use of the predator-proof fencing greatly increases the effectiveness of existing animal control efforts, shifting the focus from reducing predator numbers to eradication (Long and Robley, 2004). Research undertaken in 2002 (MacGibbon and Calvert, 2002) and completed in March 2006 (Burgett et. al. 2007) demonstrated that these fences could be designed to exclude all of the mammalian pests present in Hawai`i. Biologists familiar with these fences in New Zealand stated that “far more has been achieved at a far greater pace than expected”(T. Day pers. Comm.). Benefits included a noticeable improvement in ecosystem function, a documented increase in the number and density of native invertebrates, and an increase in the diversity of plant vegetation. In one installation, the results projected to occur within ten years of construction were observed in 18 months. The predator proof fence uses technology that has been used with great success in New Zealand in both coastal and forested areas. Trial predator-proof fences were constructed on the slopes of Mauna Loa on Hawai`i, demonstrating their effectiveness in excluding rats, cats, and mongoose and allowing the development of methods to exclude mice on ‘a‘ā substrate. Ka`ena Point was the first project-level fence of its type constructed in Hawai`i and the U.S. In Hawai`i, the use of predator-proof fencing is especially promising in that it can provide areas within which the entire ecosystem, including native vegetation, can recover and where birds and snails can breed and forage free from the threats of introduced terrestrial vertebrate predators (MacGibbon and Calvert, 2002).

Anticipated benefits of predator proof fencing at Ka`ena Point are increases in the breeding Laysan albatross and Wedge-tailed shearwater populations; the establishment of new seabird breeding populations, such as the ka‘upu or Black-footed albatross (*Phoebastria nigripes*) and the ‘ou or Bulwer’s petrel (*Bulweria bulwerii*); a greater understanding of the impact of rodents on coastal ecosystems; improved health and function of the coastal strand plant community; improved natural regeneration or the re-introduction of endangered plant populations historically found at Ka`ena; reduced risk of disease transfer to basking monk seals; and a demonstration area for residents and visitors to observe what a coastal area of the Hawaiian islands might have been like in their natural state before the introduction of invasive mammals and to develop a greater appreciation of the value of the natural and cultural resources of Ka`ena Point. Over the long-term, protecting the nesting area at Ka`ena is of particular importance to vulnerable seabirds, as most of their nesting areas are located on atolls and islands at greater threat by rising sea levels than Ka`ena (Baker et. al. 2006).

The purpose of this report is to provide an overview of the entire process that was undertaken to complete this project, from the scientific aspects to the legal compliance. Since the completion of construction, multiple predator proof fencing projects have been initiated in Hawai`i and it is hoped that by compiling all the information from our experience, that it will facilitate planning of future projects.

Objectives

The principle strategic objective of this project was to promote active ecosystem restoration through the use of predator proof fencing. The specific objectives were to:

1. Conduct public outreach to obtain, and maintain community support for the project
2. Conduct pre and post biological monitoring to assess the effectiveness of predator proof fencing as a management tool in Hawai`i
3. Construct a predator proof fence capable of excluding all non-flighted mammalian predators from Ka`ena Point
4. Remove (and continue to exclude) all non-flighted mammalian predators from Ka`ena Point
5. Document changes to the recovering ecosystem in the absence of non-native predators.

The long term objectives once predators have been removed are to continue with ongoing plant restoration, begin more aggressive seabird restoration (such as social attraction and translocation) and provide the public with an opportunity to enjoy a restored ecosystem and the educational opportunities associated with having a restored ecosystem so accessible to an urban center.

Fence design

The fence encloses approximately 20ha of the Ka`ena Point NAR. The fencing corridor is approximately four meters wide and 630 meters long. The fencing alignment largely follows a World War II-era roadbed that skirts the bottom of the hill behind and above the sand dunes. By following this track at the base of the slope, the alignment places the fence along the least visually intrusive area of the point, so that the greatest area might be enclosed while minimizing interference with viewplanes and avoiding further disturbance to the delicate habitat. Figure 1.1 illustrates the area and the fence alignment.

Figure 1.1 – Fence alignment at Ka`ena Point NAR

The existing roadbed that forms the main portion of the fence corridor (Figure 1.1) is fairly level, and as a result, limited vegetation clearing was required. Ground preparation that was required along the Waianae slope involved the use of a bulldozer and excavator to move soil or rocks to form a level stable platform and to contour the ground so that rain water moves away from the fencing. Details on the construction of the fence are discussed later in this document.

The fence design has three main elements: base fence, predator-proof mesh and skirt, and predator-proof rolled hood (see Figure 1.2). The base fence provides the structural strength and framework on which predator-proof components may be added, and is made of anodized aluminum posts and stays, with stainless steel wires and fastenings.

Anodized aluminum posts set into the ground three meters (9.8 feet) apart. One meter of the post is buried, while two meters remains above ground. Marine grade stainless steel mesh with an aperture of 6 x 25 millimeters is attached to the entire face of the base fence, and is also used to form a skirt of horizontal mesh at ground level, to prevent predators from tunneling under the fencing. The mesh extends from the top of the posts to just below ground level, while the skirt extends 300 millimeters from the fence, and is cemented to the ground.

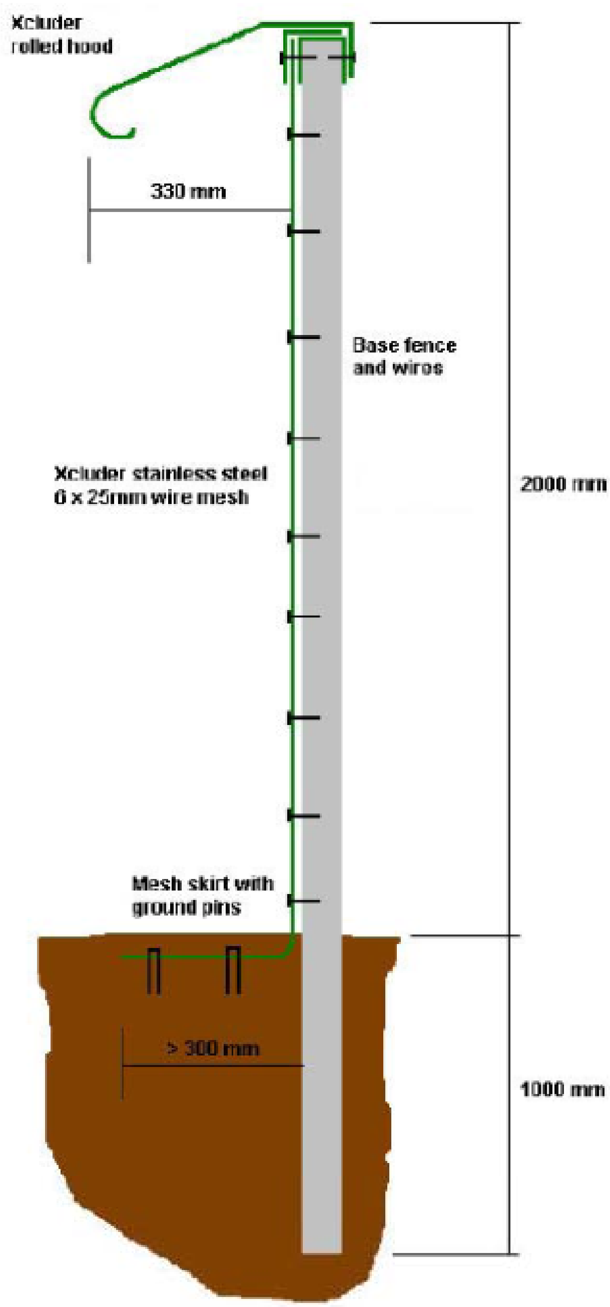


Figure 1.2 – Fence design

Figure 1.3 – Installed fence section at Ka`ena Point

Access doors were incorporated at locations where the fencing crosses existing trails at both the Mokulēʻia and Waiʻanae entrances and a third door above the Leina ka ʻUhane to allow access to a fishing koʻa (shrine). To minimize the opportunity for predator incursion if doors are propped open, a double-door system was utilized such that both doors cannot be open at the same time. Instead, a person accessing the reserve must wait for the first door to close before the second door may be opened. The area between the doors was constructed with the same quality and design as the rest of the fence and is large enough that up to nine people may enter together or so that a person can enter with a bicycle or fishing pole.

Figure 1.4: The south coastal end (left), center gate and north coastal end (right) of the fence.

Budgets and funding

Funding was obtained from six grants made specifically for this project and its related activities:

Table 1.1: Sources of funding for the Ka`ena Point Ecosystem Restoration Project

Source	Amount	Purpose
USFWS	$350,000	Fence construction, outreach, coordinatio
David and Lucille Packard Foundation	$150,000	Predator removal, seabird monitoring
David and Lucille Packard Foundation	$135,000	Fence maintenance, predator monitoring
USFWS	$70,595	Funding of public outreach ambassador
Hawai`i Tourism Authority	$50,000	Funding of public outreach ambassador
USFWS	$17,000	Public outreach for rodent control
Total	$772,595	

At the time of this report, $637,595 had been spent on this project (the fence maintenance grant of $135,000 does not begin until January 2012). A rough breakdown of how this money was spent is outlined below:

Table 1.2: Breakdown of spending for the Ka`ena Point Ecosystem Restoration Project.

Item	~Cost
Fence construction (~650m= $446/m)	$290,000.00
Predator removal (to date)	$51,000.00
Project coordination	$79,000.00
Public outreach	$69,000.00
On-site ambassador	$120,595.00
Miscellaneous and grant overhead	$28,000.00
Total	$637,595.00*

*Note that the grant of $135,000 is not included in this table as the grant period hadn't started at the time of publication

These costs do not include USFWS or DLNR staff time, and do not include the annual contract DoFAW has with USDA-WS for predator control (~$35,000/year). In addition, much of the pre-construction biological monitoring was done on a volunteer basis by a variety of individuals at both public and private institutions. All of these agencies contributed significant amounts of staff time towards the planning and execution of this project, and the actual cost of implementing this project is undoubtedly much higher. Nonetheless, these estimates can still serve as a rough guideline for future projects that are still in the planning stages.

Timeline

- 2005 – Testing of New Zealand fence technology on Hawai`i, sponsored by USFWS
- 10/2006 – > 150 seabirds killed at Ka`ena Point NAR by dogs and cats
- 11/2006 – Proposal to construct a predator proof fence at Ka`ena Point NAR
- 12/2006 – USFWS, DLNR, and The Wildlife Society, Hawai`i Chapter form a partnership to build the predator-proof fence
- 07/2007 – DLNR completes archaeological and historical properties report
- 10/2007 – Broad public and stakeholder outreach efforts commences

- 12/2007 – Draft Environmental Assessment available for public review
- 07/2008 – Modifications to fence alignment based on comments/concerns
- 07/2008 – Yearlong project on the biological monitoring of all native and pest species begins
- 10/2008 – Contested cases filed to the Board of Land and Natural Resources (BLNR)
- 05/2009 – Contested cases dismissed by BLNR due to lack of standing
- 06/2009 – Final Environmental Assessment and Cultural Assessment completed
- 08/2009 – Applications made to City & County for final project permits
- 08/2009 - Interviews conducted to hire Ka`ena Point Ambassador
- 12/2009 - David and Lucille Packard Foundation provide funding for predator removal
- 01/2010 - Right of entry permit given to TWS by the BLNR
- 01/2010 - Two (new) contested cases filed
- 08/2010 - Contested cases denied standing
- 09/2010 - Contract is signed with fencing contractor
- 11/2010 - Final permitting requirements completed
- 11/06/2010- Construction begins
- 11/16/2010- Temporary restraining order (TRO) filed against the project
- 11/18/2010- TRO denied standing in First Circuit Court
- 12/17/2010- Fence is 90% complete; break for the holidays
- 02/2011- Fence crew returns to complete project
- 02/2011- Rodent removal operations begin
- 03/2011- Fence is complete
- 06/2011- Cats, mongooses and rats have been eradicated from within the reserve
- 10/2011- Mice are eradicated from within the reserve

Limitations

Despite this project having sufficient funding and public support to complete the fence construction and initial predator removal, concerns exist over how the long-term maintenance and biosecurity of the area will be managed. Currently, there is funding through 2013 (two years post-construction) from grant money for maintenance and ongoing predator surveillance, but once this is complete the future is less certain. Several community groups and individuals have expressed an interest in assisting in maintenance operations and long-term monitoring associated with this project and it is hoped that with careful planning and coordination that these groups can be trained to provide assistance and fill in any staffing/funding gaps within DLNR. At a minimum, a maintenance and buffer pest control program that includes once-weekly inspections will need to be conducted in perpetuity in order to keep animals from re-invading the fenced area through the coastal gaps, and to conduct regular maintenance needs.

From an operational standpoint specific to the predator removal and biosecurity, there were clear limitations with the fence design which is a peninsula-style fence with unsecured openings on the coastal ends. While the openings on the coastal ends (2m and 1m respectively) are much narrower and more rugged terrain than other successful coastal peninsula fences built previously in New Zealand, the potential for re-invasion is still present and directly impacts the project's ability to conduct a true eradication and effective biosecurity. Despite these limitations, however, the level of risk associated with cancelling the project (both ecologically as well as politically) was thought to be greater than the level of risk associated with proceeding under the scenario described above, and more importantly, the predicted benefits are anticipated to far outweigh the costs. As such, efforts were made to mitigate those risks to the fullest extent possible and ensure the long term success of the project.

PERMITS AND REGULATORY PROCESS

The construction of a predator proof fence in Ka`ena Point NAR required multiple permits and regulatory checks that were required as a result of the use of federal funding, the use of state land, the nature of the cooperative agreement between the grant parties and land use regulations. The use of federal funds provided by the US Fish and Wildlife Service (USFWS) triggered a Section 7 consultation under the Endangered Species Act (ESA), National Environmental Protection act (NEPA) review, and Section 106 consultation under the National Historic Preservation Act of 1966. As significant historic properties were in the project's area of potential effect (APE) and the project could adversely affect these properties, a Section 106 Memorandum of Agreement (MOA) was required for the project.

The use of state lands triggered a State environmental review under Hawai`i Revised Statutes (HRS) Chapter 343. Construction within a state NAR required approval and cooperation of NARS staff and the System Commission.

The funding for the project was given as a grant to the Wildlife Society Hawai`i Chapter (TWS) who in turn constructed the fence on behalf of the state. Since three parties were involved in the implementation of this grant, a cooperative agreement was drafted by the Hawai`i Department of Land and Natural Resources (DLNR) to clarify each party's role in the grant and multiple permits were issued to TWS

Finally, as a result of the area being located in a county-zoned preservation district and within the designated special management area along the shoreline, a Special Management Area Use Permit (SMA), a Shoreline Setback Variance (SSV) and Shoreline Certification were required by City and County of Honolulu, Department of Planning and Permitting (DPP). As the area was also located within both a resource and limited subzone of state Conservation District, consultation with staff from the DLNR Office of Conservation and Coastal Lands was necessary to determine whether an existing Conservation District Use permit covered the project or whether a new

Conservation District Use Application was required . After consultation, it was concluded that the project was permitted under existing CDUA No. SH-2/26/82-1459, associated with the creation of the Natural Area Reserve.

Despite being located on state land, the county initially determined that a grading permit would be required for the project. It should be noted that the zoning regulations of the other counties (Maui, Hawai`i, and Kauai) provide a method to exempt projects on state land from grading and grubbing permit regulations, but the City and County of Honolulu does not. However, based on the specific information contained within the grading permit application, the City and County determined that this particular project did not require a grading permit.

Table 2.1: List of permits/consultations required for construction of a predator proof fence at Ka`ena Point NAR, issuing agency and completion date

Permit/Consultation	Issuing Agency	Completion date
ESA Section 7	USFWS	2007
EA	DLNR	June 23, 2009
Cooperative Agreement	DLNR	August 2009
NEPA	USFWS	Fall 2009
Section 106	USFWS	November 2010
SMA	DPP	Fall 2009
SSV	DPP	Fall 2009
Shoreline certification	DPP	Fall 2009
TWS right of entry permit	DLNR	Fall 2010
Grading permit	DPP	Exempt- Fall 2010
Rodenticide application permit	USFWS	February 2011

A more detailed discussion of some of the larger regulatory hurdles is presented below as an understanding of the issues, and resulting delays, encountered during these processes may provide insight to future projects on the planning process

Cooperative agreement

The funding for the project was given as a grant from USFWS to TWS who in turn constructed the fence on behalf of the state. Since three parties were involved in the implementation of this grant, a cooperative agreement was drafted by DLNR to clarify each party's role in the grant and multiple permits were issued to TWS to complete construction. The review of the cooperative agreement was brought before the BLNR for voting and approval in October 2008. BLNR meetings are open to the public and on issues where decisions are to be made, members of the public are allowed to file a request for a contested case hearing to dispute decisions under Hawai`i Administrative Rules 13-1.

During the first meeting held on 24 Oct 2008 to approve the cooperative agreement between the granting parties, four individuals filed contested case petitions against the cooperative agreement. The petitions were reviewed and denied by the BLNR at its 22 May 2009 meeting. Copies of the contested cases and their denial can be found online at the BLNR meeting website under item C-2 of the submittals 22 May 2009 meeting; copies of the cooperative agreement can be found in the submittals for the 24 October 2008 meeting.

In January of 2010 after completion of the majority of the other major permits, the project was once again brought to the BLNR to issue a right of entry permit for TWS to construct the fence. At this meeting, two additional contested case petitions were filed. As it did with the first set of contested cases, the BLNR denied the petitions at the 12 August 2010 meeting. Copies of the contested cases and their dismissals can be found online at the BLNR meeting website under item C-1 of the submittals for the 12 August 2010 meeting.

Both the cooperative agreement and right of entry permit appeared to be relatively straightforward processes, but they ultimately delayed the project by over a year as a result of the time it took to resolve the contested case requests.

The project would have been delayed even further if the petitioners had been found to have standing and a full contested case hearing had been held. While there was no way to avoid going to the BLNR twice, in retrospect, the project could have requested a right of entry permit at an earlier date (with prior chairperson approval) with a contingency clause that it was not effective until all other necessary permits were obtained. In doing this, resolution of any resulting contested case petitions could have been done concurrently with other permit applications to prevent delays in the construction date.

Environmental assessment

The first major compliance item that was initiated for this project was the preparation of an environmental assessment (EA) which began in the spring of 2007. This was done internally by DLNR and project staff who reviewed existing references relating to the Ka`ena Point area, conducted surveys for biological and historic sites, and consulted with numerous agencies, individuals and researchers to compile information on both the cultural and natural resources of Ka`ena Point. A key component of this EA was including multiple fence alignment options that either included or excluded culturally significant features, such as the Leina ka `Uhane (a point where souls are said to leap into the afterlife described in detail later), from within the fenced area with the idea being to allow the public to provide input on the various alignments during the comment period.

Given the height of the fence and the materials being used, it was expected to be a prominent feature in an otherwise open and scenic landscape and the visual effects of the fence on historic properties and their setting also needed to be taken into account. As part of the EA, a summary of known and possible historic properties at Ka`ena Point, particularly those found within the potential project area, was completed and incorporated into a cultural impact assessment that was added as an appendix to the final EA. The assessment was based primarily on field inspections conducted on 27 January and 30 June 2007 and on a review of reports and other sources available in State Parks files, including the original archaeological excavations done in the 1970's and 1980's. During the field inspections, State Parks staff and archaeologists were able to examine potential fence alignments with other parties involved in the project and to locate previously recorded historic properties. This allowed an assessment of, at least on a preliminary level, the kinds of historic properties that would need to be considered during the historic preservation review process and to propose potential fence alignments that would avoid or minimize damage to historic properties. Also discussed were actions needed to determine how the project could affect these historic properties and how those effects could be avoided or minimized. As proof of compliance with federal historic preservation laws and regulations was needed, the report also included recommendations on fulfilling those requirements.

Prior to the release of the Draft EA for public comment, pre-consultation was initiated by sending a scoping letter to over 90 government agencies, organizations and individuals that were identified as potential stakeholders for the project. During the pre-consultation period, comments were received from 21 of those entities. Comments were incorporated into the document which was then finalized for public review.

A draft EA for the Ka`ena Point Ecosystem Restoration project was made available for public comment on 23 December 2007, through publication of availability in the Bulletin of the Office of Environmental Quality Control (OEQC). The comment period was informally extended through March 2008 to accommodate comments that were received after the holidays and after a site visit with the Office of Hawaiian Affairs (OHA) in March of 2008. A total of 31 comments were received during the comment period, the majority of which were supportive of the project. Copies of all comments received during the pre-consultation and public comment period are included in the Final EA which is publically available online through OEQC.

During the spring and summer of 2008, comments were incorporated into the Final EA and further consultations were conducted within the community to notify them of the preferred fencing alignment which was to include the Leina ka ‘Uhane, with the modification of an additional gate incorporated above the Leina, and extend the fence to the existing boulder barricade on the Waialua side of the project. As the Final EA was being prepared for submission in the fall of 2008, four contested case requests were filed in response to the proposed cooperative agreement described above. Despite the two documents being unrelated to each other, DLNR felt it prudent to wait on finalizing the environmental assessment until the contested cases had been resolved. The contested cases were dismissed on 22 May 2009; the Final EA was published in the OEQC bulletin on 6 June 2009. As a result of the delay caused in publishing the Final EA, permitting activities were stalled as the remaining permits required the EA to be finalized prior to proceeding.

Special management area permit

Both Ka`ena Point State Park and the Natural Area Reserve are located in the Conservation District. The project area falls partially in the Resource Subzone (where the fencing joins the coastline) and partially in the Limited Subzone (along the old roadway). The area is zoned by the County as P-1 Restricted. The project area is located entirely within the County Special Management Area (SMA). In June 2009, DLNR applied to the City and County of Honolulu’s DPP for a SMA Use Permit. As part of the permit, DLNR provided a written statement justifying why the project was in the public interest and represented the most practicable alternative with respect to the purpose of the Special Management Area ROH 25-1. The project was also within the Shoreline Setback, which required a Shoreline Setback Variance from the City and County of Honolulu’s DPP. Similarly, the DLNR submitted an application justifying why the project was in the public interest, and represented the most practicable alternative with respect to the purpose of the shoreline setback ordinance ROH 23-1.2.

These applications required a map of the shoreline and shoreline setback prepared and certified by a registered land surveyor and certified by the State Surveyor and Director of Land and Natural Resources within one year of the application date. The application required the completion of an environmental assessment or impact statement. A mandatory public hearing was also required in the area in which the project was proposed, which occurred on October 5, 2009 with a large audience and broad public support. Then, the DPP submitted a report and recommendation to the City Council, which approved the project on October 19, 2009 (City Council Resolution 09-307).

Section 106

As a result of the USFWS providing funds for the Ka`ena Point Ecosystem Restoration Project, the project was subject to review under Section 106 of the National Historic Preservation Act (NHPA), 16 U.S.C. § 470f, and its implementing regulations, 36 C.F.R. Part 800. The project's "area of potential effect" (APE) was determined by the USFWS to include several historic properties listed in, or eligible for listing in, the National Register of Historic Places including the "Ka'ena archaeological site complex" (Site No. 50-80-03-1183), the rock formations named Leina ka 'Uhane and Pōhaku o Kaua'i, which are of known traditional cultural significance, and structures and landscape modifications associated with the island's railway and military histories. Because the project could affect significant historic properties, the USFWS entered into a MOA with the Hawai'i State Historic Preservation Office to mitigate any adverse effects to these properties. The Office of Hawaiian Affairs (OHA) signed the MOA as a consulted Native Hawaiian Organization and the NAR System of the Hawai`i DoFAW and the TWS were invited signatories. To determine the area that would be directly impacted by project-related activities, a site visit was conducted prior to the commencement of work with the fencing contractors, a biologist, archaeologist, and cultural monitor. The precise fence line, the boundaries of areas where machinery was allowed, and the staging area were delineated marked. This was to ensure that no pre-contact archaeological features or endangered plants were disturbed during construction. Several properties, including World War II military modifications to the landscape and a stone wall associated with the 1897-1947 Oahu Railway and Land Company would be crossed by the fence.

Mitigation for the proposed effect included additional historic documentation of the stone wall, painting the fence green to blend with the hillside to reduce visual impacts, hiring an interpretive ranger who was aware of the culturally sensitive nature of the site to be on-site during earth moving activities as a cultural monitor, and having an archaeologist present while ground-disturbing activities were taking place (grading and post hole digging) to ensure that archaeological resources were not adversely impacted.

While planning for the Section 106 consultation began with ample lead time, it was not submitted to the reviewing agencies with enough lead time to allow for comments to be incorporated and re-reviewed. The document was also submitted sequentially, as opposed to simultaneously, to each reviewing party which lengthened the process substantially. As a result, there was a considerable rush in the week prior to construction to finalize the document to be in compliance.

During the construction period several concerns related to the Section 106 MOA were brought up by members of the public as well as by OHA. During the delivery of the heavy machinery into the reserve, which required driving machines along the two mile unimproved dirt road, two small sections of the roadbed were altered with the bulldozer to facilitate delivery of the excavator. The roadbed was not included in the original APE because it was considered a routinely-used public access route (i.e., similar to any established road or highway) and these very minor improvements were not anticipated as being needed during project planning. When the issue was raised, USFWS responded that it did not consider the roadbed to be a significant historic property. While it is over 50 years old and historic, it is highly degraded due to the frequent damage caused by off-road vehicles and has lost its historic integrity. The minor smoothing that was done did not damage any potentially historic features of the roadbed beyond what had already been done by private vehicles. The day before construction, the APE was flagged so that the flags would not blow away or be disturbed prior to construction. Flagging tape was used instead of stakes driven into the ground to minimize ground disturbance, and the variable height reflected the low stature of the vegetation in the area. As a result of the low visibility of the flags, it was unclear to those not involved in the project if the APE had in fact been flagged.

Finally, several days after construction began, the fence contractor performed ground disturbing activity for several hours on the weekend when the cultural and archaeological monitors were not present despite having previously been told that no work was to occur that weekend. As a result of these activities, the contractor was sent a written reprimand and the USFWS responded in writing to OHA over this violation of the MOA. All three of these events could have likely been prevented with improved communication between the signatories on the document and the fencing vendor.

Conclusions

With any large project, permits are an inevitable part of the process, but the time required to complete the compliance of projects of this size is often underestimated. Even with the relatively quick commencement of the permitting process for this project, there were still multiple delays that could have been avoided. A six-month delay could have been prevented by finalizing the EA and initiating the SMA permit concurrently with the resolution of the first four contested cases since there was no legal basis that required the EA finalization to wait. Similarly, a right of entry permit could have been requested prior to obtaining all other permits, but that was contingent upon obtaining those permits, and allowed for resolution of any contested cases while final permits were being applied for. And while the Section 106 did not stall the project, it came very close to preventing the construction from starting on time since the document was submitted sequentially, as opposed to simultaneously, to each reviewing party which lengthened the process substantially. As a result, this specific process should have been initiated much earlier, and to all reviewing parties simultaneously to allow time for multiple agencies to complete their reviews without repeated follow up.

Future projects should initiate their consultations and compliance paperwork well in advance of their anticipated construction date. Completing the compliance documents took longer and required more work than obtaining funding, and while most projects will likely not have as heavy a permitting burden as this project did, starting compliance paperwork while searching for funding would help to avoid some of the issues that this project ran into.

PUBLIC OUTREACH

Introduction

Ka‘ena Point NAR, and the greater Ka`ena Point area which spans from Keawa‘ula Bay (also known as “Yokohama Bay”) on the Leeward Coast to Mokuleia on the North Shore is an area with many user groups who feel strongly about how it should be used and cared for. Historically, the Ka‘ena coast supported small fishing villages, and still is an important area for Hawaiian culture. The O‘ahu Railway and Land Company began operating a railway around the point in 1898 to service sugarcane operations. The Coast Guard constructed a passing light for navigation purposes in 1920. Because of its strategic location, Ka‘ena Point was actively used by the military for coastal defense after World War I through World War II. Military use declined after World War II and the railway ceased operation in 1947.

During the 1970s, the State began to purchase lands in the area for a proposed Ka‘ena Point State Park. In 1978, a Ka‘ena Point State Park Conceptual Plan was completed. Ka‘ena Point NAR was established in 1983, composed of twelve acres on the leeward side of the point. In 1986, an additional twenty-two acres on the windward side were added to the NAR. The project area is one of the last relatively wild coastal areas on O‘ahu and has been valued as a natural escape from the pressures of urban life and its primary uses include recreation, hiking, nature study, education, and the observation of wildlife. Shore fishing, spear fishing, and gathering of marine resources have traditionally been important uses of the Ka‘ena coast.

Ka‘ena Point itself is a culturally significant landscape. There is a strong relationship in Native Hawaiian culture between the people and the land on which they live. The ‘āina (land), wai (water), and kai (ocean) formed the basis of life and established the spiritual relationship between the people and the environment. This relationship is demonstrated through traditional mele (songs), pule (prayer chants), genealogical records, and stories about particular areas, celebrating the qualities and features of the land. The relationship to the land is also shown through the strong attachments of kama‘āina to their ancestral homelands. Within the NAR is the Leina ka ‘Uhane (Soul’s Leap), a large basalt outcrop that is said to be where souls depart into the afterlife from O‘ahu, and as such, is a sacred feature in the cultural landscape of Ka‘ena.

Based on user surveys conducted in the 1990’s, upwards of 50,000 people visit K‘aena Point area each year. As a result of the diversity and number of user groups it was decided that extensive public outreach was needed to ensure the success of the project. Pre-consultation began with the advertisement for an outreach position, followed by formation of a multi-person outreach team in October 2007. Since then, the Ka‘ena Point Ecosystem Restoration Project outreach team has been very active in the communities surrounding Ka‘ena Point (both the Mokulē‘ia and Wai‘anae sides), and have consulted with thousands of individuals and community organizations to give everyone accurate information and provide them the opportunity to give feedback on the project. As a result of their work, the vast majority of people who have been contacted support this project strongly and are interested in ensuring that Ka‘ena Point NAR is protected for the long-term, despite the vocal objections of a few.

Approach

The success of this project was due in large part to the public support garnered the outreach team. They identified and initiated personal contact with as many stakeholders as possible] developing relationships with those with a strong connection to Ka‘ena. In conjunction with personal contact, materials were developed to facilitate the transfer of information (discussed in more detail below). Printed outreach materials include two brochures, a fact sheet on owls at Ka‘ena Point, a Frequently Asked Questions sheet and a teacher education packet containing brochures and lesson plan on native coastal environments in Hawai‘i. Also, a section of a real predator-proof fence (approximately 3’ wide and 6.5’ tall) was shown to stakeholders at various meetings. Finally, a project website was developed] to provide on-demand access to all relevant project information.

Outreach efforts began in the fall of 2007 in conjunction with the release of the DLNR pre-consultation scoping letter for the environmental assessment. During this time, the outreach team met with groups such as the North Shore Neighborhood Board, Wai'anae Neighborhood Board, Mokulē'ia Community Association, Wai'anae Hawaiian Civic Club, Office of Hawaiian Affairs Native Hawaiian Historical Properties Council, Earthjustice Legal Defense Fund, Sierra Club, Hawaiian Trail and Mountain Club, 'Ahahui Mālama I ka Lōkahi, the Oahu Railway Society, The Coastal Defense Study Group, Friends of Honouliuli, Hawai'i Audubon Society and Friends of Ka'ena. Presentations were made to teachers and hundreds of students and team members also conducted many one-on-one meetings and site visits with respected kūpuna (native Hawaiian elders), community leaders, fishers and 4x4 club members where concerns were shared and addressed wherever possible.

The outreach team also conducted surveys at Ka'ena Point on three weekends to get input from current users of Ka'ena Point about why they visit Ka'ena and what they think about the proposed fencing. The same survey was administered at the popular Hawai'i Fishing and Seafood Festival held at Pier 38. Of the 141 respondents, 95% of whom were from Hawai'i, 82% supported constructing the fence, 15% were possibly supportive, and 3% were unsupportive.

Two articles urging public input were published in the Hawai'i Fishing News (circulation 10,000) the newsletter of the Hawaiian Trail & Mountain Club (circulation 300), the DLNR-DOFAW newsletter (*Nā leo o ka 'āina, Voices of the Land*) as well as via mass media. Both the *Honolulu Advertiser* and *Honolulu Star Bulletin* (the two major daily newspapers at the time) published stories. On television, news stories were aired on KHON, KHNL News 8 and KGMB. On basic cable channel OC 16's *Outside Hawai*'i program, a 30 minute television show broadcasted statewide, three stories were aired, including a 10 minute video created by Mara Productions. A presentation made to the Wai'anae Neighborhood Board was aired repeatedly in early 2008 on 'Ōlelo Community

Media. Two outreach representatives also participated in a 30 minute television show on ‘Ōlelo, “William ‘Āila Presents,” which aired in December 2008.

The outreach team also made a concerted effort to reach schools in the region. Letters and informational materials were sent to 16 schools and presentations were made to numerous school groups including the Sierra Club High School Hikers and the NOAA sponsored Papahanaumokuakea Ahahui Alakai program. Specific attention was paid to the Leeward Coast were Wai‘anae High, Nānākuli Intermediate/High, and Kamaile Academy had classroom presentations to introduce the project followed by a separate hike along the Wai‘anae coast. All schools were then brought together for an educational sharing/gathering (ho’ike) at Camp Erdman in Mokulē‘ia. Outside Hawai‘i also filmed some of the field trips and the hō‘ike and aired two additional shows. Students worked on group projects related to Ka`ena Point, which included PowerPoint presentations, games played with elementary school students, and a series of short videos. In total presentations were made to about 125 students and approximately 70 participated in the hikes. Outreach was also conducted at fairs at four of the major colleges and universities on O‘ahu. Ka`ena Point was recently chosen as the permanent site for the “Navigating Change” program, an environmental education program based at Ka`ena Point run by the National Oceanic and Atmospheric Administration.

From 2009-2011 the state also hired a Ka`ena Point Ambassador funded by a grant from the Hawai‘i Tourism Authority and the USFWS. The incumbent was stationed primarily in the Ka`ena Point NAR to educate the public, provide volunteer coordination and lead service visits as well as cultural monitoring during the construction period.

Materials produced

An important component of the public outreach process was developing educational materials \ to convey information and the outreach message to stakeholders and the general public. A key component of these materials was commissioning artwork of the area and its wildlife which was used as the foundation for all outreach materials thereby providing a more cohesive look. A variety of tools were used to accomplish public education including a website, brochures, magnets, FAQ's, fence replicas (miniature and full size) and signs that were posted in the reserve itself. Some of these items, such as the fence replicas, brochures and magnets, were brought to presentations and meetings to distribute directly to individuals. Others, such as FAQ's and website addresses were distributed via e-mail and media stories to a larger audience. Finally, for those that had not been informed of the project through direct contact with the outreach team or via television or printed media, signs were designed and posted on the reserve itself to inform visitors of the project and its purpose. Below is a summary and pictures, were applicable, of the specific materials developed.

Website

For widespread information dissemination, a website for the project was developed that contained all the content and downloadable copies of documents, brochures and videos. The website was set up soon after the formation of an outreach team and was initially housed under the Natural Area Reserves Section of the Hawai'i Department of Land and Natural Resources (DLNR) website. After the first year, the site was moved to a separate, easy to remember web address at www.restorekaena.org. To give a sense of what the fence might look like in the actual setting, artist's renderings were produced from three vantage points, which were available on the website. The organization of the website was as follows:

- **Home** 2 paragraphs introducing the project
- **Treasures**
  - Cultural resources
  - Current public use
  - Wildlife
  - Native plants
- **The Project**
  - The problem- outlined predation issue with photographs

The solution- introduced the fence concept

How would a fence affect access? Views?

Get Involved how to behave in the reserve, volunteer opportunities

News and Events- media coverage, cleanups, project updates

Education outreach efforts, ambassador information, school groups

Learn More

FAQ's- downloadable copies of the FAQ's

Downloads- brochure, EA, predator removal summary

Photos and videos photo gallery, project documentary, media clips

Blog

Contact us

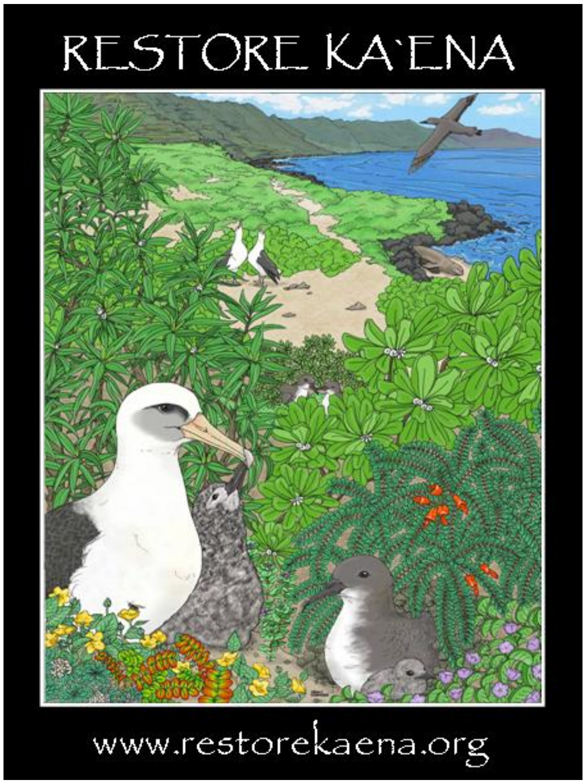
The website was updated as needed and was a convenient forum from which to distribute information, particularly when specific questions or issues were raised about a component of the project, and to announce upcoming public meetings and project events. It will remain active until the end of 2012.

Brochure

Concurrent with the development of a website a brochure was developed for distribution to individuals as well as in downloadable form on the website. As the construction date approached, a small insert was inserted that discussed the project status, construction protocols and the subsequent rodent removal so as not to reprint the entire brochure.

Magnet

At the same time that the website was moved to its unique URL, a 4" x 3" magnet was developed as an easy way to remind people to check back on the website for project updates and the latest information. The magnet was a simple black background with the project artwork as the graphic and a link to the website as seen below:



FAQ and briefing packets

An FAQ was developed as an easy to read way of answering some of the most common questions and concerns that project staff was receiving. Questions that were covered included:

Where is Ka‘ena Point?

What’s so special about Ka‘ena Point Natural Area Reserve?

What’s the problem at Ka’ena Point Natural Area Reserve?

Why are dogs not allowed?

Why build a pest-proof fence?

What will the fence look like?

Will the fence be an eyesore that takes away from the beauty of Ka‘ena Point?

How will the fence affect access?

Will cultural sites be impacted?

How long have seabirds been using Ka‘ena Point?

Will the very birds you are trying to protect fly into it and get injured or die?

What will the effects of the fence be on Pueo, the native Hawaiian Owl?

How do you know these fences work?

Who is paying for this project?

When will the fence be built?

How long will it take to build the fence and how long will it last?

How does the community feel about this project?

Will the public be able to comment on the plans for the fence?

As the construction date approached, a specific FAQ was developed since the reserve would not be closed to the public and required cooperation by everyone to make the reserve a safe place to visit during that time. Most of the common questions were addressed in the construction insert for the brochure (will the reserve remain open?, when will it be finished?, etc), but there were specific questions that were raised by community members that were addressed in the FAQ instead:

Is the construction going to impact nesting birds?

Is the fencing corridor flagged?

Were any endangered plants run over by machines and are they flagged?

Are local companies involved?

Is there a toilet for crews?

In addition to FAQ's that were geared towards the general public, an in-depth briefing packet was developed for decision makers, spokespeople and the media that provided a more in-depth summary of the project to date with sections on:

Project description

Location

Resources

Need for a predator-proof fence

Fence alignment and design

Biological monitoring
Public outreach
Chronology

The combination of the FAQ and briefing packets enabled rapid distribution of information to various individuals and groups on short notice and was invaluable in facilitating the distribution of correct information to the community. Several media advisories and news releases were developed (with accompanying video B-roll), working closely with DLNR's Public Information Officer. This was instrumental in getting media coverage at key times.

Summary

By the completion of the project, the combined outreach efforts reached nearly 3,000 people from O'ahu who may have had some connection to Ka'ena Point, and engaging those who truly care about this special place in the process of making this project the best it could be. Tens of thousands more were reached as a result of media coverage during that time. The vast majority of the public were very supportive of the project, despite a vocal minority who opposed the project. While the opponents were a vocal minority that objected to the fence primarily on spiritual grounds, they were effective at spreading their message and took a considerable amount of time to respond to. While considerable amounts of detail could be provided on those objections, they are a matter of public record and are outlined in detail in the contested case proceedings referred to earlier. For controversial projects such as these, it is important for team members to be available to respond to crises as they arise. Being pro-active is not only crucial, but one also has to react, adjust, and develop new strategies as situations arise as well as keep supporters updated throughout a potentially long and drawn out process. In conclusion, outreach is not a one-time investment where the message is disseminated in the beginning via various methods. It is a constant process that needs to adapt to the situation as it changes, and one cannot assume that a supporter will always remain so unless the team keeps in contact with them and provide updated information as needed. As a result of the dedicated and extended effort put forth by the team, this project was able to proceed to completion. With the help of a coordinated outreach team, Ka‘ena Point, one of the most publically visited state-owned natural areas in Hawai`i, and is one of the few areas that the public can enjoy and learn from watching an ecosystem restoration project in action.

CONSTRUCTION AND MAINTENANCE

A critical part of the predator proof fence construction process that is often over-looked is the relationship with the selected vendor. Establishing clear lines of communication throughout the whole process, from bidding and contracting through construction and beyond, is critical to the projects success and avoid preventable delays. This project selected Xcluder Pest Proof Fencing Co, which at the time of contract negotiations, was the only pest-proof fencing company in existence with a commercial track record. Since the completion of the Ka`ena Point fence, several other vendors, all based in New Zealand, have also emerged. Regardless, because all vendors to date are international entities and must travel to the job site and import their materials, certain precautions must be taken to prevent delays and miscommunication. This section of the report describes the contracting process with the vendor, construction logistics and long-term maintenance of the fence.

Contract with fence vendor

Each project will have different contracting requirements depending on the vendor selected and agency/institution initiating the contract. During price negotiations, particularly with an international vendor, care should be taken to ensure that all shipping, customs and local taxes are included in the final cost as in some cases the vendor may not be aware of those costs. Care should also be taken to determine how the agency will deliver funds to the vendor to prevent delays in payment reaching then. In the case of Ka`ena Point, TWS was not able to wire money internationally and instead had to send a bank check which caused considerable delays for the vendor to receive the money.

The most valuable lesson that was learned from the contracting aspect of the Ka`ena Point project was that setting concrete timelines was crucial, but meant nothing without monetary penalties attached to those deliverable dates for work that went beyond the anticipated construction period. This can go for both the agency to ensure their permits are in place ahead of time, and for the vendor to ensure the work is completed in a timely manner. In the case of Ka`ena Point, there was a degree of uncertainty on the exact start date due to the project being contingent on permit approvals and seabird breeding seasons, and the construction range stated in the contract was 1 November 2010- 31 January 2011. The construction started five days late as a result of permit delays on the project end, but as discussed later, this delay was not the ultimate cause for the protracted construction period, which ultimately ended on March 30, 2011.

Fence construction began on 06 November 2010 with the expectation that the fence would be completed prior to the holidays (22 December 2010). The contractor left for the holidays in mid-December indicating they would return after 12 January 2011. When contacted in early January, the vendor was elusive about their return date and ultimately did not return until late February when it was pointed out to them that they were in violation of their contract. The delay was caused because parts for the gate had not been ordered on time and had not made it onto a January barge for shipment to Hawai`i (despite the other fence materials being shipped in September) which meant that they could not work on the fence before the materials arrived at the end of February.

Future contracts would be well served by providing monetary penalties for work extending beyond a certain cutoff point, to provide incentives to the vendor to finish work on time. To facilitate clear communication, future contracts should also include clauses that have any off-island contractor provide copies of plane tickets/reservation so that arrival and departure times are known, copies of bills of lading with contents clearly outlined and a shipment schedule so that it is clear when materials will arrive. While a delay of one to three months may not seem significant, the commencement of the rodent removal was tied closely with the fence completion date, due to the breeding season of the rodents. As a result of the largely preventable delays, the predator removal began prior to the gates on the fence being completed which likely ended up extending the length of rodent removal due to continued immigration while the gates were not installed. In addition, since cultural and archaeological monitors were required to be present during certain phases of construction, that additional cost, the protracted rodent removal and extended employment of outreach staff cost the project a considerable amount of money.

Finally, while most predator-proof fencing contracts will state that they provide on the ground training in the maintenance and use of the fence and its components, having written instructions, and including a field-ready tool-kit list as part of the contract deliverables would have been extremely valuable and saved considerable time once regular maintenance duties were taken over. This project ended up creating our own tool kit list and maintenance instructions (complete with pictures) so that staff that were not present at the time of training would still be able to fix the fence when needed.

Construction

A construction window was established during contract negotiations tied to weather, road conditions, seabird nesting seasons and ideal rodent removal periods. Permit regulations, particularly the presence of a cultural and archaeological monitor as required under the Section 106 agreement, also dictated construction logistics to a certain extent.

Immediately prior to construction, the fence contractor was given oral as well as written instructions by project staff on appropriate behavior in the reserve as well as training on endangered species identification. The area where machinery was allowed was clearly flagged, and all endangered plants and historical features that were not to be altered were also flagged to prevent damage to the landscape. Contractors were notified of authorized walking trails, were required to bring their own portable toilet facilities and were required to pack out any waste daily. Finally, a physical copy of all permits was given to the contractor and they were required to have these with them at all times on the job site and abide by the conditions set forth in the permits at all times. For the most part, despite the delays, construction went as planned with a few minor hiccups, the most major of which is described below.

While a chain of communication was established in the contract, there was not a clear clause on who had the ultimate authority to dictate the work schedule. Because certain phases of construction were required to have both cultural and archaeological monitors present per permit requirements, there were days when work was not allowed when these monitors could not be on-site. Unfortunately there was an incident of mis-communication where the fence contractor did several hours of work without a monitor present even though they had been told not to work, which resulted in a written reprimand for both the contractor, as well as the USFWS by the permitting authority. As discussed in contract negotiations, monetary penalties tied to permit violations may have helped to prevent some of these issues.

Construction and dealing with vendors is an inherently challenging aspect of any project, and many of the issues encountered are common to any project, conservation and otherwise. While it is not possible to predict or control everything, the key changes described above could have saved this project several months, and several thousand dollars in staff time if they had been included during contract negotiations.

Maintenance

Proper and regular fence maintenance will be a critical step towards reducing the chance of re-invasion after predator removal, and a well-built pest-proof fence is only as good as the monitoring and maintenance program that supports it. Accidents, vandalism and acts of nature are likely at some stage leading to the fence being damaged or breached. A good maintenance and monitoring program will detect the breach immediately upon its occurrence, will have people and resources in place to make emergency repairs, and will reduce the likelihood of pests entering when a breach occurs. Fortunately, causes of the majority of fence breaches in New Zealand, such as treefalls, vehicles and livestock, are not issues at Ka`ena Point. Instead, human error, vandalism, and extreme wave events are more likely to cause damage at this site. A good maintenance program includes regular inspection, a rapid response protocol, and having appropriate tools and instructions available to mend repairs.

While it is anticipated that maintenance will be relatively minimal for Ka`ena Point during the first five years, there will likely be increased work required as the fence ages. Verbal training was provided by Xcluder in proper fence maintenance for all involved personnel at the conclusion of fence construction. Future projects could benefit by requesting written protocols and a toolkit list as part of their contract as this project had to develop their own which took a considerable amount of time. Fortunately, extra materials were ordered at the time of fence construction to cover the first five years of maintenance needs for the fence.

A small tool box of patch materials and tools was assembled and is carried by project staff on each visit. The most regular maintenance that needs to be performed (based on discussions with fence managers in New Zealand) are:

- Patching of any holes or warping in the mesh using wire and extra mesh on an as-needed basis (usually in response to breach reports)
- Painting of seams on hood and brackets to reduce corrosion on a regular schedule (such as quarterly)
- Regularly lubricating and tightening the screws to ensure the doors close properly and don't bounce open.
- Replacing the spring bracket in the door every 2-3 years

Inspections

A pest-proof fence will need to be physically inspected on a regular basis, ideally weekly. How regularly depends on the risks prevalent at the site. Proximity to the public (vandalism and accidental damage), the nature and size of animals adjacent to the fence (damage from large livestock such as cattle and horses), the volatility of sea-end coastlines (which could be damaged or modified in storms), the proximity, extent and size of trees, the regularity and severity of flooding, and the regularity of people entering and leaving the fenced area, plus the value of what exists inside the fence are all risks that determine the regularity of inspection. At Ka`ena Point, a complete fence inspection is done on foot weekly when perimeter bait stations are serviced and fence repairs are done on an as-needed basis. By doing inspections at the same time as regular baiting, costs are reduced considerably. This includes testing gates for functionality, sweeping out gate tracks, checking the mesh, hood and skirt along the entirety of the fence line for breaks in welds, loose bolts and scratch marks on the hood indicative of cat entry. In reality, the fence is informally inspected daily by numerous visitors using the reserve, and often obvious damage or issues are reported the day they are encountered. The formal fence inspections often find less noticeable damage, such as a weld break in the mesh that the untrained eye may not see on first glance.

During the first several months of gate operations, multiple issues were encountered with the gate interlocking mechanism (which prevents two doors from opening at once), which had been set too tightly. Typically, one door will not open until the second door is closed. In the case of Ka`ena Point, which is a popular hiking destination, the door that didn't close most often was the door on the interior of the reserve which would become jammed with small pebbles. As a result, those entering the gates from the outside were not able to open the first exterior door, and could not see what was needed to fix it, and would pull on the door until it came off its tracks. After several weekends of this, the interlock mechanism was temporarily disabled, but the door closing mechanism was tightened so that doors would shut firmly after each opening. While this does reduce the pest-proof nature of the gates to a small degree, project staff felt that it was better to avoid further damage and risk the occasional double-door opening than have the gates completely broken. Repairs that were done during the first six months of fence inspections included one weld break, and two small acts of vandalism on the gates (kicking the door panel to where it bent, and jumping on the mesh roof panel). How to conduct fence repairs is beyond the scope of this report, and will depend on the fence design selected, and consequently, is not discussed below.

Buffer pest control

A buffer zone (using traps and poisons) is recommended around the outside of the fence perimeter to reduce the likelihood of pests entering the pest-free zone through a breach in the fence. The width of this buffer zone will depend on the species of pests present, their abundance, and the plants and animals at risk inside the fence. Several species, including rats and perhaps feral cats, seem to establish the fence as a territory boundary and regularly patrol it, increasing their chances of finding a breach before it is repaired. Consequently, pests that are strongly territorial and those that travel substantial distances often need to be the most extensively controlled. When a fence breach occurs it is important that any pests that do enter the pest-free area are detected early. If a breach goes unnoticed for some time and there is no pest detection program in place, it may become necessary for the entire fenced area to be re-poisoned or trapped to attain pest free status again.

The best way to detect pest intrusions is to establish a network of bait stations, traps or tracking tunnels around the inside of the fence line and also either a grid of stations throughout the protected area or at least scattered stations in strategic locations. Such a grid of bait stations or traps will probably have been established previously to achieve complete pest eradication; retention of the station grid will certainly assist with the early detection of any re-invaders. In one New Zealand example, a small hole occurred in a pest proof fence as a result of careless use of some farm machinery. The hole went unnoticed for a week and in that time up to 10 mice may have entered the pest-free valley. Only the established bait station and tracking tunnel network enabled the mice to be located and dealt with. The biosecurity protocols at Ka`ena Point are detailed later in this report and include all of the methods described above.

BIOLOGICAL MONITORING

Introduction

Monitoring of biological resources before and after fence construction is crucial for measuring and demonstrating the benefits and effectiveness of predator fencing as a management technique compared with traditional fencing and predator control methods. However, the types and amount of information gathered can vary dramatically depending on the site, budget, and goals, and in some cases there may be insufficient baseline data available to make the desired comparisons. In such cases, the use of simultaneous treatment and control sites located inside and outside areas that have been fenced and from which predators have been excluded can be used to measure the effects of predator fences. In the case of Ka`ena Point, sufficient baseline data already existed for some taxa (seabirds), but was lacking for others (plants and invertebrates) to make these comparisons. Extensive monitoring of a variety of taxa therefore was undertaken prior to fence construction in order to document the effects of the predator proof fence.

To facilitate consistent, repeatable monitoring for a variety of species, staff from the NAR System installed a permanent, geo-referenced, 50-m interval grid oriented on magnetic north throughout the reserve (Figure 5.1), with points marked by rebar with a 10 cm reveal. The rationale for selecting a 50-m grid was to provide an adequate number of replicates within the fenced area (N=73) for ecological comparisons and to have appropriate spacing for rodent bait stations, since 50 m is the average home range size for black rats. Except for Laysan Albatross and intertidal invertebrates, all biological monitoring was done using these grid points.

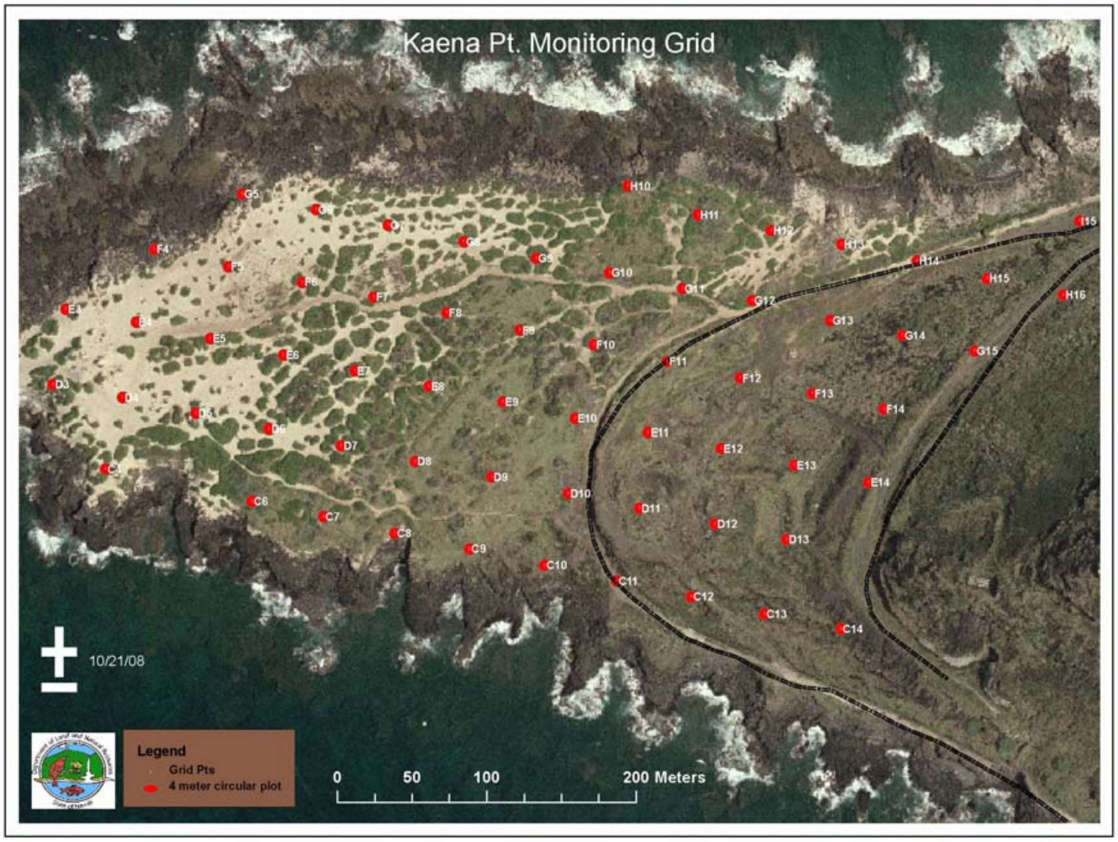


Figure 5.1- Schematic of the biological monitoring grid at Ka`ena Point

In seabird nesting areas such as Ka`ena Point, seabirds can act as the dominant species altering vegetation through physical disturbance and marine compound depositions from feces and carcasses, resulting in changes in species composition and habitat structure over time. It is thus important to monitor all aspects of the community to document these changes.

This section covers the protocols that were used to gather baseline data on each taxonomic group. The methods used for each group are presented below, but we anticipate that the before and after results for each group will be written up as stand-alone publications once sufficient 'after' data has been collected.

Seabird Monitoring

Introduced mammalian predators are one of the most serious threats to seabirds and other native bird species in Hawai`i and on many other islands (Côté and

Sutherland 1997, Scott et. al. 2001, USFWS 2006, Jones et. al. 2008). Rats, particularly black rats (*Rattus rattus*), are the primary nest predator on many island birds (Atkinson 1977, Atkinson 1985, Robertson et. al. 1994, VanderWerf and Smith 2002, VanderWerf 2009) and have caused or contributed to the extinctions or local extirpation of numerous island-nesting seabird species. Feral cats are also a serious problem for many bird species. Predation on nests by feral cats has been documented in Hawaiian seabirds, including the endangered Hawaiian Petrel (*Pterodroma sandwichensis*) (Simons and Hodges 1998, Hodges and Nagata 2001, USFWS 2005, Lohr et. al. in press).

The effectiveness of predator exclusion on bird populations can be measured by comparing population sizes, survival rates, and reproductive rates. This can be accomplished using temporal comparisons before and after fence construction, and/or simultaneous spatial comparison from inside and outside the fenced area. There is an extensive literature on bird population monitoring, and numerous techniques are available that are suitable for a variety of purposes and situations (Ralph and Scott 1980, Bibby et. al. 2000, Buckland 2006).

Bird populations may respond slowly to management and it may require several years for birds to begin using an area or for increased rates of recruitment to result in detectable population increases. It may be more feasible to detect changes in other population parameters, such as nesting success. For birds that have been extirpated, simply documenting nesting in the area following predator fencing would demonstrate success.

For the seabird species nesting at Ka`ena Point, the most suitable methods depended on their abundance and how easy they were to detect. For Laysan Albatross (*Phoebastria immutabilis*), which occur in low density but are large and easily visible, a census of nesting birds and regular nest monitoring was conducted. For Wedge-tailed Shearwaters (*Puffinus pacificus*), which occur in high densities and nest in underground burrows, census of nesting burrows was conducted at first, but the monitoring method was switched to a plot-based design.

Laysan Albatross

Laysan Albatross began nesting at Ka`ena Point in 1992 after off-road vehicles were excluded. All chicks hatched at Ka`ena Point were censused and banded with a unique, federal metal band each year by DLNR staff beginning in 1992when nesting first started . Regular monitoring of adults and chicks began in 2004 for the duration of the breeding season (Nov-Jul. Monitoring consisted of a weekly census of all birds present. Each time an adult was encountered, its location, status (incubating, brooding, or walking), and association with any other adult or chick was noted. Chicks were monitored from hatching (Feb) until fledging (July). Nest number, parent information, hatching date, disease status, and date of either fledging or death were recorded for all chicks. Starting in 2006, each bird was also given a field-readable purple plastic band numbered in white from O001-O999. Chicks that survived to fledging were banded with both a federal metal band and a field-readable plastic band.

Extensive information about the monitoring methods and results, including reproductive success, population size, and survival rates in this colony can be found in Young and VanderWerf (2008), Young et. al. (2009a,b) and VanderWerf and Young (2011). In summary, a population of approximately 365 adults are present on the colony with a maximum of 61 nests initiated in the 2012 breeding season.

Wedge-tailed Shearwaters

Wedge-tailed Shearwaters began nesting in the reserve in 1994, shortly after off-road vehicles were excluded, and a complete census during October or November of active nesting burrows has been conducted almost every year until 2008. Counts consisted of searching visually for burrows and determining whether they were occupied (presence of a chick confirmed visually or by touch), or unoccupied but active (unhatched egg, fresh droppings, feathers, tracks, or digging). Due to the increasingly large numbers of burrows and the impact a census was having on the habitat, a plot-based monitoring technique using the 50-m grid points was begun in 2008 in conjunction with a determination of what size of plot produced the most accurate results. Each point in the 50-m grid served as the center of a circular plot, and the number of burrows was counted within 4, 5, 6 and 8m radii. Plots with a radius of 8m produced results most similar to the census data likely since they represent a large total proportion of the area surveyed. From 2009 onwards, the plot design was used exclusively to monitor Wedge-tailed Shearwater reproduction.

Other Seabirds

Bulwer's Petrels nest on several islets off O`ahu but are currently not known to nest at Ka`ena Point. This species was searched for at Ka`ena by imitating its barking call at night in rocky areas preferred by this species for nesting and waiting for a response. Other nocturnal Procellariformes were monitored by listening during the dusk hours at the appropriate times of year to detect their presence. Prior to fence construction, no other seabirds were detected nesting aside from those described above.

Red-tailed Tropicbirds nest at one other location on Oahu and also on Manana Island off the eastern coast of Oahu (VanderWerf and Young, 2007). Up to seven adult Red-tailed Tropicbirds have been observed simultaneously courting at Ka`ena Point, but no nests have been observed. Individuals of this species may colonize Ka`ena Point naturally because there are colonists close by.

Invertebrate Monitoring

Invertebrates are a relatively inconspicuous but extremely important components of native ecosystems. Native invertebrate communities provide integral ecological services, including pollination and nutrient cycling, without which most Hawaiian plant species could not exist (Howarth and Mull 1992; Mitchell et. al. 2005). Changes in abundance, diversity, and species composition of the invertebrate fauna at a site may help to indicate improved ecosystem functioning. Extensive coastal strand habitat is exceedingly rare in Hawaii. Several rare invertebrate species can still be found at Ka`ena Point. A noteworthy example is a native yellow-faced bee, *Hylaeus longiceps*, which is currently being considered for federal protection (Magnacca 2007).

Because they are generally more numerous and have shorter generation times, invertebrates may show population responses to management more quickly than vertebrates. In New Zealand, abundance of beetles inside the Maungatautari predator exclosure increased 8% per month immediately after alien mammals were removed and 50 species of beetles were collected that were previously unknown at the site (Watts 2007).

There are approximately three vegetation habitat types at Ka`ena Point- coastal strand, naio shrubland, and invasive grasses. Invertebrate monitoring was done at three grid points in each habitat type at Ka`ena Point. Exact points were chosen using a random number generator to produce three selections in each habitat type in Microsoft Excel. Points D6, D7 and E7 (see Figure 5.1) were located in coastal strand sites; C7, D9 and G12 in naio shrubland, and D11, D13 and E12 were in invasive grassland. Vegetation beating, sweep netting and litter sampling were completed once at each point. In addition, one pitfall trap, one yellow pan trap and one yellow sticky card were laid out at each point (nine total) for three days.

Invertebrate specimens will be identified to species where possible. Invertebrate abundance will be measured as a total number of individuals and/or biomass captured per trapping interval / collection effort. Abundance of invertebrates in different feeding guilds (herbivores, detritivores, nectarivores, predators, parasitoids, etc.) will be examined to look for shifts in ecosystem functioning before and after predator removal. This baseline of species diversity and abundance will help determine whether predator exclusion affects invertebrate diversity, and if native species in particular will increase in abundance.

Pit-fall Traps

For ground-dwelling species, pit fall traps are an effective passive sampling method (Spence and Niemela 1994). To install pit fall traps, a shallow hole is dug in the ground and a small cup or bowl filled with a killing agent or preservative is placed inside. The lip of the container is positioned to be even with the surrounding ground, and, as a result, crawling invertebrates inadvertently fall into the container and cannot escape. Ka`ena Point pit fall traps were baited with propylene glycol (anti-freeze), and deployed for three days. Following trap collection, specimens were transferred into 70% ethanol for storage.

Yellow Pan Traps

Many insects are attracted to the color yellow, a trait which is often used to facilitate their collection (Neuenschwander, 1982). A yellow pan trap is a quick and easy way to catch specific types of invertebrates. A shallow yellow pan or bowl is either placed on the ground or into a small hole in this case so that its rim is level with the ground. The bowl is then filled with water, and several drops of detergent are added to break the surface tension. Insects that are attracted to yellow (ex. flies, wasps, and beetles) will fall in and drown. The traps will also collect invertebrates not attracted to yellow, intercepting them in the same manner as the pit-fall traps. Following collection of the pan traps, specimens were transferred to 70% ethanol for storage.

Yellow Sticky Cards

Sticky cards traps are used to collect the adult stages of flying insects (e.g., flies, gnats, shoreflies, leaf miners, winged aphids). A single Trece Incorporated Pherocon AM trap (without lure) was placed at each of the sampling points and left for three days. Sticky cards consist of 8.5” x 11” yellow card-stock, folded in two, coated with a thin veneer of a sticky paste. At each point, a trap was hung from vegetation, 0-2m from the ground, where it was visible to flying insects. Sticky cards were collected, wrapped in plastic wrap, and placed in a freezer for long-term storage.

Vegetation Beating and Sweep Netting

Vegetation beating and sweep netting are some of the most effective approaches for collecting a broad assortment of invertebrates from vegetation. To survey woody shrubs or trees, a tarp or “beat sheet” is laid under the vegetation targeted for sampling. The vegetation is then shaken by hand, or “beaten” with a sweep net handle, to dislodge invertebrates present on the foliage. Specimens were then collected by hand or with an aspirator. Since herbaceous vegetation, grasses and some shrubs do not ordinarily lend themselves to beating, they are better sampled through the use of sweep nets. Canvas insect nets were swung across vegetation, knocking off and capturing invertebrates present on the foliage. Those specimens were also collected by hand or with an aspirator. Fifteen beats and fifteen sweeps were completed at each sampling point at Ka`ena Point

Ant monitoring

Due to particular concern over the potential impacts ants may have on the ecosystem after the removal of rats, an ant monitoring protocol was established. Four replicates per habitat type (12 points total) were set up inside the reserve and 12 outside the reserve for control and experimental purposes. Ant bait (spam, peanut butter, and honey) was placed on an index card for up to two hours and then the card removed to inventory the ants. In addition, a transect design was used that bisects the preserve so that all habitat types would be surveyed, and a comparable transect was selected outside the reserve. Eleven index cards baited with peanut butter, honey, and spam were placed at 50-m intervals along the "E" transect (see Figure 5.1). Sampling was conducted twice, once each in the spring and summer.

Vegetation monitoring

The effects on native plants from browsing, trampling, gnawing and seed destruction by predators is ubiquitous and can be very serious in many areas of Hawai`i (Scowcroft and Giffin, 1983; Tomich 1986, Hess et. al. 1999). Monitoring of plant populations is important to gauge the effectiveness of predator fencing and eradication at many sites. Plant monitoring should not be limited to endangered species; changes to more common plant species that form the bulk of native habitats should also be monitored.

At Ka`ena Point, an overall inventory was done as well as a transect design that monitored percent cover, species assemblages and soil types over time to document potential changes at each grid point as a result of predator removal and associated ecosystem shifts. Each vegetation plot consisted of a 16m baseline transect, oriented from E-W, and centered on a grid point; along each baseline transect, five 16m transects oriented N-S were established at 4-m intervals producing a 16 x 16 m grid centered on the 16-m-diameter circles of the shearwater plots.

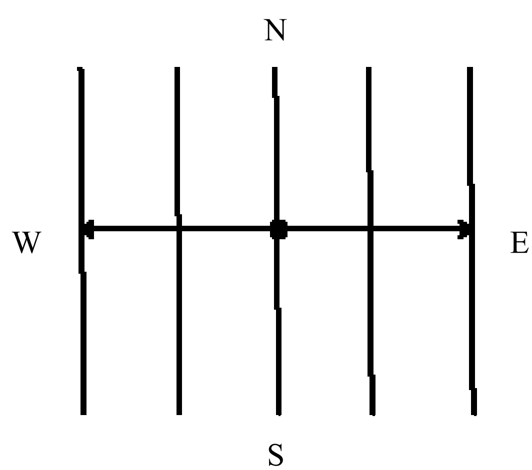


Figure 5.4- example of transect design

At every meter along the 5 N-S transects, all species intercepted by a vertical rod were counted using the point-intercept method (Mueller-Dombois and Ellenberg 1974), and the data were converted to absolute percent cover (which cannot exceed 100% for any single species, but may do so for all species combined). Substrate type (rock, sand, volcanic soil) was also recorded at all 85 point-intercept points. Data were collected at 52 of the 73 grid points; points outside the fence line, in unvegetated parts of the intertidal zone, directly on main trails, and on graded gravel slopes were omitted.

Observational data

Monitoring of plants for survival, amount of gnawing, browsing, seed predation, and other damage caused by predators is one important method of monitoring for the presence of predators, particularly at sites where baseline data on status of endangered plants is available for comparison. Natural recruitment of wild plants should also be observed and measured. At Ka`ena Point, observational data was collected on Ohai (*Sesbania tomentosa),* and coastal sandalwood (*Santalum ellipticum*), both of which are frequently targeted by rats for their fruits, and are good indicators of rodent presence.

Soil Sampling

In seabird nesting areas, seabird can act as the keystone species by altering vegetation through physical disturbance and marine compound depositions in the soil from their guano. Due to these disturbances and nutrient inputs, plant and invertebrate communities can change over time which alters habitat structure and as a result, it is important to monitor all aspects of the community to document these changes. To ensure that any changes that were associated with marine compound deposition in the soil could be quantified, soil sampling was conducted.

A push corer was used to extract ~250ml of soil samples at each grid point from the surface up to a depth of 15 cm. Samples will be sent to Agricultural Diagnostic Services at UH and have total N, P, C, pH, and salinity measured. The sampling will be repeated at least two years after predator removal to document changes in soil composition that are potentially associated with changes in seabird densities.

PREDATOR CONTROL AND BIOSECURITY OPERATIONAL PLAN

Introduction

All mammals in the Hawaiian Islands except the Hawaiian monk seal (*Monachus schauinslandi*) and the Hawaiian hoary bat (*Lasiurus cinereus semotus*) were introduced to Hawai`i by people, some intentionally for food, pets, or biocontrol agents, and others as accidental stowaways (Tomich 1986). Because Hawai`i is so isolated from continental areas, the native plants and animals that evolved in the islands are naïve to mammalian predators and often lack defenses against them (Salo et. al. 2007, Sih et. al. 2009). Polynesians colonized the Hawaiian Islands about 800 years ago (Rieth et. al. 2011) and brought with them several destructive predators including the Pacific rat (*Rattus exulans*), domestic dog (*Canis familiaris*), and domestic pig (*Sus scrofa*) (Kirch 1982, Burney et. al. 2001). Introduction of alien predators accelerated with the arrival of Europeans starting in 1778, including the black or ship rat (*R. rattus*), Norway rat (*R. norvegicus*), domestic cat (*Felis silvestris*), small Indian mongoose (*Herpestes auropunctatus*), house mouse (*Mus musculus*), and European wild boar.

Predators, particularly black rats, are the single greatest threat to seabirds worldwide (Jones et. al. 2008). Feral cats and small Indian mongooses are known to be serious predators of seabirds on Oahu and elsewhere in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002). Rodents, including black rats and Pacific rats, are known to prey on seabirds in Hawai`i (Fleet 1972, Woodward 1972, Smith et. al. 2006). Rats and house mice (*Mus musculus*) have been documented to consume native plants, their seeds, and invertebrates (Shiels 2010). There are many examples in which eradication or control of predators has resulted in recovery of native species in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002, VanderWerf and Smith 2002, VanderWerf 2009) and around the world (Côté and Sutherland 1997, Butchart et. al. 2006, Howald et. al. 2007).

Five non-native predatory mammal species are present at Ka`ena Point: feral dogs, feral cats, small Indian mongooses, black rats, and house mice. Feral dogs have been observed in the reserve only sporadically, and very few, if any, dogs are present in the reserve at any given time. Dog attacks on seabirds can occur either when feral dogs wander into the reserve or when people illegally bring pet dogs into the reserve. Feral cats are present at Ka`ena Point year round and have caused substantial damage to seabird populations in the past. Dietary analysis of feral cats caught at Ka`ena Point indicates that both seabirds and rodents are significant components of their diet (Lohr et. al. in review).

Rats and mice are thought to be important ecosystem modifiers at Ka`ena Point due to their consumption of prey at all levels of the food chain, from plants through birds. Rodents therefore were the primary target of the predator removal plan. Experience from other eradication attempts suggested that while mice do not pose the greatest risk for ecological restoration, they can be the most difficult species to eradicate for a number of reasons. Mice can:

- occupy very small home ranges (<100 m^2)
- be difficult to detect at low densities
- reinvade through small gaps in the fence, or at the fence ends
- reproduce very quickly
- occur at high densities in the absence of rats or other predators

Their response to diphacinone bait has not been thoroughly tested. Due to the uncertainty surrounding the efficacy of diphacinone in eradicating mice (Parkes et. al. 2011), the trapping grid was designed to maximize the potential for success.

Objectives

The objectives of designing the predator removal program were to select the most effective method(s) available while consideringthe pest species present, the tools legally available for use, and the timeline and funding available

It is possible that the methods chosen do not reflect the most universally effective methods employed in other countries or states, but were the ones that were most feasible given the scope and constraints on this project. Trapping data from 2000-2010 collected by the U.S. Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services (Wildlife Services) were analyzed for larger mammals, and a rodent study was conducted to provide information on rodent abundance and home range size in order to effectively plan for multispecies predator removal and long term control.

Pre-eradication Pest Control and Monitoring Methods

Predator Control 2000-2010

Predator control was initiated by the DLNR starting in 1992 using 10-20 cage traps for feral cats and mongooses and several bait stations for rodents that were placed within the core seabird nesting areas (~7ha). In 2000, DLNR contracted Wildlife Services to continue and expand the predator control. Wildlife Services visited Ka`ena Point an average of three days per week to conduct control activities. Methods included the use of 9 x 9 x 26“ single-door Tomahawk cage traps, Bridger or Victor #1.5 padded or offset leg-hold traps (starting in 2008), and night shooting. Up to 32 cage traps and 10 leg-hold traps were used each year (Table 6.1). Traps were placed strategically throughout the entire reserve so as best to intercept predators (Figure 6.1).

Table 6.1: Summary of cat and mongoose trapping effort at Ka`ena Point from 2000-2010.

Year	# cage traps	# cage trap-nights	# leg-hold traps	# leg-hold trap-nights
2000	unknown	unknown	0	0
2001	unknown	unknown	0	0
2002	unknown	unknown	0	0
2003	unknown	unknown	0	0
2004	31	2697	0	0
2005	31	10429	0	0
2006	32	10528	0	0
2007	32	10397	0	0

2008	30	9093	3	62
2009	27	7773	6	136
2010	25	8139	10	361

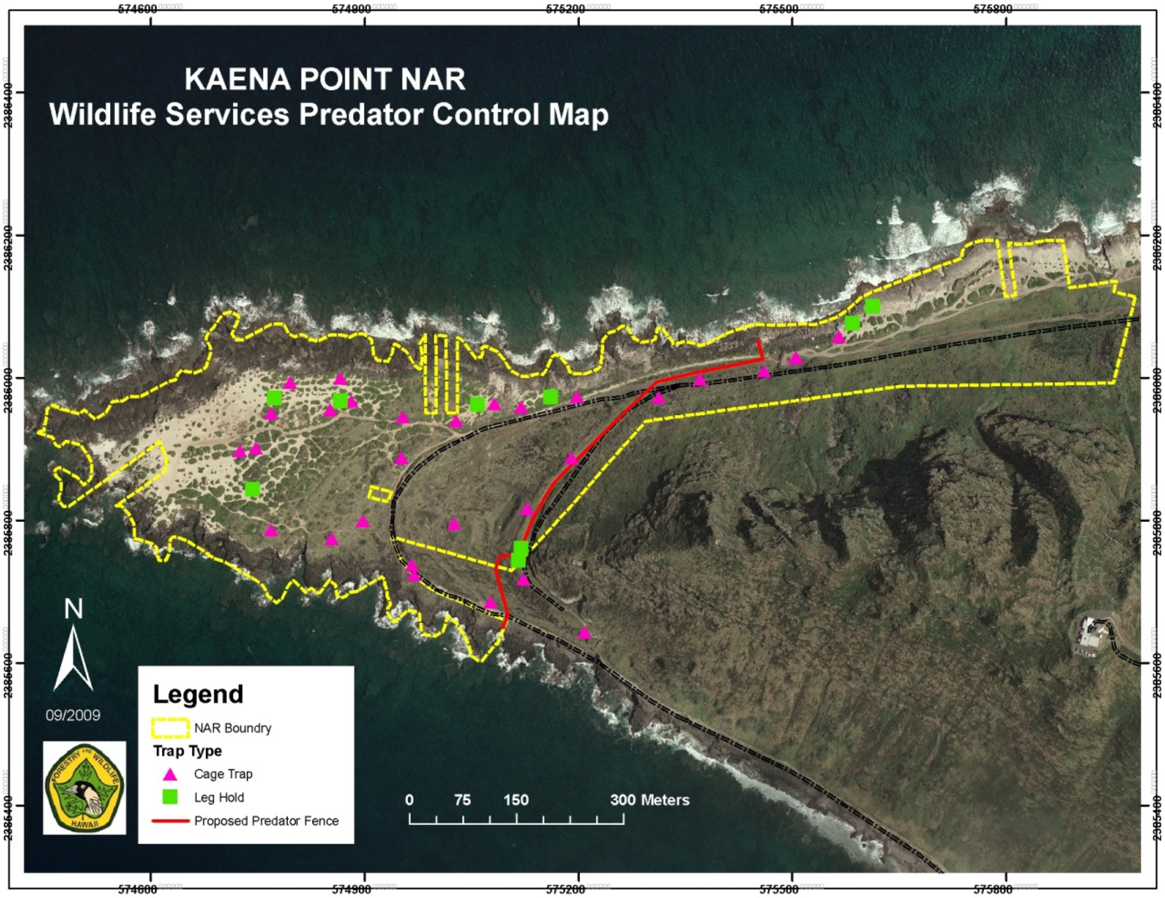


Figure 6.1: Trap placement by Wildlife Services in Ka`ena Point Natural Area Reserve in 2009.

Rodent Monitoring 2008-2009

In the fall of 2007, a permanent, 50-m geo-referenced grid oriented on magnetic cardinal compass bearings was installed in Ka`ena Point NAR to facilitate monitoring and other management activities. A combination of live and snap traps were used in April, July, and November 2008 and February 2009 to investigate rodent species composition, abundance, habitat use, and seasonal variation in rodent populations. These months were chosen because they are representative of the climatic seasons in Hawai`i. Rodent traps were placed along transects running east to west that encompassed all three habitat types discussed earlier in similar proportions.

Victor® rat snap traps were placed at 50-m intervals and baited with fresh coconut chunks along transects D and G (N=23 traps) and 4 traps spaced approximately 20m apart were placed along the shoreline at each of the proposed fence ends (N=8 traps). Victor® mouse traps were placed at 10-m intervals along a 400-m section of transect E (N=40 traps) and also were baited with fresh coconut chunks. All rodent traps were pre-baited while unset for three nights and either covered with 1" chicken-wire mesh or tied onto low lying vegetation to prevent seabird interference while allowing rodents access. Traps were then set for three nights and checked daily for catch. Trap status and rodent species caught were noted and all specimens were frozen for future analyses.

Rodent Home Range Size Estimation

Live traps were deployed during the July and November monitoring events to capture live rodents for tracking purposes To estimate rodent home-range size. Haguruma® live cage traps were used for rats and Eaton® repeater mouse traps were used for mice. Both trap types were baited with a combination of fresh coconut and peanut butter.

All rodents captured were sexed, weighed, and identified to species. A small spool of white thread was glued to the back of each rodent captured. Spools used with rats weighed less than 2g and held up to 200m of thread; much smaller spools were used for mice. The end of the thread was tied to a piece of vegetation and the rodents were released. Two or three days later, GPS tracks of the path of the rodents were taken by following the thread. Maximum distance travelled was measured for each animal, and substrate and habitat type also were noted.

Pre-eradication Pest Control and Monitoring Results and Discussion

Large Mammal Control 2000-2010

A total of 150 feral cats, 493 mongoose, and nine feral dogs were removed from Ka`ena Point NAR from January 2000 through December 2010 (Table 6.2), for an average annual removal rate of 13.6 feral cats, 44.8 mongooses, and 0.82 feral dogs.

Table 6.2. Numbers of feral cats, mongoose, and feral dogs removed by different methods at Ka`ena Point Natural Area Reserve from 2000-2010.

	Cats				Mongoose				Dogs
Year	cage trap	Leg-hold	firearm	Total	cage trap	Leg-hold	firearm	Total	firearm
2000	6	0	14	20	15	0	0	15	0
2001	10	0	1	11	11	0	0	11	2
2002	16	0	4	20	37	0	0	37	0
2003	14	0	12	26	34	0	0	34	0
2004	6	0	5	11	67	0	0	67	0
2005	4	0	3	7	80	0	0	80	2
2006	7	0	3	10	58	0	3	61	4
2007	3	0	3	6	51	0	0	51	0
2008	2	6	1	9	65	1	3	69	0
2009	5	9	0	14	55	2	0	57	1
2010	1	14	1	16	7	4	0	11	0
Total	74	29	47	150	480	7	6	493	9

Capture rate of feral cats in live traps declined over time, possibly because cats reaching Ka`ena Point had been trapped and released elsewhere previously and had become “trap shy”. Beginning in 2008, padded (Victor) and offset (Bridger) leg hold traps were employed in addition to live traps and catch rates rose dramatically (Figure 6.2).

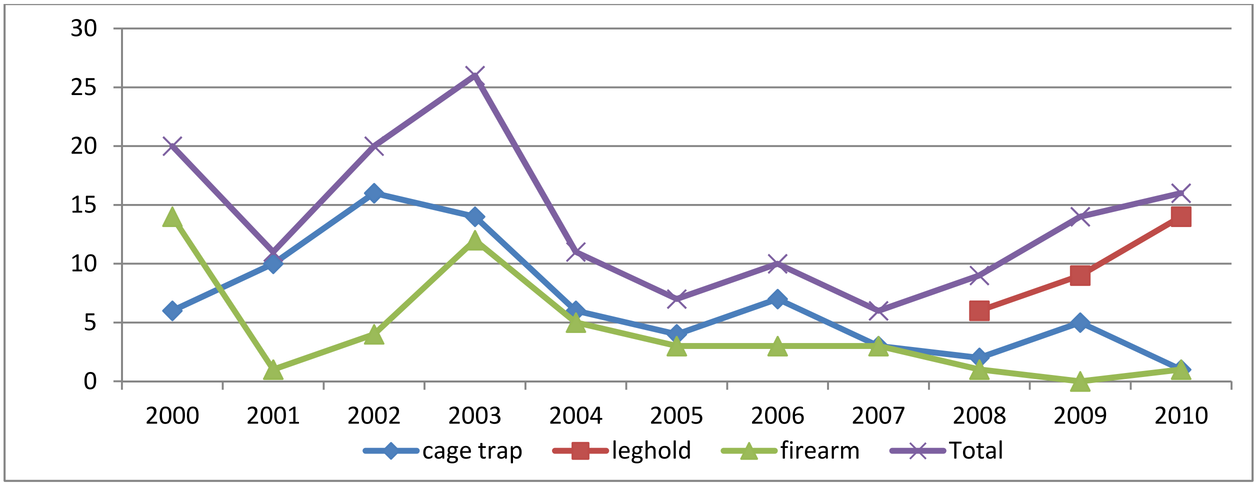


Figure 6.2: Number of cats removed by different methods at Ka`ena Point from 2000-2010.

The capture rate of feral cats was substantially higher in leg-hold traps than in cage traps (Table 6.3), with leg-hold traps being an average of 327 times more efficient than cage traps. Although the total number of cats captured each year from 2008-2010 was not as high as in some previous years (Table 6.2), these captures were achieved with many fewer traps and trap-nights (Table 6.1). For mongoose, cage traps appeared to be somewhat more effective, though leg-hold traps were deliberately placed to target feral cats, such as along cat tracks. These results indicate that cage trapping is not an effective control method for cats at this site, and that it is more expensive due to the greater trapping effort required. Padded leg-hold traps clearly are the preferred method for cat removal at Ka`ena Point.

Table 6.3: Comparison of trapping rate of feral cats and mongooses using cage traps and leg-hold traps at Ka`ena Point Natural Area Reserve.

	Cats			Mongoose
Year	#/cage trap-night	#/leg-hold trap-night	Leg-hold vs. cage traps	#/cage trap-night
2004	0.0022			0.0248
2005	0.0004			0.0077

2006	0.0007			0.0055
2007	0.0003			0.0049
2008	0.0002	0.0968	484x	0.0071
2009	0.0006	0.0662	110x	0.0071
2010	0.0001	0.0388	388x	0.0009

Seasonal Rodent Abundance and Habitat Use

Black rats and house mice were the only rodent species caught at Ka`ena Point. No Pacific rats or Norway rats were caught. Mouse catch rates were approximately two to eight times higher than rat catch rates (Figure 6.3). The pattern of seasonal abundance was similar for both species, with peaks in spring and lows in late fall, suggesting a spring reproductive peak (Figure 6.3), which agrees with other studies conducted in Hawai`i (Parkes 2009). Assuming the area sampled for mice was 0.4 ha (40 traps at 10-m intervals, yielding a strip 10-m wide and 400-m long), the density of mice ranged seasonally from 48-78/ha. Similarly, if the area sampled for rats was 6.75 ha (27 traps at 50-m intervals), the density of rats ranged from 0.6-2.1/ha depending on the season. The finding that mice are so much more abundant than rats is unusual and suggests that mice are not controlled by rats at this site, which is contradictory to several previous studies (Billing 2000, Billing & Harden 2000, Witmer et. al. 2007). Moreover, the density of mice per hectare is comparable to sites in New Zealand where rats have been eliminated but mice are still present and have experienced a competitive release. Mice were often observed in the reserve during daylight hours. To our knowledge this was one of the highest reported densities of mice co-existing with black rats in a natural setting and presented important implications for choosing a removal strategy.

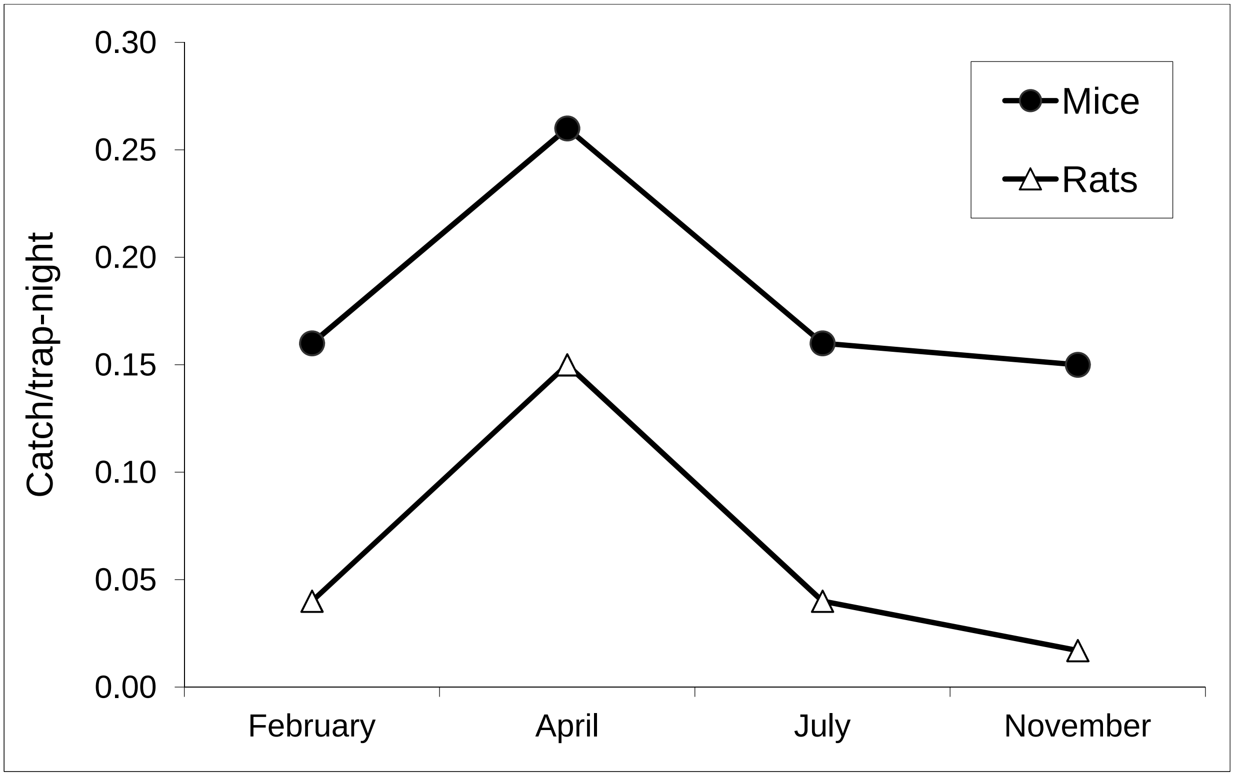


Figure 6.3: Catch rates of rodents at Ka`ena Point by season

Rodent Habitat Use and Spatial Distribution

The spatial distribution and habitat use of rodents in the reserve differed somewhat among seasons. During the peak in density in April, mice were captured in all habitat types and were widespread throughout the reserve, and rats also were found in all habitat types. When rodent densities were lower (July-February), mouse captures were more scattered, and most rats were captured near the shoreline in traps placed in the intertidal area at either end of the proposed fenceline, where marine intertidal invertebrates provide a rich source of food.

Rodent Home Range Size

A total of two rats and four mice were captured for tracking. One of the rats and one of the mice expired while in hand, so only one rat and three mice were tracked. The movements of the rat were traced using the thread after two days, during which time it was active in an area dominated by grassy vegetation and bare rocky substrate near where it was caught. The thread apparently broke during this time because neither the rat nor the spool was recovered. The size of the area covered by the rat during this time, as indicated by the path of the thread, was 45 m by 25 m, and most of the movement was centered around a cavity in the rocks that held approximately 40 L water which presumably acted as one of the few water sources in the reserve.

The three mouse tracks were followed after three days. The spool from each mouse was recovered, suggesting all three mice had groomed the spool off. Similar to the rat, the habitat used by all three mice was low grassy vegetation with a rocky substrate that provided numerous underground crevices. Maximum distance travelled from the point of capture was approximately 12m for all three mice. Because the error associated with GPS readings was large relative to the distances moved by mice, distances were directly measured in the field with a measuring tape. The home range size estimates presented here are minimum values and were based on just a few days of movements for each animal.

Monitoring conclusions

Feral cats, small Indian mongoose, black rats, and house mice were constantly present at Ka`ena Point NAR despite ongoing predator control. Mice were present at high density, while black rats were less abundant. Dogs were present only sporadically and in low numbers.

Based on our data, the most effective methods of predator removal were determined to be: 1) a combination of shooting and leg hold trapping for cats, 2) cage trapping and diphacinone poison in bait stations for mongoose, 3) shooting for feral dogs, 4) diphacinone poison in bait stations on a 25 m grid for black rats, and 5) a combination of the 25-m diphacinone bait station grid and mouse traps on a 12.5-m grid for mice. Even if the mouse home range size was larger than measured, because of the high density of mice in the reserve, it was determined that an interval of 12.5 m between mouse traps (half the distance between bait stations) might be needed to ensure that all mice were exposed to traps and/or bait stations and increase the chances of successful mouse eradication. A larger distance between mouse traps might have been sufficient, but a conservative approach was judged to be prudent. Similarly, bait stations targeting rats were spaced 25-m apart to ensure that all black rats were exposed to bait, and to allow for the possibility that Polynesian rats (which have smaller territory sizes than black rats (Shiels 2010) may be present in the reserve in low densities and were simply not detected during the trapping events.

Since the larger mammals are thought to breed year round, it was decided that control operations should begin immediately after fence construction to avoid any further predation on seabirds. Rodent removal operations were conducted in the winter prior to the commencement of the rodent breeding season in hopes of reducing the effort required to remove all animals.

Diphacinone has been used to control rodents in Hawaiian coastal habitats (F. Duvall pers. comm.) and was used to successfully eradicate Pacific rats on Mokapu Islet off of Molokai (Dunlevy & Scarf 2007). Diphacinone also has been used to eradicate black rats in a variety of locations worldwide (see Donlan et. al. 2003, Witmer et. al. 2007 for examples), though it appears to be less effective than brodificoum, particularly for mice (Parkes et. al. 2011). However, diphacinone is the only poison approved for conservation purposes in Hawai`i.

Predator Removal Operational Plan

Large Mammal Removal

Large mammals (feral dogs, feral cats, and mongooses) were continuously targeted during and immediately following fence construction to prevent losses of Laysan albatross chicks and Wedge-tailed shearwater adults. Feral dogs have been observed in the reserve only sporadically, and the activity associated with fence construction appeared to have scared them off.

Feral cats and mongooses were removed with a combination of cage-traps (9x9x26-inch single door Tomahawk traps) baited with commercial pet food, and leg hold traps (Victor #1.5 padded or Bridger offset leg hold traps). Cage traps were placed throughout the reserve, but leg-hold traps were placed strategically in locations most likely to intercept predators, particularly cats. Cat removal was supplemented with opportunistic night shooting. To help inform cat removal and improve trap placement, four remote cameras with infra-red motion-activated triggers (Scoutguard SG550) were used to identify individual cats and determine areas of high predator activity.

Rodent Removal

In order to generate baseline data on relative rodent abundance prior to removal, tracking tunnels were placed on every 50-m grid point (N=73), and 200m-long transects with mouse live-traps at 10-m intervals were placed both inside and outside the reserve, and both were run prior to commencement of baiting. Tracking tunnels also were run approximately monthly throughout the removal operation to provide an additional method of measuring rodent abundance.

Rodents were targeted with Ramik mini-bars® (HACCO Inc., Randolph, Wisconsin, USA) containing 0.005% diphacinone placed in tamper-resistant Protecta® plastic bait stations (Bell Laboratories, Madison, Wisconsin, USA) to shield them from rain and reduce the risk of poisoning to non-target species. Entrances to the stations were large enough to allow access by mongooses.

Bait stations were placed in a 25-m grid pattern throughout the reserve (Figure 6.4) and filled with up to 11 1-oz blocks per station. The maximum allowable amount of bait as specified under the product label is 16 oz/station, but we decided to place no more than 11 blocks in each station because that was the maximum number that could be accommodated on the spindles provided with the stations to prevent bait from being shaken out of the station. Bait stations were generally not placed below the vegetation line on the coast to reduce the possibility of them being washed away by high surf. With 25-m spacing, there were 291 stations in the reserve. The 50-m grid points previously installed to facilitate monitoring and management were used as starting points, and additional points were located at 25-m intervals using a laser range finder. Bait stations were serviced twice per week during the first month, and after that frequency was adjusted based on levels of take to ensure that an adequate supply of bait was available at all times. Frequency of maintenance was once per week during the second month, once every two weeks for the next three months, and once a month thereafter.

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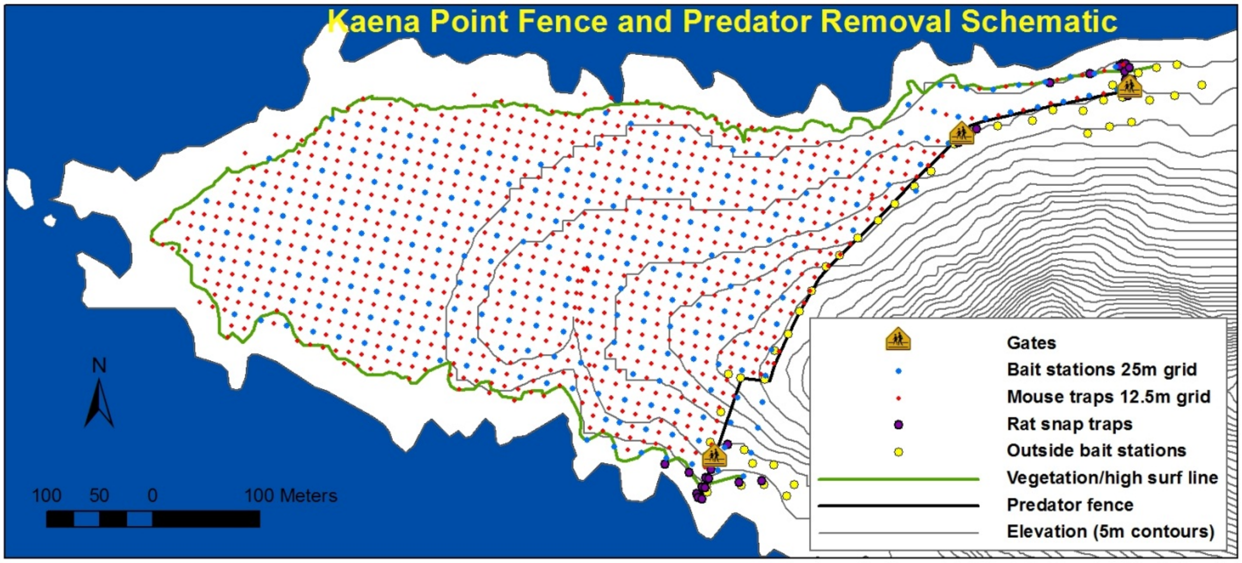

Figure 6.4. Locations of bait stations and traps used in predator removal and in detection and prevention of incursions.

Two weeks after baiting started, multiple-catch Catchmaster™ mouse live-traps baited with peanut butter were placed every 12.5m within the fence using a laser rangefinder. This resulted in lines containing only mouse traps alternating with lines that contained mouse traps and bait stations in an alternating pattern (Figure 6.4). On transects that already contained bait stations, mouse traps were alternated with bait stations, so that mouse traps were 25 m apart, but with a method of control every 12.5m since they alternated with bait stations. Live rodents were humanely euthanized using cervical dislocation. Traps were checked with the same frequency as bait stations; twice weekly during the first month and less often thereafter as needed.

At the time of writing, predator removal operations were still ongoing; final results will be published in a separate document once operations are complete.

Biosecurity

Incursion Prevention and Monitoring

Monitoring for incursions, or re-invasions that occur after fence completion, is vital to the success and sustainability of the Ka`ena Point Ecosystem Restoration Project. Preventing incursions from occurring is more cost-effective than dealing with them afterwards., Incursions should be prevented to the maximum extent practicable using all reasonable measures. However, due to the open ends of the fence at the shoreline, occasional incursions are to be expected, and having protocols in place to detect and deal with them is essential.

The first step of the biosecurity plan was the establishment of a regular fence inspection and maintenance schedule to ensure that the fence remains pest proof. This includes weekly checks for breaches and holes in the fence, and sweeping rocks, sand, and other debris from inside the gates, particularly the tracks of the sliding doors, to ensure the gates open and close properly. Section four of this document, construction and maintenance, provides more details on fence maintenance.

Secondly, to keep pest pressure off the fence, predators were controlled along the entire length of the exterior of the fence and on the interior and exterior of the fence end at each shoreline (Figure 6.4). This is accomplished using a combination of bait stations and snap traps that are checked and maintained weekly. Bait boxes containing diphacinone were placed 25m apart and up to 50m out from the fence line (i.e. two rows of parallel bait stations). On the fence ends, the bait stations were expanded in a fan-shaped pattern extending 125m from the fence ends (4-5 bait stations deep). To help prevent rats from approaching the fence ends and possibly gaining access to the reserve, rat traps were placed at 10-15 m intervals along the outside of the fence end (Figure 6.4). In case rats or mice did make it around the fence end, rat traps and mouse traps were placed at 10-15 m intervals along the inside of the fence end and along the shoreline inside the fence up to 75 m from the terminus. This system of traps inside and outside the fence formed a “gauntlet” through which predators would have to pass to reach the interior of the reserve. Rodents are likely to use the fence and the shoreline as movement corridors, so targeting these areas increased the chance of interception.

The gauntlet of rat and mouse traps provided one method of detecting incursions. another means of detecting incursions, a system of tracking tunnels throughout the reserve in a 50-m grid, which also was used to monitor the progress of predator removal, was run monthly to monitor the presence of rodents. In addition, the tracking tunnels located within the gauntlet of traps at the fence ends were checked weekly at the same time the traps were checked. It is hoped that most incursions will be contained within the gauntlets immediately inside the fence ends. If incursions are detected in the interior of the reserve (more than 100m from the ends), this will trigger an increased incursion response using additional traps and bait stations, described in the next section of this chapter.

Larger predators, including feral cats, dogs, and mongooses, can be readily tracked in the sandy soil present over much of the reserve. Searching for tracks and droppings is the primary method of detecting incursions by larger animals.

Eleven months post construction, bait stations were still deployed on a 25m grid in the interior of the reserve, and expectations are that some of these bait stations will be removed, but that a permanent 50m grid will remain in place for biosecurity purposes. In addition to extensive rodent control, regular large predator (cat and dog) control operations will continue as described above. These consist of spotlight surveys/shooting as well as targeted trapping in the surrounding areas outside the fence. To date the spotlight shooting has proven to be successful in removing cats from areas adjacent to the fence, reducing the possibility of animals moving around the fence ends into the protected area.

Incursion Response

Responding rapidly to any incursions that occur to contain them and remove all animals that have reinvaded is vital to the continuing success of the ecosystem restoration plan. Response protocols were designed to ensure that incursions are dealt with in an efficient and coordinated manner. The frequency of reinvasion will likely be related to the density and home range size of the animal in question, and each species will require a slightly different response. Response plans were therefore designed for each species and are described separately.

Dogs can be expected to occur occasionally in the reserve after the fence is complete because people may ignore the signs and bring pet dogs with them through the gates. Dog tracks are easily visible on the sandy soil, so it may be possible to determine whether any dog tracks observed are from pets that were brought through the gates by people, or feral dogs that went around the fence along the shoreline. In the event that dog tracks are detected away from the established trails and/or dog predation on seabirds is observed, USDA WS or DOFAW will be contacted immediately and shooting and/or leg-hold trapping will be scheduled until the dog is removed or there is no fresh dog sign.

The sandy soil that covers much of Ka`ena Point is also useful for detecting incursions of feral cats and mongoose, both of which have distinctive tracks. Any track lines observed will be followed to help delimit the area being used by the animal, and its entry point into the reserve if possible. In the event that a cat or mongoose enters the reserve and does not appear to leave, cage trapping and leg hold trapping will commence in areas of known activity until the animal is caught, or until it has been determined that it has left the reserve. Remote cameras with motion-sensitive triggers will be deployed continuously in the reserve to help detect incursions of all species, and to aid in trap placement and monitoring of animal movement during that period.

If rats or mice are detected more than 100m from the fence ends (i.e., beyond the regular “gauntlet” of biosecurity traps), traps will be placed every 25 m (rats) or 12.5 m (mice) for 100 m (rats) or 50 m (mice) around the site(s) of detection, and bait stations within 100 m of the detection will be stocked with diphacinone until the animal is caught or it is clear that bait is no longer being taken by rodents. Tracking tunnels will be run regularly to verify presence/absence. If rodent incursions recur frequently after fence construction, the possibility of attempting a hand broadcast each year could be considered if the necessary efficacy trials and label amendment for diphacinone are completed.

LESSONS LEARNED

As with any project that introduces a new management technique and breaks ground on a new topic, there are lessons learned along the way that can serve future projects. The goals of this report were not only to document the process that this project went through, but also to provide some constructive suggestions for future projects so that others can learn from both what was and was not done correctly. The main lessons learned from this project are outlined below and roughly follow the sections of the report. While it is recommended that readers review most of this report in depth to put these suggestions in context of the project as a whole, at the very least this can serve as a guide for where to start.

Compliance and budgeting

Compliance

With any large project, permits are an inevitable part of the process, but the time required to complete the compliance of projects of this size is often underestimated. Even with the relatively quick commencement of the permitting process for this project, there were still multiple delays that could have been avoided. A six-month delay could have been prevented by finalizing the EA and initiating the SMA permit concurrently with the resolution of the first four contested cases since there was no legal basis that required the EA finalization to wait. Similarly, a right of entry permit could have been requested prior to obtaining all other permits, but that was contingent upon obtaining those permits and allowed for resolution of any contested cases while final permits were being applied for. And while the Section 106 consultation did not stall the project, it came very close to preventing the construction from starting on time as the document was submitted sequentially, as opposed to simultaneously, to each reviewing party which lengthened the process substantially. This specific process could have been initiated much earlier, and given to all reviewing parties simultaneously to allow time for multiple agencies to complete their reviews without repeated follow up.

Future projects should initiate their consultations and compliance paperwork well in advance of their anticipated construction date. Completing the compliance documents took longer and required more work than obtaining funding, and while most projects will likely not have as heavy a permitting burden as this project did, starting compliance paperwork while searching for funding would help to avoid some of the issues that this project ran into.

While much of this report has focused on what could be improved, there are many things about this project that were done correctly. With the compliance documentation, immediate preparation of the EA was very appropriate. While it took a significant amount of time to finalize the EA, this document was the longest and most time consuming to produce and formed the foundation for applying for the remainder of the permits. It also served as a great outreach tool for those wanting more in-depth information about the projects. A well-written EA will serve projects well and help to organize the planning process.

Budget

The initial budget for this project was $350,000 provided by the USFWS that was to cover all aspects of the project. As the project progressed, and it became clear that additional work and thus funding for various items (such as outreach, biological monitoring etc.) was needed, grants were applied for from a variety of agencies resulting in a total funding amount of $772,595 which was more than double the initial estimate. Fortunately, almost all project staff were involved in applying for various grants, and this proactive approach to sourcing out funding was what made this project possible. That being said, the project could have still used additional funding.

The costs outlined above do not include USFWS or DLNR staff time, and do not include the annual predator control contract DoFAW has with USDA-WS. In addition, much of the pre-construction biological monitoring was done on a volunteer basis from a variety of individuals at both public and private institutions. Currently, there is not funding to conduct post-predator removal biological monitoring, which will be a significant cost.

All of these agencies contributed significant amounts of staff time towards the planning an execution of this project, and the actual cost of implementing this project is undoubtedly much higher. Nonetheless, these estimates can still serve as a rough guideline for future projects that are still in the planning stages.

Outreach

The success of this project was due in large part to the public support that was garnered as a result of the efforts of the outreach team. This team utilized a variety of tools, but the key to their (and ultimately the project's) success was interacting one on one with community members on a regular basis and keeping everyone informed with the correct information through a variety of sources (brochures, websites, media etc) and for the duration of the project. One of the most difficult components of this project was dealing with a very vocal, but small minority who were opposed to the project and continually spread mis-information. The outreach team was well prepared to deal with this and were mostly successful in providing correct information to the public. In all projects, there will always be a few individuals that do not support it, and at a certain point, those in charge need to make a clear decision to proceed even in the face of opposition and just continue to work at keeping all parties informed on the status of the project.

Construction and maintenance

Future contracts would be well served by providing monetary penalties for work extending beyond a certain cutoff point to provide incentive to the vendor to conduct work on time. To facilitate clear communication, future contracts should also include clauses that have any off-island contractor provide copies of plane tickets so that arrival and departure times are known, and copies of bills of lading with contents clearly outlined and a shipment schedule so that it is clear when materials will arrive.

For the construction phase of a project, establishing a clear chain of communication is not only critical, but also specifying who has ultimate authority to dictate the work schedule. Because certain phases of construction were required to have both a cultural and archaeological monitor present per permit requirements, there were days when work was not allowed when these monitors could not be on-site. Unfortunately there was an incident of mis-communication where the fence contractor did several hours of work without a monitor present when they had been told not to work which resulted in a written reprimand for both the contractor, as well as the agency under the permit guidelines. As a result, monetary penalties tied to permit violations would have helped to prevent some of these issues.

Finally, while most predator proof fencing contracts will state that they provide on the ground training in the maintenance and use of the fence and its components, having written instructions, and including a tool-kit list as part of the contract deliverables would have been extremely valuable and saved considerable time once regular maintenance duties were taken over by the project staff. This project ended up drafting its own tool kit list and maintenance instructions (complete with pictures) so that staff that were not present at the time of training would still be able to fix the fence if needed.

Biological Monitoring

Installing the permanent, geo-reference grid as described in section five was an extremely valuable tool that greatly facilitated both monitoring, and rodent removal activities and would be highly recommended for future projects. The amount and breadth of monitoring done on a variety of taxa was also a great improvement over many projects. That being said, there were a few aspects of this component of the project that could have been improved.

Specific to the botanical monitoring, performing seed predation studies on focal species and/or quantifying pre and post-predator removal seed predation rates would have been a beneficial, and immediate metric of measuring change. While the monitoring scheme chosen will document larger scale ecosystem shifts, it would have been ideal to have included specific data on the predation aspect (seed consumption) that is thought to cause the most damage to the endangered plants at Ka`ena.

For all monitoring programs, it is ideal to have comparisons not only pre- and post -predator removal comparisons from within the fenced area, but also outside (control) vs. inside (experimental) at the same time to determine if changes are part of normal environmental cycles, or if they can in fact be attributable to predator removal. While this was done for some taxa (some inverts and pest species), it was not for others, primarily as a result of a lack of a native species monitoring budget. Ideally, the pre and post monitoring would have made an excellent graduate student project, but in the absence of a grad student dedicated to conducting the monitoring and analyses, additional funding would have helped alleviate this problem.

Finally, as discussed above, budgeting not only for pre-construction monitoring, but also post-construction follow up monitoring would have greatly helped to complete the second phase of the project.

Predator removal and biosecurity

The predator removal and biosecurity components of this project have gone about as smoothly as they could have, given the obstacles faced. Due to the limitations in tools (bait box application of a first generation anti-coagulent vs. broadcast of a more effective toxicant) and the poor timing (exceptionally high rain prior to gate installation), the predator removal was still a success. This was primarily due to a small core team who were committed to going out in the field for an extended period to get the job done. Selecting detail-oriented staff who understand the differences between control and eradication is crucial, since the difference between success and failure can be as small as failing to close a single mouse trap and allowing a single rodent territory to persist.

The challenging part of conducting a predator eradication from inside a fenced area is that it must be done reasonably soon after the completion of construction to prevent predators from breeding out of control in the protected area. As a result, suggestions presented above in the compliance and construction sections that keep the construction timeline on target will also serve the removal component well.

For biosecurity, the plan that was initially drafted was modified multiple times in the field once pest behaviors around the fence ends became known. While it is crucial to have a biosecurity plan in place at the time of pest removal, it should also be expected to change over time and adapt to the specific conditions. The most important part of the biosecurity is to budget for at least weekly visits to ensure that coastal ends are continually checked for the presence of rodents.

Project Coordination

For projects of this size and scope, it is ideal to have a dedicated individual acting as the coordinator to ensure that details are not overlooked and that there is a point person for others to contact with questions. In many cases, and perhaps ideally, this would be an agency staff member with the time required to dedicate to the project who is familiar with the site, flora, fauna and regulatory framework. In this case, an outside project coordinator was contracted due to the large size of the project, and the limited time that involved agency staff had available to oversee the project's needs. Each situation (in-house vs. contracted project coordinator) will have its pluses and minuses, and what is best for future projects will depend on the size of the project, the budget and ultimate needs. In either situation though, project coordinators should anticipate dedicating at least half of their time to a project of this size during the months prior to, and during construction and predator removal.

Suitability of predator proof fencing for other sites

While Ka`ena was an ideal site for fencing in terms of the physical landscape, not all sites in Hawai`i will be as easy to construct fences on, and several features of the Ka`ena fence design could have been improved upon. Peninsula-style fences that have coastal gaps will always have significant pest incursion problems and agencies will need to budget for the time required to keep pest animals out and possibly for future re-eradications from within this type of fence design. To date this has not been a large issue at Ka`ena with larger mammals such as mongooses, cats or dogs (<2 incursions/year of each species). However, it has been a significant issue with rodents, even with a less than 2m gap at each end. At a minimum, a maintenance and buffer pest control program that includes once-weekly inspections will need to be conducted in perpetuity in order to keep animals from re-invading the fenced area through the coastal gaps, and to conduct regular maintenance needs. For fences that completely encircle a site, this could likely be reduced. As a result, for sites where there is a greater than 2m gap between the fence end and low tide mark (including cliff faces), careful consideration should be given to whether a budget exists to manage those ends properly. In many cases, an enclosure may be a more logistically and financially feasible option.

Another aspect that needs to be considered is the vegetation immediately surrounding the fence line. Predator proof fences require a 4m wide vegetation free corridor to ensure that pests cannot use vegetation to jump over the fence. In heavily forested areas this will entail substantial amounts of clearing and regular trimming to ensure that branches do not overhang and will require bringing large equipment to remote sites. Additionally, in situations where bodies of water (streams, ponds etc.) are crossed, special efforts must be made to ensure those remain pest-proof. Areas prone to flash floods and/or that have stream beds with large boulders that are dry most of the year, but then experience heavy stream flow in a short period, will be especially challenging to make pest proof and avoid damage from water and moving rocks. As such, sites that have these properties should consider these factors during not only the planning stages, but ultimately during the long term maintenance phases. Scofield et. al. (2011) provide a critical review of the effectiveness of predator proof fencing in New Zealand that addresses some of these issues.

Summary

This project while behind schedule and over budget, successfully completed construction of Hawai`i's first predator proof fence and removed all invasive mammals from the inside the fenced area. While there are many aspects of the project that could have been improved, the end goal was ultimately achieved despite some vocal (and creative) opposition. Less than one year later we are already starting to realize the biological benefits generated from releasing native species from predation pressure. While predator proof fences are certainly not suitable for every site, they are a new and valuable conservation tool that should continue to be employed in Hawai`i for some species, as this may be their last hope at survival. It is hoped that this project is the first of many.

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ORIGINAL PAPER

Multi-species predator eradication within a predator-proof fence at Ka'ena Point, Hawai'i

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Abstract Ka'ena Point Natural Area Reserve on O'ahu hosts one of the largest seabird colonies in the main Hawaiian Islands and supports three species of endangered plants. In order to stop chronic predation by invasive alien mammals on native species, a peninsula-style predator-proof fence was constructed around a 20-ha portion of the reserve in 2011. Multi-species predator removal efforts began upon fence completion; diphacinone poison in bait boxes spaced 25 m apart was used to remove black rats, house mice, and small Indian mongooses. House mice also were removed with multiple-catch live traps spaced 12.5 m apart. Feral cats were removed with padded leg-hold traps. Feral cats and mongooses were eradicated in 1 month, black rats were eradicated in 2.5 months, and house mice were eradicated in about 9 months. Since eradication, incursions of cats and mongoose have been rare (1/7.2 months), but incursion frequency has been higher for black rats (1/56 days) and house mice (1/36–47 days). Buffer predator control was conducted to limit predator access and prevent reinvasion around the fence ends along the shoreline. Even with the high initial fence cost and ongoing predator incursion management, this method is expected to become more cost effective than previous predator control efforts after 16 years. Record numbers of Wedge-tailed shearwaters and Laysan albatrosses have fledged from the reserve after predator eradication, and regeneration of native plants and invertebrates is being observed. With careful planning and persistence, predator fences can be a cost-effective method of protecting natural resources, and multiple species of predators can be eradicated with traps and first-generation anti-coagulents.

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Keywords Hawai'i · Island species · Predator eradication · Predator fence

Introduction

Introduced mammalian predators are the most serious threat to many species, particularly on islands, and are the largest cause of animal extinctions in the past few centuries (Croll et al. 2005; Reaser et al. 2007;

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Salo et al. 2007). Predators have been eradicated from many islands and the number of eradications conducted each year has been increasing (Keitt et al. 2011), preventing the extinction of many species and leading to the recovery of others. In cases where it is impractical to remove all predators using methods currently available, predator-proof fences and large trapping grids have been used to create "mainland islands" in which predators are managed (Saunders 2001; Burns et al. 2011). Most eradications and management programs have focused on single species, most often rats (*Rattus* spp) and feral cats (*Felis catus*), but more recently, eradication efforts have begun to target multiple species simultaneously (Innes and Saunders 2011). Multi-species eradications often are more cost-effective (Griffiths 2011) and can help avoid undesirable shifts by top predators to native species that can occur when smaller predators that serve as alternate prey are eradicated (Witmer et al. 2007; Griffiths 2011; Innes and Saunders 2011).

In the Hawaiian Islands, all mammals except the Hawaiian monk seal (*Monachus schauinslandi*) and the Hawaiian hoary bat (*Lasiurus cinereus semotus*) were introduced by people, some intentionally for food, pets, or biocontrol agents, and others accidentally as stowaways (Tomich 1969). Because Hawai'i is so isolated from continental areas, the native plants and animals that evolved in the islands are naïve to mammalian predators and often lack defenses against them (Salo et al. 2007; Sih et al. 2010; VanderWerf 2012). Polynesians colonized the Hawaiian Islands about 800 years ago (Rieth et al. 2011) and brought with them several destructive predators including the Pacific rat (*Rattus exulans*), domestic dog (*Canis familiaris*), and domestic pig (*Sus scrofa*; Kirch 1982; Burney et al. 2001). Introduction of alien predators accelerated with the arrival of Europeans starting in 1778, including the black or ship rat (*R rattus*), Norway rat (*R norvegicus*), domestic cat (*F. catus*), small Indian mongoose (*Herpestes auropunctatus*), house mouse (*Mus musculus*), and European wild boar (*S. scrofa*). The suite of alien predators now present in Hawai'i presents a serious threat to the survival of many of Hawai'i's native species (Ziegler 2002; Lindsey et al. 2009), with ground-nesting birds and fruiting plants being especially vulnerable.

Ka'ena Point Natural Area Reserve (NAR) is located at the northwestern tip of the island of O'ahu and contains one of the best remaining examples of a native coastal ecosystem in Hawai'i. Ka'ena Point also hosts one of the largest seabird colonies in the main Hawaiian Islands, three species of endangered plants (one of which is endemic to the area), and is a pupping ground for the endangered Hawaiian monk seal. Exclusion of off-road vehicles in the early 1990s allowed habitat recovery to begin and encouraged two species of seabirds, the Laysan albatross (*Phoebastria immutabilis*) and Wedge-tailed shearwater (*Puffinus pacificus*), to begin nesting in the reserve. However, despite regular predator control, up to 15 % of albatross nests failed each year because of predators, hundreds of shearwaters were periodically killed, and native plants and their seeds were under constant threat (Young et al. 2009; Lohr et al. 2013). To end the chronic, and sometimes catastrophic, predation affecting the natural resources at Ka'ena Point, a peninsula-style predator-proof fence capable of excluding all mammalian predators was constructed around a 20-ha portion of the reserve in 2011 (Young et al. 2012).

The fence is 630 m long and runs from one shoreline to the other, with the ocean acting as a barrier at each fence end (Fig. 1). The northern terminus of the fence is within 2 m of the shoreline at low tide, and at high tide is virtually at the water's edge. The southern terminus is atop a small cliff, with the ocean directly below. The fence is 2 m tall, has aluminum posts covered with a fine (6 mm × 25 mm) polymer-coated stainless steel mesh, and has a sloped aluminum hood at the top. At the bottom of the fence, a 30 cm wide horizontal skirt is cemented onto the ground to prevent animals from digging underneath. Access through the fence for pedestrians is provided by three enclosed gates with sliding double-doors. These features prevent animals ranging in size from mice to dogs from jumping or climbing over, squeezing through, or digging under the fence, and was tested in 2005 and determined to be capable of excluding all non-native mammalian predators in Hawai'i (Burgett et al. 2007). However, because the hood is only on the outside of the fence, it allows animals present inside the fence to exit by climbing out. The majority of the fence was completed by December 2010, but the gates were not installed until March 2011.

Once a predator-proof fence has been built, all predators within the fence must be removed as soon as possible to prevent their populations from growing, and an effective biosecurity program must be implemented to prevent incursions and potential

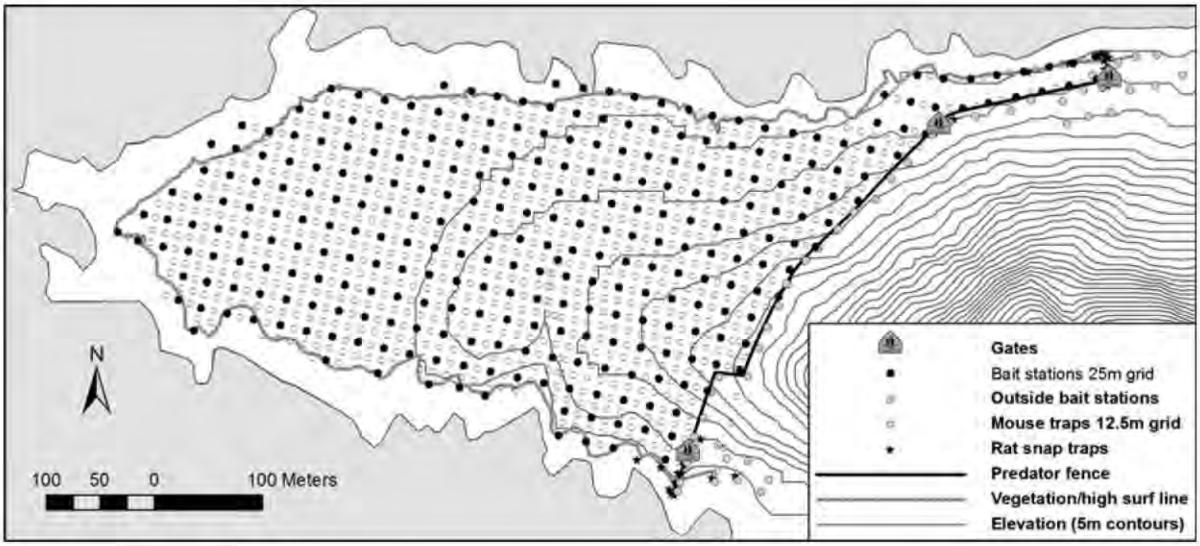

Fig. 1 Map of Ka'ena Point Natural Area Reserve showing locations of the predator-proof fence, bait stations, and traps used in predator removal and incursion detection and prevention

reinvasions. Peninsula-style fences that do not fully enclose an area are especially susceptible to reinvasion because of the gaps between the fence ends and the shoreline. If all predators are eradicated and incursions are effectively managed, the fenced area can function as a 'mainland island' that is similar in many ways to an offshore island.

Five non-native predatory mammal species were present at Ka'ena Point: feral dogs, feral cats, small Indian mongooses, black rats, and house mice. Although dogs, cats, and mongooses were primarily responsible for the conspicuous predation events on seabirds that received extensive media coverage (Honolulu Star Bulletin 2006), rats and mice are important ecosystem modifiers because they consume prey at all levels of the food chain, from plants through birds, and they can be more difficult to eradicate than larger predators (Howald et al. 2007).

The primary objectives of this study were to design and implement effective predator removal and biosecurity programs for the Ka'ena Point predator-proof fence, while considering the pest species present and the tools legally available for use in Hawai'i. To help accomplish this, we conducted two years of planning and research prior to fence construction to determine which predator species were present, their densities, and their responses to various control methods (Young et al. 2012). Because the value of predator-proof fences has been questioned recently (Scofield et al. 2011) and more information is needed on their utility (Innes et al. 2012), we also compared the costs and benefits of fence construction and predator eradication with those of the predator control methods used previously at the site. While great advances have been made in the field of multi-species predator removals, particularly in New Zealand, some of the toxicants and other tools regarded as most effective are not legal in some countries or states. The information presented in this study on the costs of predator fences and the use of trapping and first-generation anti-coagulents to eradicate multiple species of predators will be useful to biologists and managers in other locations.

Methods

Study site

Ka'ena Point Natural Area Reserve was established by the State of Hawai'i in 1983 to protect a remnant coastal dune ecosystem from off-road vehicles, erosion, and the spread of invasive species. The reserve encompasses 30.6 ha at the northwestern tip of the island of O'ahu. The reserve is open to the public by pedestrian access, and visitors are required to remain on a system of trails. The substrate consists of lava rock shoreline that is impacted by large waves during the winter months, a small beach of coral rubble, and shallow sandy soils overlying lava bedrock. Ka'ena means "the heat" in Hawaiian, and the climate is indeed warm and dry, with average monthly maximum temperatures of 25.9–30.1 °C and average annual rainfall of 613 mm (Western Regional Climate Center). The vegetation is mixed dry shrubland and grassland <1 m in height, with species composition varying by substrate. Native plants dominate the sandier areas near the shoreline, particularly naupaka (*Scaevola taccada*) and the endangered legume 'ohai (*Sesbania tomentosa*). Higher areas with rockier substrate support a mix of native species including naio (*Myoporum sandwicense*), 'ilima (*Sida fallax*), and pā'ū 'o hi'iaka (*Jacquemontia ovalifolia*), and alien species such as kiawe (*Prosopis pallida*) and various grasses. 'Akoko (*Chamaesyce celastroides kaenana*), an endangered euphorb endemic to Ka'ena Point, also occurs in rocky areas.

As the habitat condition improved following the exclusion of off-road vehicles, two species of seabird colonized the reserve: the wedge-tailed shearwater, a species that is widespread in the tropical Pacific and Indian oceans, nests in underground burrows and rocky crevices from May to November, and the Laysan albatross, which forages widely over the North Pacific but breeds primarily in the Hawaiian Islands, nests on the surface, with eggs laid in November–December and chicks fledging in June–July (Young et al. 2009). Predator control was initiated to protect these new seabird colonies in 2000, when the Hawai'i Division of Forestry and Wildlife contracted the US Department of Agriculture (USDA) Wildlife Services to remove feral dogs, feral cats, and mongooses with live traps and shooting. Although numbers of both seabird species were growing in response to the ongoing management, predation remained a problem, particularly for the much smaller shearwater, and reproduction was poor in some years.

Baseline predator data collection

Prior to fence construction, we compiled existing data and collected additional baseline data on each species of predator present at Ka'ena Point, and we used this information to design the predator removal program. For larger mammals (dogs, cats, and mongooses), data were available from 11 years of predator control conducted by the USDA. A total of 150 feral cats, 480 mongooses, and nine feral dogs were removed from Ka'ena Point Natural Area Reserve from 2000 to 2010, for average annual removal rates of 13.6 feral cats, 43.6 mongooses, and 0.82 feral dogs. Shooting was the most effective method of controlling dogs, and padded leg-hold traps were the most effective method of controlling cats (Young et al. 2012).

For rodents, we conducted quarterly trapping with snap traps for 1 year to determine the species present and their relative abundance at different seasons (Young et al. 2012). Black rats and house mice were the only rodent species detected. Capture rates of mice were two–eight times higher than the capture rates of rats, depending on the season, and the pattern of seasonal abundance was similar for both species, with peaks in spring and lows in late fall, suggesting a spring reproductive period. To estimate home range sizes of rats and mice, and thus the required spacing for traps and/or bait stations, we captured individuals of each species in live traps, glued a small spool of light-weight thread onto the fur of their back, and released them. The movements of each animal were traced by following the thread two–three days later, by which time the animal had groomed the spool off its back. The maximum distance moved was 45 m for rats and 12 m for mice. More detailed methods used for rodent baseline data collection are provided in Young et al. (2012).

Predator removal

Regular control programs conducted by USDA for feral dogs, feral cats, and mongooses were continued during fence construction to prevent predation on nesting seabirds. Feral cats were removed with a combination of leg hold traps (Victor #15 padded or Bridger offset leg hold traps) and cage-traps (9 × 9 × 26-inch single door Tomahawk traps) baited with commercial cat food. Traps set for cats also were suitable for capturing mongooses, although no mongooses were caught in traps during fence construction. Up to 29 cage traps were placed throughout the reserve, and up to nine leg-hold traps were placed strategically in locations most likely to intercept predators, particularly cats (Young et al. 2012). To help inform removal efforts and improve trap placement, four remote cameras with infra-red motion-activated triggers (Scoutguard SG550) were used to identify individual cats and determine areas of high cat activity. Inspection of sandy areas for tracks provided additional information on the presence and movement patterns of cats and mongooses and aided in trap placement.

We targeted rodents and mongooses with Ramik mini-bars® containing 0005 % diphacinone (HACCO Inc., Randolph, Wisconsin, USA). Diphacinone is widely used for rat control (VanderWerf 2009; Parkes et al. 2011), and also is effective for small Indian mongooses (Smith et al. 2000; Barun et al. 2011). We placed bait in tamper-resistant Protecta® plastic bait stations (Bell Laboratories, Madison, Wisconsin, USA) to shield them from rain and reduce the risk of poisoning to non-target species. Entrances to the stations were large enough to allow access by mice, rats, and mongooses. Bait stations were positioned throughout the fenced area in a 25-m grid pattern (the closest spacing allowed under the product label; Fig. 1) using laser rangefinders and were filled with up to 11 one-oz blocks per station. The maximum allowable amount of bait specified on the product label is 16 oz per station, but we placed no more than 11 oz in each station because that was the maximum number that could be secured to prevent bait from being shaken out of the station. We did not place bait stations below the vegetation line on the coast to reduce the possibility of them being washed away by high surf. With 25-m spacing, there were 289 stations inside the fence (Fig. 1). We stocked bait in the stations on 23–24 February 2011, 1 month prior to the completion of the fence gates, to ensure that the majority of rodents were removed before their breeding season began, which was expected to occur in March. We serviced bait stations twice per week during the first month; after that we adjusted the frequency depending on the level of take to ensure that an adequate supply of bait was available at all times. Frequency of maintenance was once per week during the second month, once every two weeks for the next three months, and once a month thereafter. Application of diphacinone bait was conducted in compliance with US Environmental Protection Agency registration number 61282-26 and special local need registration HI-980005.

We were not confident that the 25-m bait station grid alone would be sufficient to eradicate mice because there is some uncertainty about the efficacy of diphacinone on mice (Parkes et al. 2011), and because the small distances travelled by mice tracked at Ka'ena Point (~12 m; Young et al. 2012). Therefore, on 10 March 2011, 14 days after the commencement of baiting, we placed Catchmaster™ multiple-catch mouse traps baited with peanut butter and roasted peanuts at 12.5 m intervals throughout the fenced area, except where a bait station already was present. These traps have openings too small for seabirds to enter and are thus safe to use in seabird colonies. This resulted in rows containing only mouse traps alternating with rows that contained mouse traps and bait stations (Fig. 1). On transects that already contained bait stations, mouse traps were alternated with bait stations, so that mouse traps were 25 m apart, but with a method of control every 12.5 m. We checked the traps with the same frequency as bait stations; twice weekly during the first month and less often thereafter as needed.

We measured progress of rodent removal in several ways. First, we compared the capture rate of mice over time with baseline data that had been collected immediately before removal efforts commenced using the same Catchmaster™ multiple catch live-traps placed every 10 m along 200 m transects inside the reserve. Second, we used tracking tunnels with inked cards baited with peanut butter to detect the presence of mice, rats, and mongoose and measure their relative abundance. We placed the tunnels in a 50-m grid pattern throughout the fenced area ($N = 73$). We first deployed tracking tunnels on 2 March 2012, one week after baiting began and one week before mouse traps were deployed, and we ran them at approximately monthly intervals during the remainder of the removal operation.

We used several criteria to judge whether eradication of each predator species had been achieved because the species differed in their incursion potential and we used different methods to detect them. Feral dogs, feral cats, and mongooses were relatively easy to detect and incursions proved to be rare (see "Results" section), so eradication was determined to be the first instance when no detections were made with any method, including traps, tracking tunnels, cameras, droppings, or observations of animals or their tracks. For rodents, determining an exact eradication date was more problematic because it was difficult to distinguish the last remaining survivors from new animals that had re-invaded. Data from other projects suggest that rodents do not venture further than about 100 m in their first few days in a new area (Innes et al. 2011), so all rodents detected

>100 m from the fence ends or gates were judged to be survivors.

Incursion prevention and detection

We defined an incursion as the detection of a predator inside the fence subsequent to the eradication of that species. For rodents, we counted as an incursion any evidence in traps, bait stations, or tracking tunnels inside the fence after the eradication date, particularly within 100 m of the fence ends. For larger mammals, we counted as an incursion any evidence in tracking tunnels, remote cameras, scat, tracks in the sand, or direct observation. We calculated the incursion rate for each species as the number of detections divided by the number of days post-eradication.

As part of the biosecurity plan to keep pest pressure off the fence and reduce the chance of predator incursions and re-invasion, we conducted weekly predator control outside the fence using diphacinone bait stations and snap traps. We placed bait stations at 25 m intervals along the entire length of the exterior fence and up to 50 m out from the fence (Fig. 1). On the fence ends, we placed bait stations in a fan-shaped pattern extending 125 m from the fence. We also monitored the fence weekly for breaches and holes, and we swept rocks, sand, and other debris from inside the gates, particularly the tracks of the sliding doors, to ensure the gates opened and closed properly. To prevent rats from approaching the fence ends and possibly gaining access to the reserve, we placed rat snap traps in covered boxes to prevent seabird injury at 10–15 m intervals along the outside of each fence end (Fig. 1). In case rats or mice did make it around the fence end, we placed rat traps and mouse traps at 6.5–12.5 m intervals along the inside of the fence end and along the shoreline inside the fence up to 100 m from the end. The 100 m extent was largely determined by the local topography, but also followed recommendations by Innes et al. (2011) based on the behavior of rats re-invading a fenced area. This system of traps outside and inside the fence formed a "gauntlet" through which predators would have to pass in order to reach the interior of the reserve. Rodents have been shown to use fences and shorelines as movement corridors, so targeting these areas increased the chance of interception (Innes et al. 2011). In addition, tracking tunnels located <100 m from each fence end were run weekly at the same time the biosecurity traps were checked to provide an additional method of detection for rodents that may be trap shy.

If we detected rodents in the interior of the reserve (>100 m from the ends), this triggered an incursion response using additional traps and fresh bait in the area immediately around the area of detection for up to one month (i.e., a 'spot treatment' following protocols suggested by Maitland 2011). If no rodents were detected after one month, or if the animal was captured in a trap, this incursion response was withdrawn. Feral cats, feral dogs, and mongooses could be readily tracked in the sandy soil present in much of the reserve. If a cat or mongoose was detected in the reserve, we deployed cage traps and leg hold traps in the area until the animal was caught, or until it was determined that it had left the reserve.

Results

Large mammal removal

When the gates were installed on 29 March 2011, thereby completing the fence construction, there was no evidence of dogs or mongooses inside the fence. It is possible that any feral dogs present had been scared away by the construction activity and exited through the gate openings. Mongooses had likely consumed

Table 1 Summary of predator eradications and incursions by species at Ka'ena Point

Species	Control start date	Perceived eradication date	# Days to eradicate	Incursion rate (days)
Feral cat	23 February 2011	30 March 2011	35	1/217
Mongoose	23 February 2011	30 March 2011	35	1/217
Black rat	23 February 2011	10 May 2011	74	1/57
House mouse	23 February 2011[a]	19 Oct–29 Nov 2011	237–278	1/36–47

[a] Mouse live traps were deployed on 3 March 2012

the diphacinone bait and perished during the month of baiting that occurred before the gates were installed, since none were captured in traps during that period. A single feral cat was captured in a padded leg-hold trap one day after the gates were installed. This cat, and no others, had been detected with trail cameras for over a month before it was trapped. If any other cats were present they likely exited the fenced area shortly thereafter (Table 1).

Rodent removal

Take of diphacinone bait from stations was high for the first two weeks, then declined rapidly and remained low for the remainder of the removal operation (Fig. 2). A total of 9,341 oz (264 kg) of bait was deployed in the 289 stations inside the fence over a period of 252 days, for an average take of 0.13 oz (0.0036 kg) per station per day. Rat droppings and mouse droppings were observed inside many stations during the first few weeks. The low level of bait consumption that occurred later appeared to be from remaining mice and insects. Tracking tunnel data collected one and three weeks after baiting began showed a decrease in abundance of rats (5 % presence to 0 %) and mice (45 % presence to 25 %). A rat caught in a snap trap near the southern fence end on 10 May 2011, 74 days after control efforts began, was judged to be the last resident.

The diphacinone bait greatly reduced mouse abundance; the capture rate of mice in live traps declined from 0.38 mice/trap-night before baiting began to 0.014 mice/trap-night after two weeks of baiting, a 96 % decline. The mouse capture rate in live traps continued to decline, but mice persisted for several more months. The first trap check that resulted in zero mouse captures was on 13 October, and the last detection of mice on tracking tunnels in the interior of the reserve was on 19 October, 223 days after live trapping began and 237 days after baiting began (Fig. 3). It is possible no resident mice remained in the reserve after that date, but single mice were caught in the snap trap gauntlet near the northern fence end on 26 October and 3, 11, and 29 November (Fig. 4). The fact that these mice were captured along the shoreline close to the fence end suggests they entered the reserve along the shoreline and were re-invaders, but it is also possible they were the last survivors attempting to exit the reserve. No mice were detected subsequently by any method in the interior of the reserve, lending support to the conclusion that mice captured near the fence ends were re-invaders. The exact date of mouse eradication is thus difficult to determine, but likely occurred 237–278 days after removal efforts began.

Incursion rates

Two cats were detected inside the fence between 30 March 2011 (considered the eradication date) and 14 June 2012, resulting in an incursion rate of approximately one every 217 days or 7.2 months One of these cats was detected on a trail camera near the fence line 70 days after eradication, but it was not detected again on camera or by any other method and is assumed to have left the fenced area on its own. On 5 January 2012, a cat and cat tracks were observed in the interior of the reserve, and trapping was immediately initiated. The cat was caught in a padded leg-hold trap on 12 January 2012 before any evidence of seabird predation was observed.

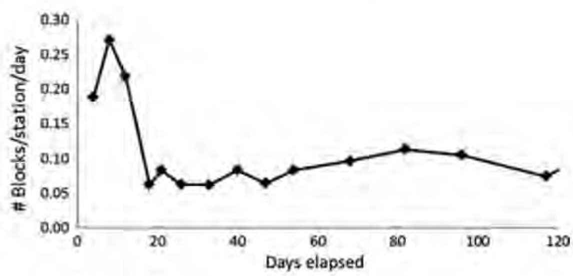

Fig. 2 Take of diphacinone bait from stations at Ka'ena Point Natural Area Reserve. High levels of take during the first 2 weeks were by rats and possibly mongoose; low bait take thereafter was by mice and insects

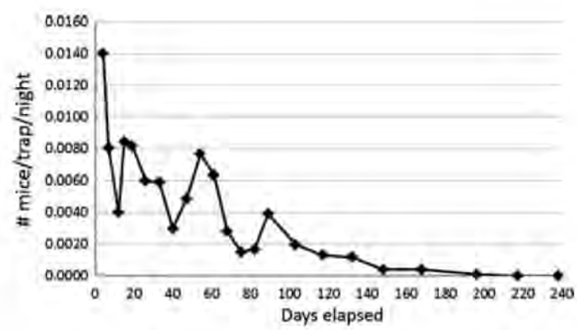

Fig. 3 Capture rate of mice in live traps during the eradication over time

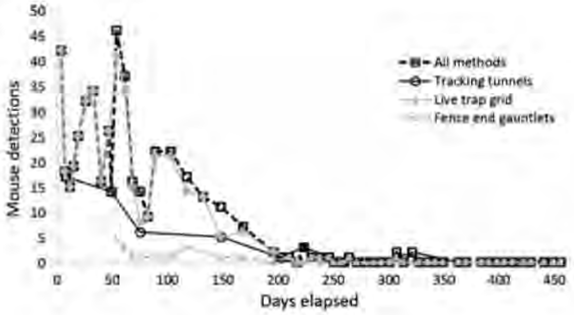

Fig. 4 Number of mice detected over time by method. Eradication probably was achieved between days 252–278; see text for explanation. Subsequent detections were considered incursions

Two mongooses were detected inside the fence from 30 March 2011 to 14 June 2012, resulting in the same incursion rate as for cats, one every 217 days or 7.2 months. One of these mongooses was detected from scat 128 days after eradication, immediately following a weekend when one of the gates was inadvertently stuck open. The scat was on top of a bait station, and enough bait had been taken from the station to constitute a lethal dose; the animal was not detected again. The second mongoose was detected visually and by tracks 254 days post-eradication, and was caught in a leg-hold trap 29 days after it was first detected. No seabird predation was observed as a result of these incursions.

The incursion rate of rats was higher. Seven rats were detected inside the fence during the period after rats were judged to have been eradicated (10 May 2011–8 June 2012; 394 days), resulting in an incursion rate of one every 56 days. Five of the seven rats that made it past the fence were captured in traps immediately inside the fence ends, all of which were *R. rattus*. Two rats survived the gauntlet and were detected with tracking tunnels in the interior of the reserve 162 and 302 days post-eradication, respectively. In those instances, snap traps were placed in the area of detection and bait stations in the area were refreshed. Although neither individual was trapped, there was evidence of bait take and no subsequent detections on tracking tunnels, suggesting that the rats had either died from consuming the bait or exported themselves.

For mice, the incursion rate was more difficult to measure, but probably was about once every 36–47 days. If the eradication date was judged to be 3 November 2011 (the first occasion after no mice were captured in the interior of the reserve), then six incursions occurred during the 217 days between then and 8 June 2012, resulting in an incursion rate of one every 36 days. If two mice that were captured in snap traps near the northern shoreline on 11 and 29 November 2012 are counted as the last survivors instead of invaders, then four incursions occurred during the 191 days between then and 8 June 2012, resulting in an incursion rate of one every 47 days. The final four mouse detections were in traps or on tracking tunnels within 100 m of the fence ends. No mice have been detected in the interior of the reserve (>100 m from the fence ends) since being eradicated.

Cost-benefit analysis

The predator control efforts conducted from 2000 to 2011 by USDA under contract from DOFAW cost $35,000 per year, not including administrative staff time to oversee the contracting. This work entailed three visits per week to check cat and mongoose traps, occasional supplemental visits for night-shooting, and sporadic rat control. In comparison, construction of the predator fence cost $290,000, including materials, labor, and travel from New Zealand and living expenses of the fencing crew in Hawai'i (Table 2), and not including administration, regulatory compliance documents, or public outreach efforts conducted before the fence was constructed. Materials cost included 40 m of spare parts for fence maintenance. Eradication of predators from the fenced area cost approximately $55,500, including supplies, labor, and expenses (Table 2). Labor consisted of 1,240 worker-hours during 30 visits by 5–7 workers over a 9 month period at an average rate per worker of $30 per hour (including benefits). After predator eradication, implementation of the biosecurity plan cost $10,000 per year, including weekly checks of bait stations and traps along the shoreline at the fence ends, inspecting the fence for breaches, and sweeping and maintaining the gates. Fence maintenance costs have been about $2,000 per year thus far but are not well known yet and may rise as the fence ages; $4,000 per year over the life of the fence might be more realistic and we used this to calculate cumulative costs. Some of the predator removal and biosecurity work was conducted simultaneously with other management and research activities (e.g., VanderWerf and Young 2011), so their

Table 2 Breakdown of predator fence construction and predator eradication costs at Ka'ena Point Natural Area Reserve, Hawai'i

Item	Cost
Fence construction	
Materials	$290,000
Labor	$109,000
Travel + living expenses	$44,000
Total	$443,000
Predator eradication	
Bait boxes + bait	$6,090
Mouse traps	$6,046
Bait for mouse traps	$275
Tracking tunnels + cards	$1,500
Vehicle mileage	$3,713
Helicopter time	$680
Labor	$37,200
Total	$55,504

actual cost was somewhat lower than reported here (Table 2).

We anticipate that the "break even point" of the fence cost will occur in about 16 years (Fig. 5). At that time, the cumulative cost of annual predator control would have been about the same as the cumulative costs of fence construction, predator eradication, and annual fence maintenance and biosecurity. The life-span of the fence is projected to be about 20–25 years, though parts of the fence near the northern shoreline that experience more salt spray may require replacement earlier.

Discussion

To our knowledge, this is the first successful eradication of this suite of predators, including mice in particular, that used a combination of diphacinone bait and trapping. Other successful multi-species eradications typically have used aerial broadcast application of second generation anti-coagulents, such as brodifacoum, which are more effective than first-generation anti-coagulents like diphacinone, because they require only a single feeding for an animal to ingest a lethal dose (Parkes et al. 2011). Broadcast methods and other toxicants were not available for use in this project because of regulatory restrictions in Hawai'i.

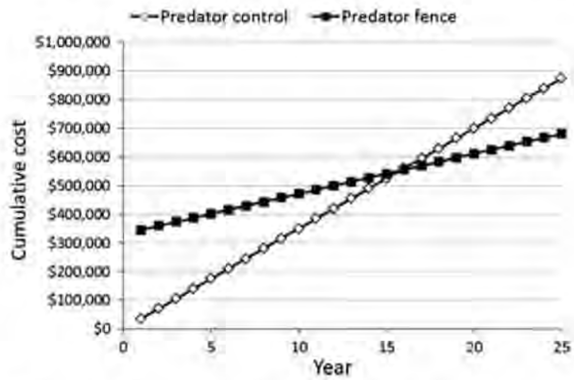

Fig. 5 Cumulative costs of protecting natural resources at Ka'ena Point Natural Area Reserve using a predator fence versus annual predator control. Cost of the predator fence includes costs of fence construction, predator eradication, annual fence maintenance, and weekly biosecurity checks

Although the predator removal methods we used may not be those generally preferred or regarded as most effective, they were most feasible given the scope of the project and the constraints we faced, and our results demonstrate that a multi-species eradication can be achieved with these methods.

The general criteria which must be met for an eradication to succeed are that: (1) All animals must be put at risk by the eradication technique; (2) The animals must be put at risk at a rate exceeding their rate of increase; and (3) Immigration must be zero (Parkes 1993). The last criterion is inherently violated at Ka'ena Point because the fence ends were open, and we recognize that peninsula-style fences may never be considered true eradications for this reason. Confirming eradication can be difficult in many circumstances, and Solow et al. (2008) attempted to address the issue of how to confirm the absence of something. The current standard to determine the success of an offshore island rodent eradication is two years without rodent sign (Parkes et al. 2011), which isn't applicable in a case such as this where immigration can be continual.

Eradicating cats, mongooses, and even rats was relatively straightforward at Ka'ena Point, and determining when eradication had been achieved for these species also was fairly straightforward. The number of feral cats and mongooses present in the reserve before fence construction probably was small, and their presence was easily detected with remote cameras, tracks in sand, and tracking tunnels. Judging when rats had been eradicated was a little more difficult, but again, few rats were present and the frequency and distribution of detections made it more clear when eradication had been achieved. Mice, however, took substantially more effort to eradicate and determining an eradication date was not possible because it was not clear whether some mice detected were the last survivors or the first re-invaders. Future studies would be well-served to use biomarking of individuals outside the fenced area in order to distinguish survivors from re-invaders. Never the less, we are confident that all predators, including mice, have been eradicated or reduced to negligible levels for conservation purposes, and that this status can be maintained.

The incursion rates at Ka'ena Point were similar to those at another peninsula-style predator-proof fence at the Tawharanui open sanctuary in New Zealand, despite differences between the sites in the size of the gap between the fence end and shoreline (2 m at Ka'ena Point vs. up to 60 m at Tawharanui; Maitland 2011). These results suggest that Ka'ena Point either has significantly more predators immediately outside the fence, resulting in higher pressure on the fence, that the shoreline at Ka'ena Point is more attractive to predators than that at Tawharanui, or that incursions aren't detected as readily at Tawharanui. At Ka'ena Point, the bait take in buffer predator control areas just outside the fence is sometimes quite high, suggesting the pest pressure on the fence is high. The rocky intertidal area along the shoreline at Ka'ena Point supports many marine invertebrates, and this rich foraging habitat may be more attractive to rodents than the sandy substrate at Tawharanui and cause them to unintentionally bypass the fence. The narrow gap between the fence end and water line at Ka'ena Point provides an excellent opportunity to intercept rodents as they enter the fence, and most rodents are caught within a few meters of the fence end, often in the first trap.

We encountered several complications during predator removal efforts that warrant discussion. Before predator control commenced, heavy rainfall had resulted in unusually lush vegetation growth and an ample supply of food and water was available for rodents, which potentially could have discouraged them from consuming bait or entering traps. A similar scenario occurred during an attempted eradication of Pacific rats (*R. exulans*) using aerial broadcast of diphacinone on Lehua Islet, Hawai'i in 2009, and the abundance of natural food was thought to have contributed to the failure of that eradication (Parkes and Fisher 2011). However, use of bait stations and ability to restock them as needed for several months allowed us to outlast the boom in natural food and achieve eradication. If a broadcast bait application had been attempted at Ka'ena Point, it would have involved two drops of 5.7 kg (12.5 lb) of bait per ha over the 16.3-ha area above the high surf line, or a total of 185 kg of bait versus the 264 kg that was ultimately used in bait stations. If the two drops had been spaced five–seven days apart as prescribed on the product label, the eradication attempt may have failed due to the unusually abundant natural food supply.

Supporting the idea that eradications within fenced areas should occur soon after construction, the initial mouse trapping rate outside the fence was much lower than that inside the fence (0.06 mice/trap-night vs. 0.38), probably because large predators were present in higher densities outside the fence where they were not controlled and were suppressing mouse numbers. Several of the live traps that caught mice outside the fence had mongoose scat on them and had been damaged, suggesting that larger predators were trying to access the mice caught in the traps. Delaying control of predators inside the fence likely would have caused intolerable damage to nesting seabirds and native plants. If only larger predators are controlled, rodents may experience predator release and increase in abundance. Thus, the timing of fence completion, predator removal, and seasonal variation in predator abundance must all be considered together to optimize removal effort and chances for successful eradication.

The results of this study are encouraging for future projects using first generation anti-coagulents on this suite of predators. The baiting program resulted in a substantial decline in abundance of mice after two weeks (45 % decline in tracking tunnels, 96 % decline in live-trapping). Since multiple tracking tunnels can be marked by the same individual, the live trap catch rates are likely to be a better index of abundance. Thus, diphacinone alone appeared to have eliminated up to 96 % of the mice in just two weeks even though the spacing of bait stations (25 m) was larger than the average travel distance of the mice (~12 m). It is likely that as mice were removed, home ranges of remaining animals expanded and thus allowed more individuals access to bait. If the pesticide label allowed closer bait box spacing so that the range of every mouse overlapped with at least one bait station, the diphacinone could have eliminated even more mice and possibly all of them, which is worth investigating for future eradications. We suggest that our methods (a combination of first-generation anti-coagulent bait and traps) could be used to eradicate similar suites of predators at other sites that are comparable in size and topography.

The predator fence thus far appears to be a cost-effective method of protecting the natural resources at Ka'ena Point. The projected long-term cost savings may not be as large as originally forecast, but the cost of fence construction and predator eradication still is anticipated to compare favorably with the cumulative cost of annual predator control. Whether the fence actually results in a long-term cost savings will depend on the lifespan of the fence and fence maintenance costs, which are not yet known. However, we emphasize that the fence and predator eradication have provided a higher level of protection to native species, and that comparing the costs alone is insufficient. Previous predator control efforts helped to increase the reproduction of albatrosses and shearwaters (Young et al. 2009), but some birds were still lost to predators every year. Furthermore, previous predator control focused only on feral dogs, feral cats, and mongooses, it did not ameliorate the effects of rats and mice and thus provided little protection for native plants and invertebrates. In contrast, the fence excludes all predators and provides greater protection to all native species in the reserve and not just seabirds.

Despite the ongoing incursions, there is no evidence of reinvasion by any predator in the reserve interior, and the biological outcome achieved with the fence has already exceeded the protection provided by predator control that was conducted before fence construction. Record numbers of Laysan albatross and Wedge-tailed shearwater chicks fledged from the reserve after predators were eradicated (LCY and EAV, unpubl. data). We also anticipate regeneration of native plants and invertebrates, and recolonization by other seabirds Ka'ena Point also can serve as a site for active restoration, including translocation of endangered seabirds such as the Hawaiian petrel (*Pterodroma sandwichensis*) and outplanting of endangered plants.

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Technical Report 198

The Nihoku Ecosystem Restoration Project: A case study in predator exclusion fencing, ecosystem restoration, and seabird translocation

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This technical report series began in 1973 with the formation of the Cooperative National Park Resources Studies Unit at the University of Hawai'i at Mānoa. In 2000, it continued under the Pacific Cooperative Studies Unit (PCSU). The series currently is supported by the PCSU.

The Pacific Cooperative Studies Unit at the University of Hawai'i at Mānoa works to protect cultural and natural biodiversity in the Pacific while encouraging a sustainable economy. PCSU works cooperatively with private, state and federal land management organizations, allowing them to pool and coordinate their efforts to address problems across the landscape.

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EXECUTIVE SUMMARY

Newell's Shearwater (*Puffinus auricularis newelli;* NESH) and Hawaiian Petrel (*Pterodroma sandwichensis;* HAPE) are both listed under the Endangered Species Act of 1973 and are declining due to collisions with power lines and structures, light attraction, predation by feral cats, pigs, rats, and introduced Barn Owls, habitat degradation by feral ungulates (pigs, goats) and invasive exotic plants. Protection of NESH and HAPE on their nesting grounds and reduction of collision and lighting hazards are high priority recovery actions for these species. Given the challenges in protecting nesting birds in their rugged montane habitats, it has long been desirable to also create breeding colonies of both species in more accessible locations that offer a higher level of protection. Translocation of birds to breeding sites within predator exclusion fences was ranked as priority 1 in the interagency 5-year Action Plan for Newell's Shearwater and Hawaiian Petrel. In 2012, funding became available through several programs to undertake this action at Kīlauea Point National Wildlife Refuge (KPNWR), which is home to one of the largest seabird colonies in the main Hawaiian Islands. The project was named the "Nihoku Ecosystem Restoration Project" after the area on the Refuge where the placement of the future colony was planned. The Nihoku Ecosystem Restoration Project is a result of a large partnership between multiple government agencies and non-profit groups who have come together to help preserve the native species of Hawaiʻi. There were four stages to this multi-faceted project: permitting and biological monitoring, fence construction, restoration and predator eradication, followed by translocation of the birds to the newly secured habitat. The translocation component is expected to last five years and involve up to 90 individuals each of NESH and HAPE.

Prior to fence construction, baseline monitoring data were collected in order to provide a record of initial site conditions and species diversity. Surveys were conducted quarterly from 2012-2014, investigating diversity and richness of plant, invertebrate, mammalian, and avian species. A 650 m (2130 ft) long predator proof fence was completed at Nihoku in September 2014, enclosing 2.5 ha (6.2 ac), and all mammalian predators were eradicated by March 2015. From 2015-2017, approximately 40% of the fenced area (~1 ha) was cleared of non-native vegetation using heavy machinery and herbicide application. A water catchment and irrigation system was installed, and over 18,000 native plants representing 37 native species were out-planted in the restoration area. The plant species selected are low-in-stature, making burrow excavation easier for seabirds while simultaneously providing forage for Nēnē (*Branta sandvicensis*). Habitat restoration was done in phases (10-15% of the project per year) and will be continued until the majority of the area has been restored. In addition to habitat restoration, 50 artificial burrows were installed in the restoration to facilitate translocation activities.

From 2012-2017 potential source colonies of NESH and HAPE were located by the Kauaʻi Endangered Seabird Recovery Project (KESRP) with visual, auditory, and ground searching methods at locations around Kauaʻi. The sites that were selected as source colonies for both species were Upper Limahuli Preserve (owned by the National Tropical Botanical Garden; NTBG) and several sites within the Hono o Nā Pali Natural Area Reserve system. These sites had high call rates, high burrow densities to provide an adequate source of chicks for the

translocation, and had active predator control operations in place to offset any potential impacts of the monitoring. Translocation protocols were developed based on previous methods developed in New Zealand; on the ground training was done by the translocation team by visiting active projects in New Zealand. In year one, 10 HAPE and eight NESH were translocated, and the goal is to translocate up to 20 in subsequent years for a cohort size of 90 birds of each species over a five year period. Post-translocation monitoring has been initiated to gauge the level of success, and social attraction has been implemented in an attempt to attract adults to the area. It is anticipated that the chicks raised during this project will return to breed at Nihoku when they are 65-6 years old; for the first cohort released in 2015 this would be starting in 2020. Once this occurs, Nihoku will be the first predator-free breeding area of both species in Hawaiʻi.

1 INTRODUCTION

1.1 Project background

Islands make up 1.3% of the U.S. land area yet are home to 43% of species listed under the Endangered Species Act (ESA) and 53% of extinctions (Reaser et al. 2007, Spatz et al. 2017). Invasive species are one of the primary threats to island ecosystems and are responsible for approximately two-thirds of all island extinctions in the past 400 years (Blackburn et al. 2004, Reaser et al. 2007, Helmstedt et al. 2014, Tershy et al. 2015). Hawaiʻi not only is the state with the greatest number of threatened, endangered, and extinct species, but also the state with the highest proportion of endemic flora and fauna (Ziegler 2002). Non-native mammals, primarily rats (*Rattus* spp.), cats (*Felis catus*), mongooses (*Herpestes auropunctatus*), goats (*Capra hircus*), sheep (*Ovis aries*), and pigs (*Sus scrofa*), in addition to invasive weeds, disease, and fire, have had devastating impacts on ESA listed and at-risk species and are major factors in population declines and extinctions in Hawaiʻi and elsewhere (Ziegler 2002, Reaser et al. 2007).

Newell's Shearwater (NESH; *Puffinus auricularis newelli*) and Hawaiian Petrel (HAPE; *Pterodroma sandwichensis*) are listed under the ESA and are Hawaiʻi's only endemic seabirds. They are both declining due collisions with power lines, light attraction, predation by feral domestic cats, rats, mongooses, and introduced Barn Owls (*Tyto alba;* BAOW), and habitat degradation by feral ungulates (pigs, goats) and invasive exotic plants. Radar survey data indicate the populations of NESH and HAPE on Kauaʻi have declined by 94% and 78%, respectively, between 1993-2013 (Raine et al. 2017). Protection of NESH and HAPE on their nesting grounds and reduction of collision and lighting hazards are high priority recovery actions for these species. One of the most effective ways to secure their nesting grounds is to exclude predators from entering the area with fencing and subsequent mammalian predator removal. However, since virtually all of their current breeding colonies are in high-elevation montane environments, effective predator exclusion fencing has not been possible until very recently.

Predator exclusion fencing, i.e., fencing designed to keep all non-volant terrestrial vertebrates out of an area, has been used widely with positive results (Day & MacGibbon 2002, Young et al. 2013, VanderWerf et al. 2014, Tanentzap & Lloyd 2017, Anson 2017). The fencing excludes animals as small as two-day old mice, and prevents animals from digging under or climbing over the fence. Fence designs developed in New Zealand have been shown previously to exclude all rodents and other mammalian pests in New Zealand, and more recently in Hawaiʻi (Day & MacGibbon 2002; Young et al. 2012 and 2013). Resource managers in New Zealand have built more than 52 predator exclusion fences that protect more than 10,000 hectares, and these fenced areas are now refuges for a majority of the endangered species. Six predator exclusion fences have been built in Hawaiʻi to date that exclude all mammalian predators. The use of predator fencing greatly increases the effectiveness of existing animal control efforts, shifting the focus from perpetually attempting to control predator numbers to eradication (Long and Robley 2004). Predator fencing makes it feasible to remove all animals from within the fenced unit and to focus control efforts on buffer areas around the perimeter of the fence. In Hawaiʻi, the use of predator fencing is especially promising because it can provide areas within which the entire ecosystem, including native vegetation, can recover and where birds and snails can breed and forage free from the threats of introduced terrestrial vertebrate predators (MacGibbon and Calvert 2002; VanderWerf et al. 2014).

The impetus for this project was a settlement from a lawsuit against various entities for take of NESH and HAPE under the ESA on the island of Kauaʻi, Hawaiʻi. This project was conceived in 2011 and began in earnest in 2012 in order to create breeding colonies of NESH and HAPE that were safe from predators as well as from power lines and light attraction. This would be accomplished through constructing a predator exclusion fence, removing the predators, and establishing the seabird colonies through translocation and social attraction. The site chosen for this project was Kīlauea Point National Wildlife Refuge (KPNWR) on the North coast of Kauaʻi, Hawaiʻi. The Refuge was chosen for its location as well as its permanent, dedicated land use for conservation purposes.

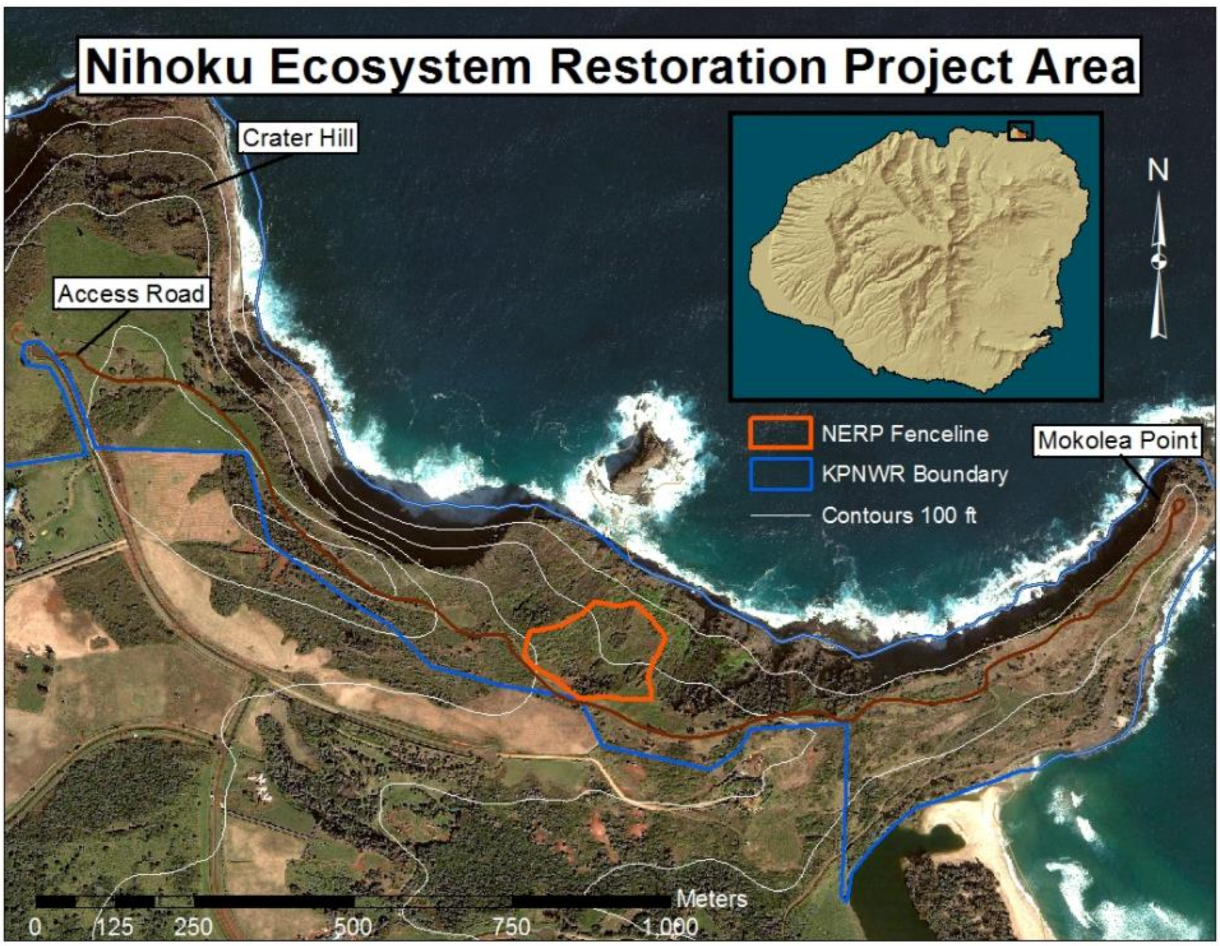

Figure 1: Nihoku Ecosystem Restoration Project area within Kilauea Point National Wildlife Refuge (KPNWR).

KPNWR is managed by the U.S. Fish and Wildlife Service (USFWS) under the U.S. Department of the Interior, and is one of the few places in the main Hawaiian Islands (MHI) with an abundant diversity of seabirds (Pyle and Pyle 2017). A remarkable 27 seabird species have been observed at Kīlauea Point over the years, making it one of the premier sites for seabirds in Hawaiʻi (USFWS 2017). Wedge-tailed Shearwaters (*Ardenna pacifica*) are the most numerous seabird species on the Refuge, with an estimated 8,000-15,000 breeding pairs. The Red-footed Booby (*Sula sula*) colony is the largest in the MHI, with a maximum of 2,536 nests counted. About 200 pairs of Laysan Albatrosses (*Phoebastria immutabilis*) nest on and near KPNWR, the largest colony outside the Northwestern Hawaiian Islands (NWHI). About 350 pairs of Red-tailed Tropicbirds (*Phaethon rubricauda*) nest on the Refuge, as well as smaller numbers of White-tailed Tropicbirds (*P. lepturus*). The Refuge harbors up to 13 breeding pairs of NESH. The Refuge is the only easily accessible location where this threatened species nests and thus is a source of much information on NESH breeding biology. Additionally, there are 300 Nēnē (Hawaiian Goose, *Branta sanvicensis;* HAGO) in the Kīlauea Point area, making the Refuge population one of the largest concentrations on the island as well as providing a high-island refugium for seabird populations potentially displaced by sea level rise as a result of climate change in the Northwestern Hawaiian Islands (NWHI; Reynolds et al. 2017).

The area on the Refuge that was chosen to construct the fence, called Nihoku, is between the Crater Hill and Mōkōlea Point sections of the Refuge. It was chosen for its bowl-shaped sloped topography that faces northeast into the prevailing winds. The site has no visible light sources, has ideal wind and slope conditions to facilitate flight for the birds, and was suitable for a fully enclosed predator exclusion fence (vs. a peninsula style fence). However, the habitat in the chosen location was not suitable for either NESH or HAPE and a high level of habitat restoration would need to occur to make it suitable for both species. Thus in order to create a safe and suitable breeding colony for these two species, considerable modification and effort was needed. The project was named the "Nihoku Ecosystem Restoration Project" (NERP) in recognition that the ultimate goal, in addition to creating a seabird colony, was a full ecosystem restoration. There were four stages to this multi-faceted project: permitting and biological monitoring, fence construction, restoration and predator eradication, followed by translocation of the birds to the newly secured habitat.

The purpose of this report is to provide an overview of the process that was undertaken to complete this project, including the fence construction, planning for seabird translocations, and the legal compliance. Predator exclusion fencing and seabird translocation projects continue to be initiated in Hawaiʻi and it is hoped that the information compiled from this experience will contribute toward the greater body of knowledge on the subject, and serve to facilitate planning of future projects.

1.2 Objectives

The objective of this project was to create safe nesting habitat for Newell's Shearwaters and Hawaiian Petrels, Hawaiʻi's only two endemic seabirds, and to enhance the existing breeding colonies of Laysan Albatross and Nēnē that already nest in the area.

Evaluation Metrics:

The following metrics were used to evaluate success at each stage of the project:

- Area of habitat enclosed with predator exclusion fencing and cleared of predators

- Number of seabird breeding pairs protected, by species
- Change in number of seabird breeding pairs, by species
- Change in breeding success of listed bird species (HAPE, NESH and Nēnē)
- Numbers of NESH and HAPE chicks successfully translocated
- Number of NESH and HAPE chicks successfully fledged per year, including natural nests and translocated chicks.
- Numbers of NESH and HAPE breeding pairs resulting from natural colonization (socially attracted)
- Numbers of NESH and HAPE breeding pairs resulting from translocated chicks.

1.3 Partners

The Nihoku Ecosystem Restoration Project is a result of a large partnership between multiple government agencies and non-profit groups who have come together to help preserve the native species of Hawaiʻi. The USFWS serves as the landowner and partner where the project is conducted. The USFWS works with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people, and is steward to the National Wildlife Refuge System. Kīlauea Point National Wildlife Refuge is home to Nihoku, and was established in 1985 to preserve and enhance seabird nesting colonies.

Pacific Rim Conservation (PRC) is a non-profit organization that coordinates the Nihoku Ecosystem Restoration Project with all partners. Their role is to oversee all aspects of the restoration, predator exclusion fence, and care of the translocated chicks. PRC conserves and restores native species throughout Hawaiʻi and the Pacific.

The Kauaʻi Endangered Seabird Recovery Project is a joint project of the Pacific Cooperative Studies Unit of the Research Corporation of the University of Hawaiʻi and the Hawaiʻi Division of Forestry and Wildlife (DOFAW) project. Their role is to undertake all of the montane habitat management and research of the seabirds being brought to Nihoku, particularly locating suitable chicks for translocation, monitoring them through the season and physically translocating them to Nihoku. The project focuses primarily on conservation and research of Kauaʻi's three endangered seabirds– Newell's Shearwater, Hawaiian Petrel and Band-rumped Storm-Petrel (*Oceanodroma castro*).

American Bird Conservancy (ABC) is a funder and assists with project development and execution when needed. ABC's focus is on efficiency and working in partnership, to take on the toughest problems facing birds today, innovating and building on sound science to halt extinctions, protect habitats, eliminate threats, and build capacity for bird conservation.

The National Fish and Wildlife Foundation (NFWF) provides funding support for Nihoku. Chartered by Congress in 1984, NFWF works to protect and restore the nation's fish, wildlife, plants and habitats. Working with federal, corporate and individual partners, NFWF has funded more than 4,000 organizations and committed more than $2.9 billion to conservation projects.

The National Tropical Botanical Garden (NTBG) is a Hawaiʻi-based not-for-profit institution dedicated to tropical plant research, conservation, and education. NTBG assists with habitat restoration at Nihoku, and its Upper Limahuli Preserve serves as a source colony from which some of the translocated seabirds were taken.

The David and Lucille Packard Foundation Marine Birds Program focuses on enhancing ocean biodiversity by protecting seabirds and shorebirds and their habitats around the world. The Foundation provides funding support for this project.

1.4 Timeline and chronology

- 2011 – Project initiation and Nihoku selected as project site
- 9/2012 – Permitting process initiated for all county, state, and federal permits
- 2012-2014 – Pre-construction biological monitoring (conducted quarterly)
- 2012-2017 – Source colony searches undertaken to locate seabirds for translocation
- 4/2013 – Archaeological assessment performed
- 5/2013 – Scoping letters sent to community & stakeholders for the environmental assessment of fence construction
- 3/2014 – Final Environmental Assessment of the Nihoku Ecosystem Restoration Project at Kīlauea Point National Wildlife Refuge and Finding of No Significant Impact statement
- 5/2014 – Special Management Area (SMA) permit issued by the county of Kauaʻi
- 6/2014 – Ground-breaking blessing ceremony. Fence construction started
- 9/2014 – Fence construction completed
- 11/2014 – Mammalian predator eradication initiated
- 3/2015 – Mammalian predator eradication completed (including mice)
- 3/2015 – Phase I habitat restoration started (~0.2 ha). Construction of water catchment system. Installation of seabird nest boxes, social attraction system
- 10/2015 – Environmental Assessment of "Management Actions for immediate implementation to reduce the potential for extirpation of ʻUaʻu (Hawaiian Petrel) from Kauaʻi" and Finding of No Significant Impact statement
- 10/2015 – First HAPE translocation commences
- 12/2015 – First HAPE cohort fledged from Nihoku (9 of 10 chicks)
- 5/2016 – Phase II habitat restoration (~0.4 ha) with volunteer-coordinated effort
- 8/2016 – Final Environmental Assessment of "ʻAʻo (Newell's Shearwater) Management Actions" and Finding of No Significant Impact statement
- 9/2016 – First NESH translocation
- 10/2016 – First NESH cohort fledged from Nihoku (8 of 8 chicks)
- 10/2016 – Second HAPE translocation
- 12/2016 – Second HAPE cohort fledged from Nihoku (20 of 20 chicks)
- 6/2017 – Phase III habitat restoration (~0.4 ha) with volunteer-coordinated effort

- 9/2017 – Second NESH translocation
- 10/ 2017 – Third HAPE translocation
- 11/2017 – Second NESH cohort fledged from Nihoku (18 of 18 chicks)
- 12/2017 – Third HAPE cohort fledged from Nihoku (20 of 20 chicks)

2 Permits and Regulatory Process

In preparation for the predator exclusion fence construction as well as for the translocation, a total of 12 permits or consultations were needed and are summarized in Table 1 below. Permits that required extensive review or input are discussed in further detail.

Table 1: Summary of permits and consultations for the Nihoku Ecosystem Restoration Project

Permit	Responsible agency	Issued for
Coastal Zone Management Federal consistency review	DBEDT-OP	Fence construction
Special Management Area permit	County of Kauaʻi	Fence construction
NEPA Compliance: Fence EA	USFWS	Fence construction
ESA section 7 consultation	USFWS	Fence construction
NHPA Section 106 consultation	USFWS/DLNR	Fence construction
Rodenticide application permit	USFWS	Predator removal
Scientific collection permit	DLNR	Translocation
Special use permit	DLNR	Translocation
HAPE and NESH recovery permit	USFWS	Translocation
NEPA Compliance: HAPE translocation EA	USFWS	Translocation
NEPA Compliance: NESH translocation EA	USFWS	Translocation
Refuge special use permit	USFWS	Translocation

2.1 Environmental assessments

A total of three environmental assessments (EAs) were prepared by Anden Consulting for this project: one for fence construction, and one each for translocation of HAPE and NESH, and these documents formed the foundation from which all other permits and consultations were based. All three can be downloaded from www.nihoku.org. Initially, project partners discussed including these activities in the Comprehensive Conservation Plan (CCP) for KPNWR, which was scheduled to go out for public review in 2012. However, as a result of delays encountered during that process, the project decided to move forward with its own EA for fence construction.

The proposed actions included in the draft EA for the fence construction were:

(1) fence construction
(2) predator eradication and monitoring within the fenced area; and

(3) native habitat restoration through invasive species removal and revegetation with native plants.

The fence construction and habitat restoration EA evaluated potential impacts associated with Alternative A, the no action alternative, and Alternative B, the proposed action, and were fully disclosed, analyzed and described in detail. The implementation of the proposed action was determined to not result in significant impacts to any affected resources. The USFWS incorporated a variety of public involvement techniques in developing and reviewing the EA. This included direct mail of an initial scoping letter to a wide variety of Federal, State and County agencies, non-governmental organizations, and individuals, several public presentations about the project, direct mail (to the scoping distribution list) inviting review and comment on the Draft EA, press releases about the project, and posting information about the project and the Draft EA on the KPNWR website. The EA was available for a 45- day public review beginning on September 16, 2013 during which time six public comment letters were received. The comments received expressed concerns over impacts to State water quality, public access to nearby sites, and introduction and spread of invasive species. Responses to the public comments were prepared and are included in the Final EA which was released in March 2014. Based on the public comments received and considered, Alternative B as described in the EA was slightly modified to incorporate those comments and a finding of no significant impact (FONSI) was published on 4 March 2014.

While the fence EA was being written and reviewed, it became clear that finalization of the KPNWR CCP was not going to occur in a timeframe that was compatible with commencement of the next stage of the Nihoku project, and so the decision was made to do separate EAs for both the HAPE and NESH translocations. The HAPE EA evaluated management actions for immediate implementation to reduce the potential for extirpation of the endangered ʻUaʻu (*Pterodroma sandwichensis*, Hawaiian Petrel, HAPE) from Kauaʻi, Hawaiʻi. Alternatives considered included:

- Alternative A (Current Management): Continuation of current management activities related to the HAPE on Kauaʻi including predator control and invasive plant removal.
- Alternative B: Continuation of current management actions as described under Alternative A, and social attraction (playing recordings of HAPE calls) would be used to lure prospecting adult HAPE to the predator-free fenced area at Nihoku. Artificial burrows also would be installed.
- Alternative C (Preferred Alternative): Included all management actions described under Alternatives A and B, and the addition of chick translocation to the predator-free fenced area at Nihoku. Proposed actions related to chick translocation included (1) collection of chicks from source locations; (2) chick care at the translocation site; and (3) monitoring for HAPE at Nihoku.

The same public engagement strategy used for the fence EA was repeated for the HAPE EA. It was available for a 45-day public review ending 31 August 2015, during which time five public comment letters were received. Responses to the public comments were prepared and included as an appendix since one of the comments was extensive. Based on the review and analysis in the EA and the comments received during the public review period, the USFWS selected Alternative C for implementation because it had a higher potential for establishing a new breeding colony of HAPE that was protected from predation by introduced mammals and birds, which would reduce the probability of extirpation of HAPE from Kauaʻi.

For NESH, the same strategy and alternatives outlined for HAPE were used. The EA was available for a 30-day public review ending 10 June 2016, during which time six public comment letters were received. Responses to the public comments were prepared and included as an appendix because, similarly to the HAPE EA, several of the comments were extensive. Based on the review and analysis in the EA and the comments received during the public review period, the USFWS selected Alternative C for implementation because it had a higher potential for (1) establishing a new ʻAʻo breeding colony at KPNWR that was within an accessible, predator-free area, adjacent to the ocean, away from utility lines and disorienting lights and (2) evaluating the feasibility of social attraction and chick translocation as species recovery techniques, which would inform future seabird management.

2.2 Special management area permit

Hawaiʻi's Coastal Zone Management Act outlines objectives, policies, laws, standards, and procedures to guide and regulate public and private uses in the coastal zone management area, which is defined to be the entire State of Hawaiʻi. Since the project area was located entirely within the County Special Management Area (SMA) along the coastline, a SMA permit was required in order to construct the fence. Since the project cost fell under the $500,000, a minor SMA permit was applied for that did not necessitate a public hearing. The final determination was that the project would be consistent with the objectives and policies outlined in Hawaiʻi Revised Statutes (HRS) Chapter 205A-2 because it would preserve the quality of coastal scenic and open space resources and minimize adverse impacts on coastal ecosystems. The NERP would also be consistent with the Special Management Area guidelines outlined in HRS Chapter 205A-26 as it is proposed solely for the benefit of native wildlife and habitat. An approved SMA permit was issued in May 2014.

2.3 Federal recovery permit

Recovery permits are issued by the USFWS to qualified individuals and organizations to achieve recovery goals of ESA listed species, including research, on-the-ground activities, controlled propagation, and establishing and maintaining experimental populations. The information obtained from activities covered under recovery permits provides the USFWS with a better understanding on how best to conserve, manage, and recover federally protected species. Since the translocation of NESH and HAPE was being conducted by PRC, a non-profit non-governmental entity, a recovery permit was required from the USFWS for the action. The translocation plan and EAs for both species were used as the foundation for this permit. The permit request was approved in October 2015 for HAPE and amended in 2016 to include NESH, at which point the USFWS issued a biological opinion on the expected impacts of issuing the permit.

2.4 Land-owner permits

Various land-owner permits were required during this project to work on or remove birds from areas for translocation since the source colonies were spread out and located on federal, state and private lands. Formal special use and scientific collection permits were obtained from DLNR for both removing the birds and for working in a Natural Area Reserve. Similar permits were obtained from KPNWR for work on the Refuge and for translocating a NESH chick from within the existing Refuge colony to Nihoku. For private landowners, such as the National Tropical Botanical Garden, written agreements were put in place that explained partner roles and expectations as well as the biological impact of removal of birds for translocation.

2.5 Archaeological surveys and section 106 consultation

Steps were taken to determine the cultural and historical significance of the project area: (1) preparation of an Archaeological Assessment in May 2013 by Cultural Surveys Hawaii; (2) review of a previous Archaeological Inventory Survey completed in 1989 for KPNWR expansion; and (3) informal consultation with a variety of organizations and individuals who might have information regarding the project area, including the Kīlauea Point Natural History Association, Office of Hawaiian Affairs, and State Historic Preservation Division. The 2013 Archaeological Assessment met the State's requirement for an archaeological inventory survey (per HAR 13-13-276). No cultural resources were found within the project's area of potential effect during the survey. The full Archaeological Assessment was included as Appendix C in the fence environmental assessment. Although no specific resources were found in the project area during the archaeological survey, the general area is of cultural significance and has been treated as such.

2.6 Conclusions

While the number and length of permits required for this project was extensive, given the logistical constraints of moving two different listed species between sites with three different landowners, all partners showed a strong willingness to collaborate in order to achieve the goals of the project. Future projects should attempt to incorporate anticipated future management actions (such as fence construction and translocation) into existing planning documents to avoid the need for multiple EAs. In hindsight, it might have been preferable to combine all three EAs into one document, or into the CCP, but the timing would have delayed implementation of certain stages of the project. Given the declining populations of the seabirds, it was determined that delay associated with combining all the actions into one compliance document could potentially foreclose the possibility of action, hence the decision to move forward with independent NEPA documents.

3 PUBLIC OUTREACH

3.1 Introduction

In order to maintain good relations and transparency with the public, partners, and stakeholders, it is paramount that a well-planned outreach effort be included in a restoration project of this scale. Because the concepts for this project have their origins off-island (first in New Zealand and then at Kaʻena Point on Oʻahu), it also presented an important educational opportunity to introduce the public to contemporary methods in island conservation which were largely unfamiliar to many Kauaʻi residents.

3.2 Approach

The strategy taken with this project, given its close proximity to a residential neighborhood, was face to face interactions with the community as well as development of various educational materials to ensure all stakeholders were reached. Starting in 2013, PRC gave annual public talks at the Princeville Library to update the public on the project. From 2012-2014 PRC staff met with Refuge staff twice monthly to brief USFWS staff on the project; from 2014-2017, meetings with staff have been on average every two months with frequent e-mail and phone updates. PRC has also given annual tours to the project site for the public during Refuge week in October and numerous stakeholder tours on an on-demand basis. In addition to holding public meetings and site visits, PRC and KPNWR have attended several community meetings to discuss both the fence construction and seabird translocations, and all have been positive. Numerous press releases have been issued by all partners on this project resulting in dozens of popular media articles on the project with the majority of these documents permanently posted on the project website.

For the EA processes specifically, the USFWS incorporated a variety of public involvement techniques in developing and reviewing the EA. This included direct mail of an initial scoping letter to a wide variety of Federal, State and County agencies, non-governmental organizations, and individuals, several public presentations about the project, direct mail (to the scoping distribution list) inviting review and comment on the Draft EA, press releases about the project, and posting information about the project and the Draft EA on the KPNWR website. Upon finalization of each EA, a press release was done to announce its completion.

For the translocations, each year at least one press release has been done either at the beginning or end of the translocation season, to announce the project and its results for the year. Finally, project biologists have given numerous scientific presentations on the results of this work at various local, national and international scientific meetings.

3.3 Materials produced

- Posters – posters describing the project background, purpose, and outcomes were presented at the Hawaiʻi Conservation Conference and Pacific Seabird Group meetings, and one remains on permanent display at the KPNWR visitors center.
- Brochures – project brochures were developed and printed during the scoping phase of the project and then revised once translocations had been conducted. They were

formatted for both tri-fold printing and as two page pdf documents that can be downloaded from the project website. Each year approximately 200 brochures are distributed directly and many more are downloaded from the website.

- Videos – three short (< five minute) videos have been produced on the project by ABC; one on the translocation itself, one on the habitat restoration, and one on the artificial burrow design. All videos are permanently posted on the project website.
- Website – a dedicated project website (www.nihoku.org) was developed and is described below.

3.4 Website and blog posts

In 2016, a website was developed exclusively for the project at www.nihoku.org. The purpose of the website was to provide an easy to access location for project information and to house increasing numbers of important documents, such as EA's, project FAQ's and blog posts. The website is broken down into the following pages:

- Home – description of project objectives and background
- Threats – threats to NESH and HAPE and justification for the project
- Solutions – explanations of predator exclusion fencing, habitat restoration, managing montane colonies, and social attraction/translocation
- Partners – a list of partners, their missions, and roles in the project
- Downloads – project fact sheets, photo galleries, videos, EAs, and new releases
- News – current announcements, select media articles, blog posts
- Support Nihoku – a donation page directing individuals to either ABC or PRC's page

The website is updated monthly to add information and keep it current.

Blog posts were done regularly starting with the HAPE translocations in 2015 with 3-4 per year being published. ABC took the lead on writing and publishing these posts on their website and their length ranges from 500-1000 words. During the translocation period, frequent Facebook posts by all partners resulted in tens of thousands of views.

3.5 Summary

In the first five years of this project, the combined outreach efforts reached several thousand people directly through public presentations and one on one contact. Indirect reach through popular media articles is thought to be approximately three million individuals per year based on analyses provided by ABC through an independent contractor. In short, widespread media coverage has resulted in broad public awareness and support for this project, and hopefully, about the conservation status of these species as a whole.

4 BIOLOGICAL MONITORING

4.1 Introduction

Monitoring of biological resources before and after predator removal is crucial for measuring and demonstrating the benefits and effectiveness of predator fencing as a management technique compared with traditional fencing and predator control methods (VanderWerf et al. 2014). However, the types and amount of information gathered can vary dramatically depending on the site, budget, and goals, and in some cases there may be insufficient baseline data available to make the desired comparisons. In such cases, the use of simultaneous treatment and control sites located inside and outside areas that have been fenced and from which predators have been excluded can be used to measure the effects of predator fences. In the case of Nihoku, sufficient baseline data already existed for some taxa (seabirds), but was lacking for others (plants and invertebrates) to make these comparisons. Extensive monitoring of a variety of taxa therefore was undertaken prior to fence construction in order to document the effects of the predator exclusion fence.

To facilitate consistent, repeatable monitoring for a variety of species, a geo-referenced, 50 m interval grid oriented on magnetic north was installed (Figure 2), with points marked by white PVC with a 10 cm reveal. The rationale for selecting a 50 m grid was to provide an adequate number of replicates within the fenced area (N=14) for ecological comparisons and to have appropriate spacing for rodent bait stations, since 50 m is the average home range size for Black Rats (VanderWerf et al. 2014). The grid consists of stations inside the fence (experimental) and outside the fence (control) spaced every 50 m, resulting in 14 points inside the fenced area and 10 outside. With the exception of bird species, all biological monitoring was done using these grid points.

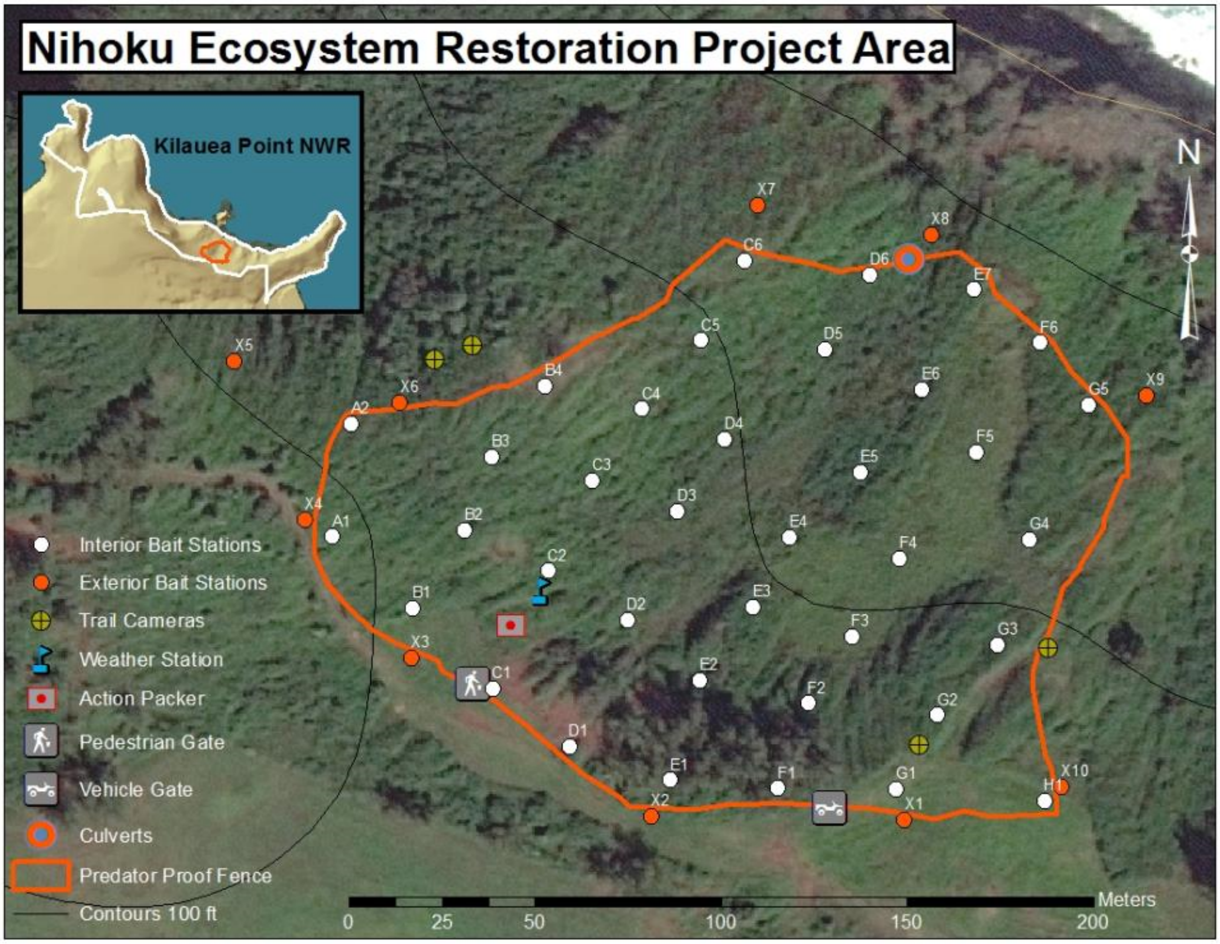

Figure 2: Nihoku fence monitoring grid with final fence line.

4.2 Methods

Seabird and Nēnē

All native bird species within the project area were, and continue to be, monitored in order to gather data on native species present and their reproductive success prior to predators being removed. Monitoring of existing Nēnē and Albatross nests in the project area was undertaken by conducting nest searches throughout the area and by recording the band number of individuals encountered. When nests were found, their contents were noted and the fate of the chicks was followed through to fledging.

During the NESH and HAPE breeding season (April - November), evening auditory and visual surveys for nocturnal seabirds were undertaken in 2013 and 2014 at six points in the project area. Surveys were done for two hours beginning at dusk following techniques outlined in Raine et al. 2017. In addition to the auditory surveys, automated recording units (song meters SM2+, Wildlife Acoustics) were deployed in two locations in June to collect recordings of any nocturnal seabirds present. One unit was deployed within the project site, while the other was placed for comparison within the small Newell's Shearwater colony at KPNWR. At the existing NESH colony, auditory playback was turned off once per week to allow the song meter to record NESH activity. Recorders were programmed to record one min of auditory data of every five minutes from dusk until dawn. The song meters were collected in November at the end of the breeding season. During both auditory and song meter surveys, Barn Owls were monitored to determine the predation risk of the incipient colony at Nihoku.

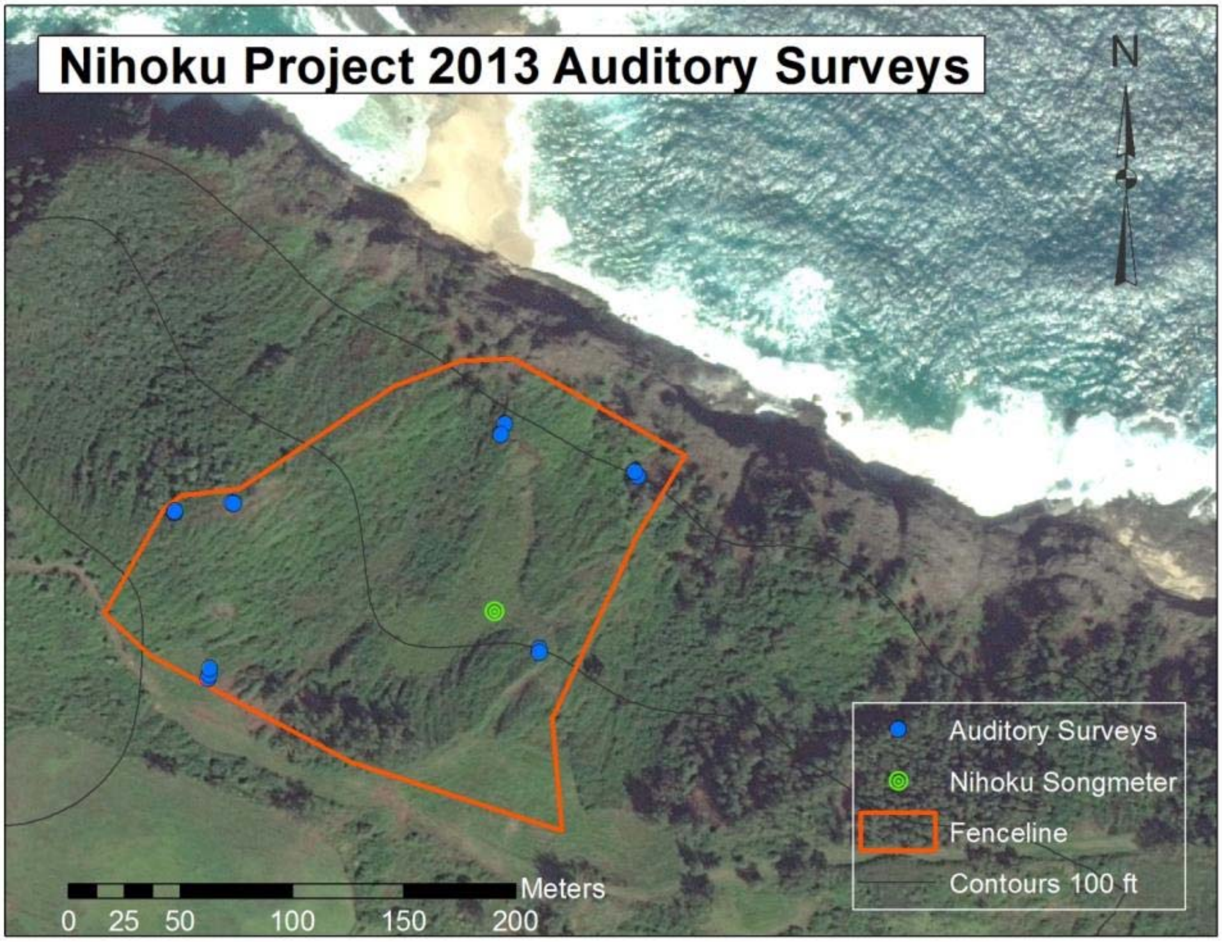

Figure 3. Auditory and song meter survey locations at Nihoku, with initial proposed fence line.

Detecting changes in bird population size associated with predator removal may require many years of monitoring, and it may be more feasible to detect changes in other population parameters, such as nesting success. Bird populations may respond slowly to management, and it may require several years for birds to begin using an area or for increased rates of recruitment to result in detectable population increases. For birds that have been extirpated, simply their presence in the area following predator fencing would demonstrate success.

Invertebrates:

Invertebrates are a relatively inconspicuous but extremely important component of native ecosystems. Native invertebrate communities provide integral ecological services, including pollination services and nutrient cycling, without which most Hawaiian plant species could not exist (Howarth and Mull 1992). Changes in abundance, diversity, and species composition of the invertebrate fauna at a site may help to indicate improved ecosystem functioning.

Invertebrates were monitored in December 2012, February, June, and September of 2013 using a variety of methods designed to capture animals that used different foraging methods (e.g., winged vs. not) and in different levels of the habitat (e.g., leaf litter vs. arboreal). Sampling was done at each grid point (N=24), and all insects gathered were stored in ethanol for future sorting. Methods for each of the sampling techniques are described below.

Pitfall Traps

For ground-dwelling species, pitfall traps are an effective passive sampling method (Spence and Niemela 1994). To install pitfall traps, a shallow hole was dug in the ground and a small cup or bowl filled with propylene glycol (anti-freeze) was used both as an attractant and preservative. The lip of the container was positioned to be even with the surrounding ground to ensure that crawling invertebrates fell into the container and could not escape. The Nihoku pitfall traps were baited and deployed for three days. Following trap collection, specimens were transferred into vials with 70% ethanol for storage.

Yellow Pan Traps

Many insects are attracted to the color yellow, a trait which is often used to facilitate their collection (Neuenschwander 1982). A yellow pan trap is a quick and easy way to catch specific types of invertebrates that are attracted to the color yellow (e.g., flies, wasps, and beetles). At Nihoku, a shallow yellow bowl was placed into a small hole so that its rim was level with the ground. The bowl was filled with water, and several drops of detergent were added to break the surface tension. The traps also collected invertebrates not attracted to yellow, intercepting them in the same manner as the pit-fall traps. Following collection of the pan traps, specimens were transferred to 70% ethanol for storage.

Yellow Sticky Cards

Sticky cards traps are used to collect the adult stages of flying insects (e.g., flies, gnats, shoreflies, leaf miners, winged aphids). Sticky cards consisted of 4”x 14” yellow card-stock, folded in two, coated with a thin veneer of a sticky paste (Seabright Laboratories Sticky Aphid Whitefly Trap without lure). At each gridpoint, a trap was hung from vegetation at the top of the canopy approximately 2-5 m from the ground, where it was visible to flying insects for up to three days. Sticky cards were collected and wrapped in plastic wrap for long-term storage.

Vegetation Beating and Sweep Netting

Vegetation beating and sweep netting are some of the most effective approaches for collecting a broad assortment of invertebrates from vegetation. To survey woody shrubs or trees, a 1x1 m canvas drop cloth, or “beat sheet”, was laid under the vegetation targeted for sampling. The vegetation was then shaken by hand, or “beaten” with a sweep net handle, to dislodge invertebrates present on the foliage. Specimens were then collected by hand or with forceps. Since herbaceous vegetation, grasses, and some shrubs did not lend themselves to beating, they were sampled with sweep nets. A canvas insect net was swung across vegetation, knocking off and capturing invertebrates present on the foliage. Those specimens were also collected by hand or with forceps. Fifteen beats and fifteen sweeps were completed at each of 24 sampling points within the Nihoku Ecosystem Restoration Project area.

Ant monitoring

Ants had a separate protocol to monitor for their presence because they are a documented threat to nesting seabirds in Hawaiʻi (Plentovich et al. 2017). At each of 24 sampling gridpoints spaced at 50-m intervals, two index cards were baited, one with spam and the other with peanut butter and honey to attract ant species with different dietary preferences, and left for two hours following protocols developed by the USFWS. Each card was then collected, the number of ants was noted, and the species were identified. Sampling was conducted five times in seasonal (quarterly) intervals. Species that were not easily identifiable were sent for further analysis to external entomologists.

Invertebrate specimens were identified to species where possible and invertebrate abundance was measured as a total number of individuals and/or biomass captured per trapping interval/ collection effort. Abundance of invertebrates in different feeding guilds (herbivores, detritivores, nectarivores, predators, parasitoids, etc.) will be examined to look for shifts in ecosystem functioning before and after predator removal.

Plants

Plant surveys were conducted using a hybrid plot – point-centered quarter design for density of trees and shrubs. Around each grid point, a 5m radius circular plot was constructed by laying out two 10 m long strings at marked in the center at 5 m, in North to South and East to West orientations, with markers intersecting, creating 4 quadrants.

Plant species were identified and recorded inside each quadrant in terms of percent cover by stratum. Quadrants were divided into three strata, or layers: Ground Cover, Shrub Layer, and Canopy Cover. Ground cover consisted of all plants less than 10 cm tall, and also included leaf litter, bare soil, and bare rock, totaling 100%. Shrub layer consisted of all plants between 10 centimeters and 2 m tall, and sometimes included open space, totaling 100%. Canopy layer consisted of all plants greater than 2 m tall, and open canopy, totaling 100%. Canopy height was measured using a clinometer/rangefinder, or by hanging a tape measure from the tallest tree within the 5 m plot.

Slope and aspect were measured at the center point using a compass with a clinometer arrow. Topographic position was recorded based on a list of pre-defined descriptors: Level, Lower-slope, Mid-slope, Upper-slope, Escarpment/Face, Ledge, Crest, Depression, and Draw. Soil texture and color were recorded, according to the Unified Soil Classification System and the Munsell Soil Color Chart index (http://soils.usda.gov/education/resources/lessons/color/).

Surveys were conducted quarterly in 2013, and an overall Refuge inventory was done March 19-22 by the Refuge in addition to the plot design so that we had an idea of percent cover, species assemblages and soil type.

Soil and weather

Soil samples were collected at each of the 24 survey points. Using a metal trowel, soil was collected from within 1 m of each gridpoint by inserting the trowel to a depth of up to 15 cm from the surface (generally only 5-10 cm) and rotating 360 degrees. Loose soil was placed in a labeled Ziploc bag and stored at room temperature for future analysis.

A Davis Instruments Vantage Vue weather station was installed within the project site on June 27, 2013 to passively collecting weather data. Data was downloaded monthly and batteries replaced in the wireless console approximately once per month. Weather data was collected from June 2013 to February 2015.

4.3 Results

Seabirds, Nēnē and owls:

In 2014, a total of two Nēnē nests and five Laysan Albatross nests were found within the proposed fence area (Figure 4). Neither Newell's Shearwater nor Hawaiian Petrel were detected during auditory surveys or with song meters, but numerous Wedge-tailed Shearwaters were detected, from birds nesting outside the project area (Figure 5). In addition, two Kermadec Petrels (*Pterodroma neglecta;* KEPE), which breed in New Zealand and the southern hemisphere, were seen regularly flying through the project area, vocalizing frequently and potentially doing courtship flights. While there are not any records of Kermadec Petrels nesting in Hawaiʻi, the behavior they exhibited during these surveys suggested they may be prospecting for nesting locations if they were not nesting already. This species has been recorded in previous years at KPNWR, and has occurred regularly at KPNWR throughout the breeding season for the last four years. Barn Owls were detected sporadically in small numbers.

Figure 4. Native bird nests recorded at Nihoku from 2012-2014, with initial proposed fence line.

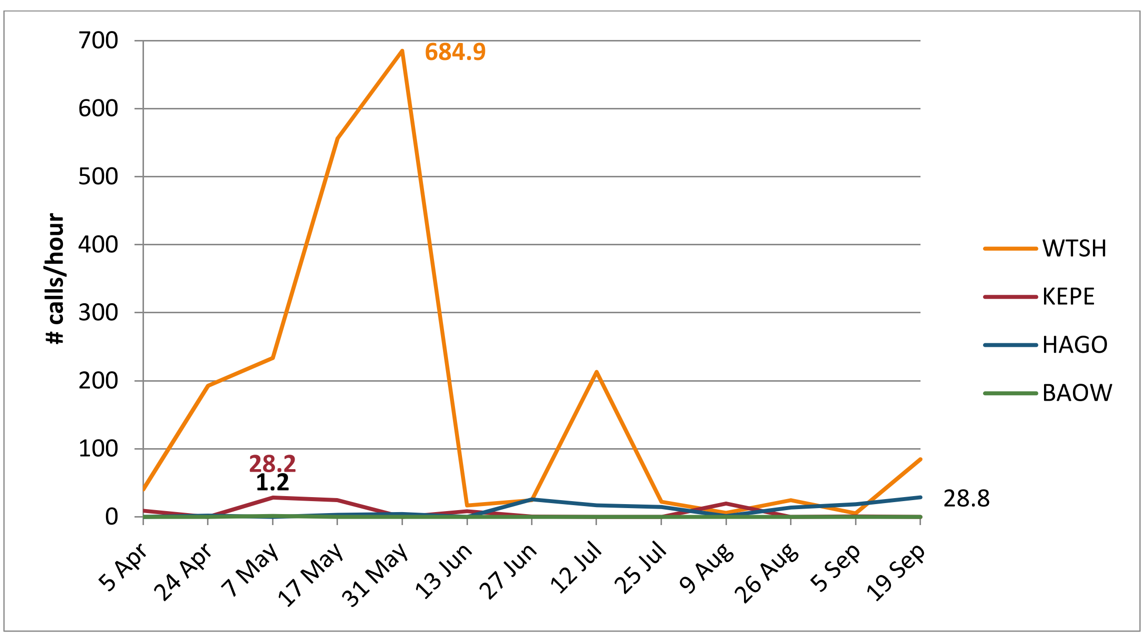

Figure 5: Frequency of avian species detected during evening auditory surveys from six points within the Nihoku fence area. Highest average detections per hour are labeled in corresponding

colors. WTSH = Wedge-tailed Shearwater; KEPE = Kermadec Petrel; HAGO = Hawaiian Goose (Nēnē); BAOW = Barn Owl.

Invertebrates

General insect collections were sent to external entomologists for storing and sorting at a later date. Ants were all identified to species (Figure 6).

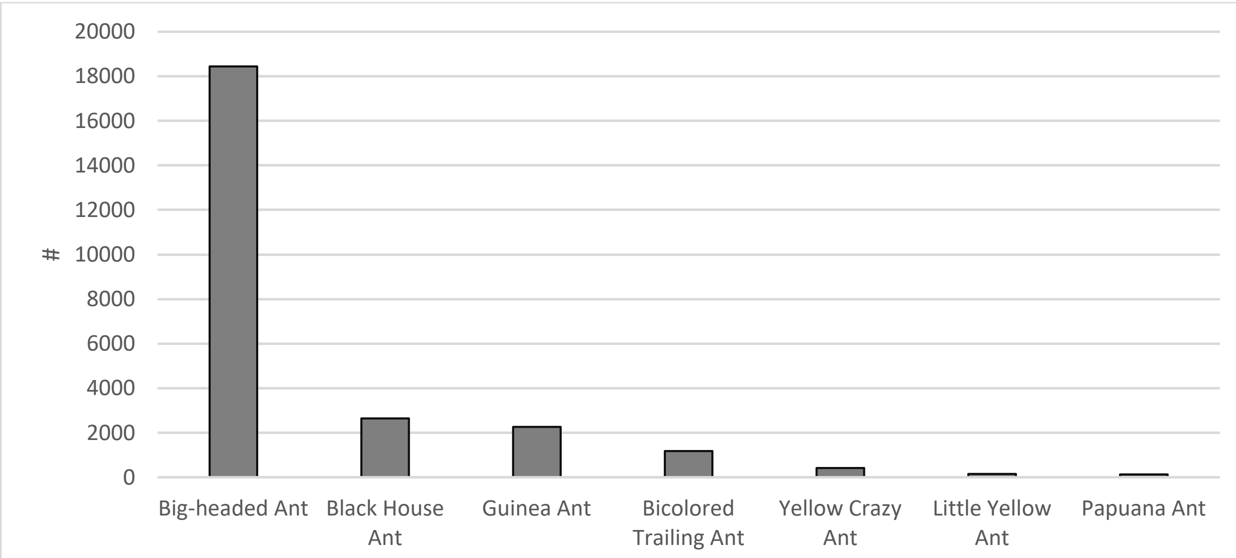

Figure 6: Species composition and relative abundance of ants at Nihoku.

No evidence of Little Fire Ants (*Wasmannia auropunctata*) or Tropical Fire Ants (*Solenopsis geminata*) were observed at the site, but one unidentified ant sent to entomologists was identified as *Solenopsis* sp. Fire ants are known threats to seabirds and were a concern for this project. Yellow Crazy Ants (*Anoplolepis gracilipes*), another ant known to threaten certain seabird species, were detected at Nihoku on several grid points. The recorded density of Yellow Crazy Ants is likely lower than the actual density, as this species is extremely agile and difficult to collect. At least one incident of colonization by Leptogenys Ants (*Leptogenys falcigera*) was witnessed, but not collected during ant sampling.

Plants:

A total of seven native plant species were detected (Figures 5-7), none of which were dominant within survey plots and none of which were listed species. The most common native species were naupaka (*Scaevola taccada*), ʻūlei (*Osteomeles anthyllidifolia*), ʻakoko (*Euphorbia celastroides var. stokesii*), and hala (*Pandanus tectorius*). Introduced *Schinus terebinthifolius*, commonly known as Christmas berry or Brazilian pepper tree, was by far the most abundant plant species in all three layers, and occupied >50% of shrub and canopy layers within the vast majority of survey plots (Figures 5-7). No rare or endangered plant species were detected that year. Across strata and 3 seasons of data collection, only 5.1% of total plant density recorded was native.

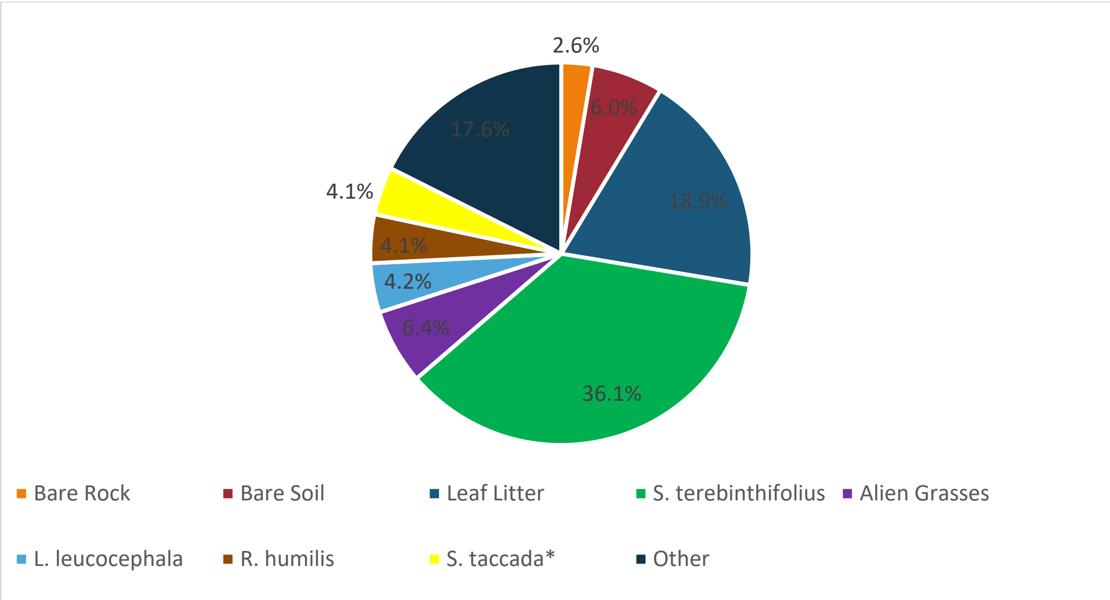

Figure 7: Pre-restoration plant species composition of ground cover stratum at Nihoku.

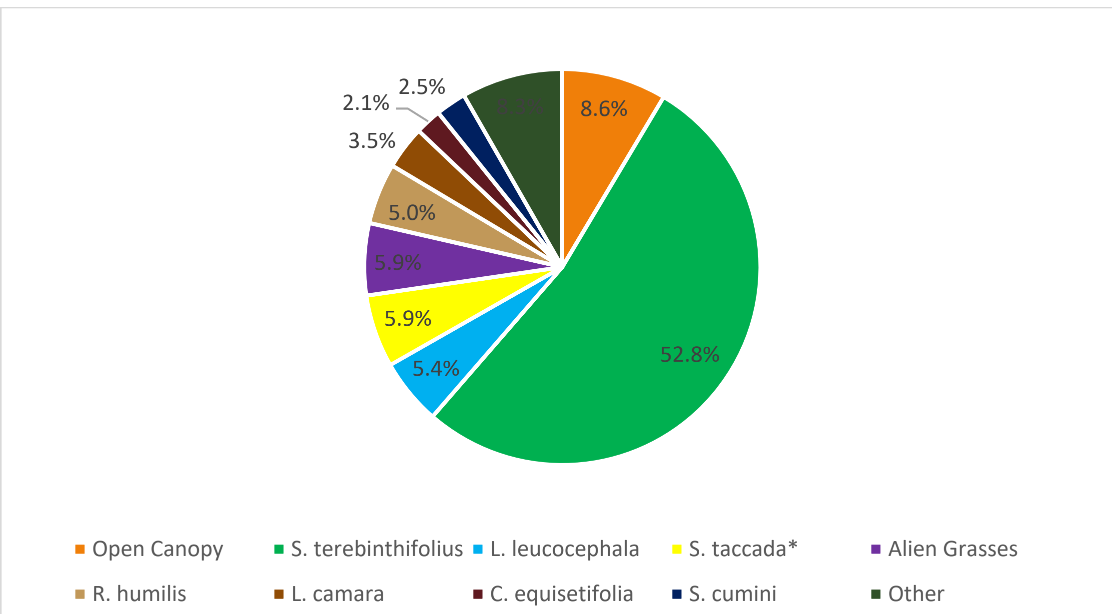

Figure 8: Pre-restoration species composition of shrub cover stratum at Nihoku. Note that >50% of this stratum was occupied by *Schinus terebinthifolius*.

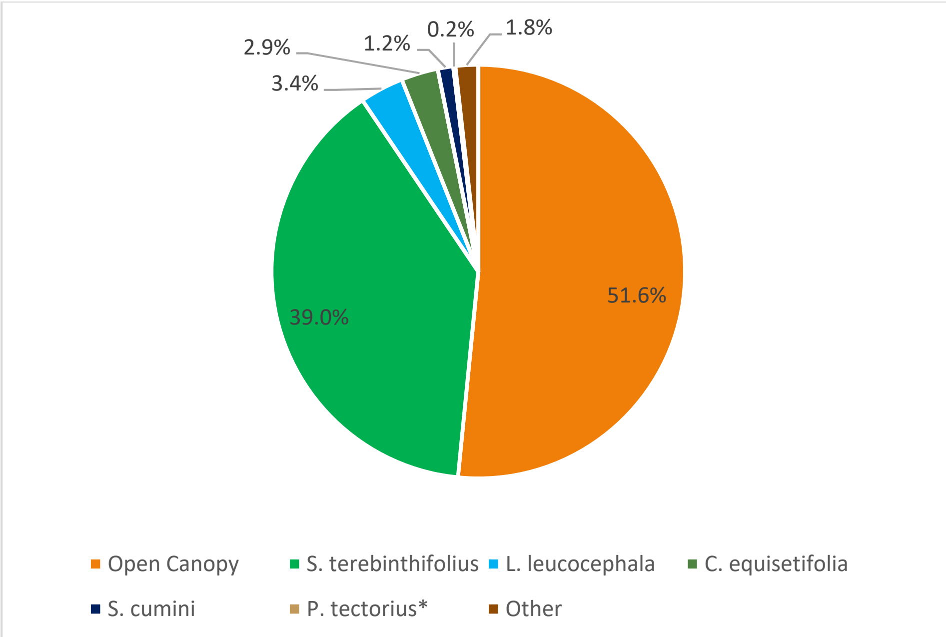

Figure 9: Pre-restoration species composition of canopy cover stratum at Nihoku. Note that only 0.2% of this stratum was occupied by native species.

Weather

From June-March, the Nihoku based weather station logged an average of 3.82 mm of rain per month, with peaks in the winter months.

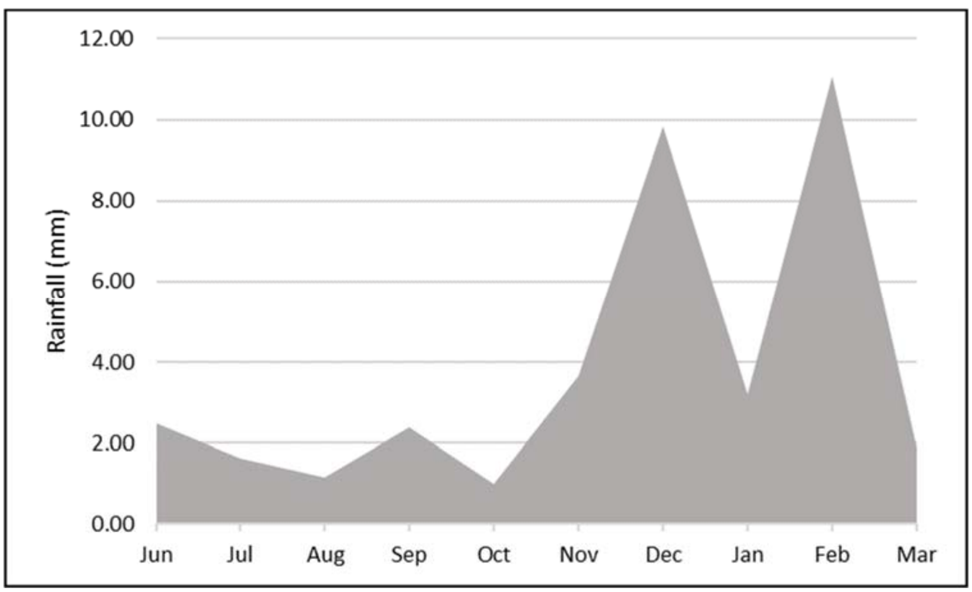

Figure 10: Average rainfall by month at Nihoku project site

5 PREDATOR FENCE SPECIFICATIONS

5.1 Introduction

The fence design, materials, and construction specifications are summarized in Table 2 and described in detail below. These were based on the specifications required to completely exclude the mammal species found on Kauaʻi, as determined by extensive research in New Zealand and trials in Hawaiʻi (Day and MacGibbon 2002, Burgett et al. 2007), and previous experience constructing predator fences in Hawaiʻi (Young et al. 2012, Young et al. 2013). The goal was to create an effective barrier against all known mammalian pests known to occur on Kauaʻi, as well as potential future pests (such as mongooses).

Table 2: Summary specifications of Nihoku predator exclusion fence.

Nihoku fence statistics	
Length	2,132 feet; 650 m
Area enclosed	6.2 acres; 2.5 ha
# pedestrian gates	1
# vehicle gates	1
Project manager	Pacific Rim Conservation
Builder	JBH Ltd
Date completed	September 2014
Cost/ft	$137.43
Cost/m	$451
Materials cost	$193,403.34
Labor cost	$99,596.66
Total cost	$293,000.00

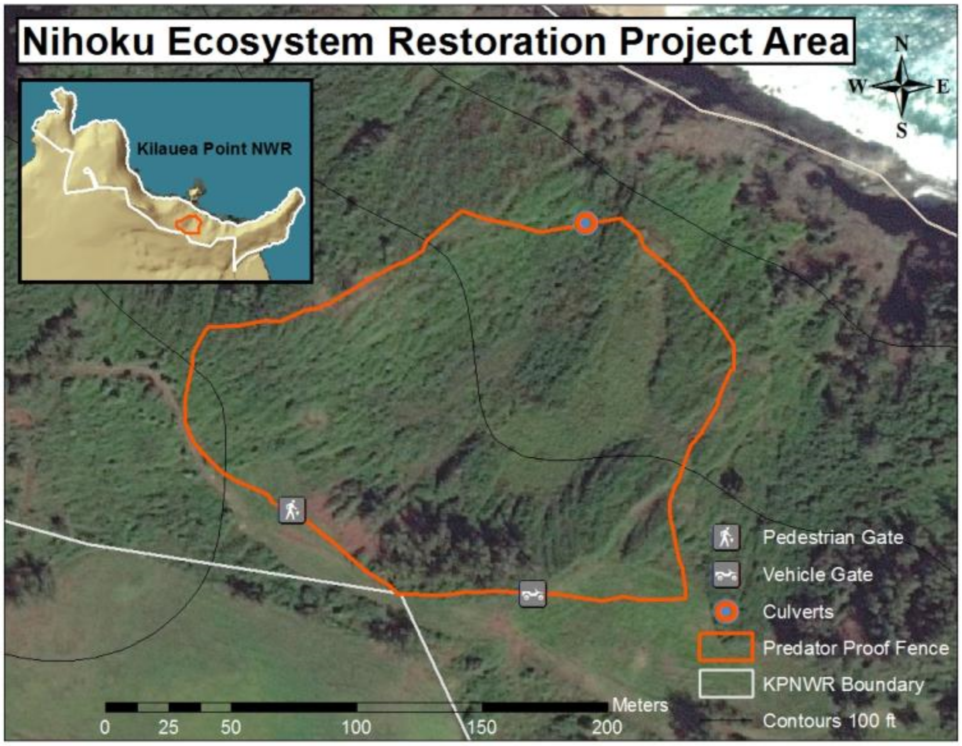

Figure 11: Final Nihoku predator fence alignment.

Figure 12: Nihoku fence photograph facing northeast.

5.2 Cost

The total cost for the 650m fence was $293,000. Of those costs, $99,596.66 was for labor and $193,403.34 for materials. The price per meter was $451/m. The cost was virtually identical to that of the Kaʻena Point fence, but an increase in quality due to the materials selected (Nihoku was all stainless steel vs. multiple metals at Kaʻena).

5.3 Fence design

The predator exclusion fence design has three main elements: fence posts, mesh (including the underground skirt), and rolled hood (see Figure 13 below). The fence posts provide the structural strength and framework on which other components are mounted, and was made of 2 inch square stainless steel posts and stainless steel fastenings. Posts were spaced two meters (6.6 feet) apart, with one meter of the post set below ground and two meters protruding above ground. Marine grade (316) stainless steel mini chain link mesh with an aperture of 10 x 8 millimeters was attached to the entire face of the base fence, and was also used to form a skirt of horizontal mesh at ground level, to prevent predators from tunneling under the fencing. The mesh extends from the top of the posts to just below ground level, while the skirt extends 300 millimeters from the fence and is buried 5-10 cm (2-4 in) underground.

The fence is high enough (2m) that animals, including cats, cannot jump over it, has a curved hood to prevent animals from climbing over the top, small aperture mesh (10 x 8mm) to prevent animals from squeezing through, and a skirt under the ground to prevent animals from digging underneath. Since the area where the fence was placed was not accessible to the public, a single door gate design was used for pedestrian gates instead of the double door gates at the public access Kaʻena Point fence (Young et al. 2012). Additionally, a vehicle gate was installed at Nihoku to allow heavy equipment into the area for restoration activities. All materials, including hood and posts, were 304 grade stainless steel with the exception of the mesh, which was 316 stainless steel. Materials were purchased directly from Pest Proof Fencing Co. in New Zealand and shipped to Hawaiʻi.

A single culvert was installed at the bottom (north) end of the fence where there was a natural ephemeral drainage feature. Despite little evidence of regular running water, it was clear that water did occasionally flow during periods of high rain. A three-foot-wide PVC tunnel was installed under the fence line, and cinderblock tiles were used to fill in the space around the culvert. Once it was complete, the fence was built overtop of the culvert, cemented in place, and a mesh screen was installed over the culvert openings to ensure it remained pest proof.

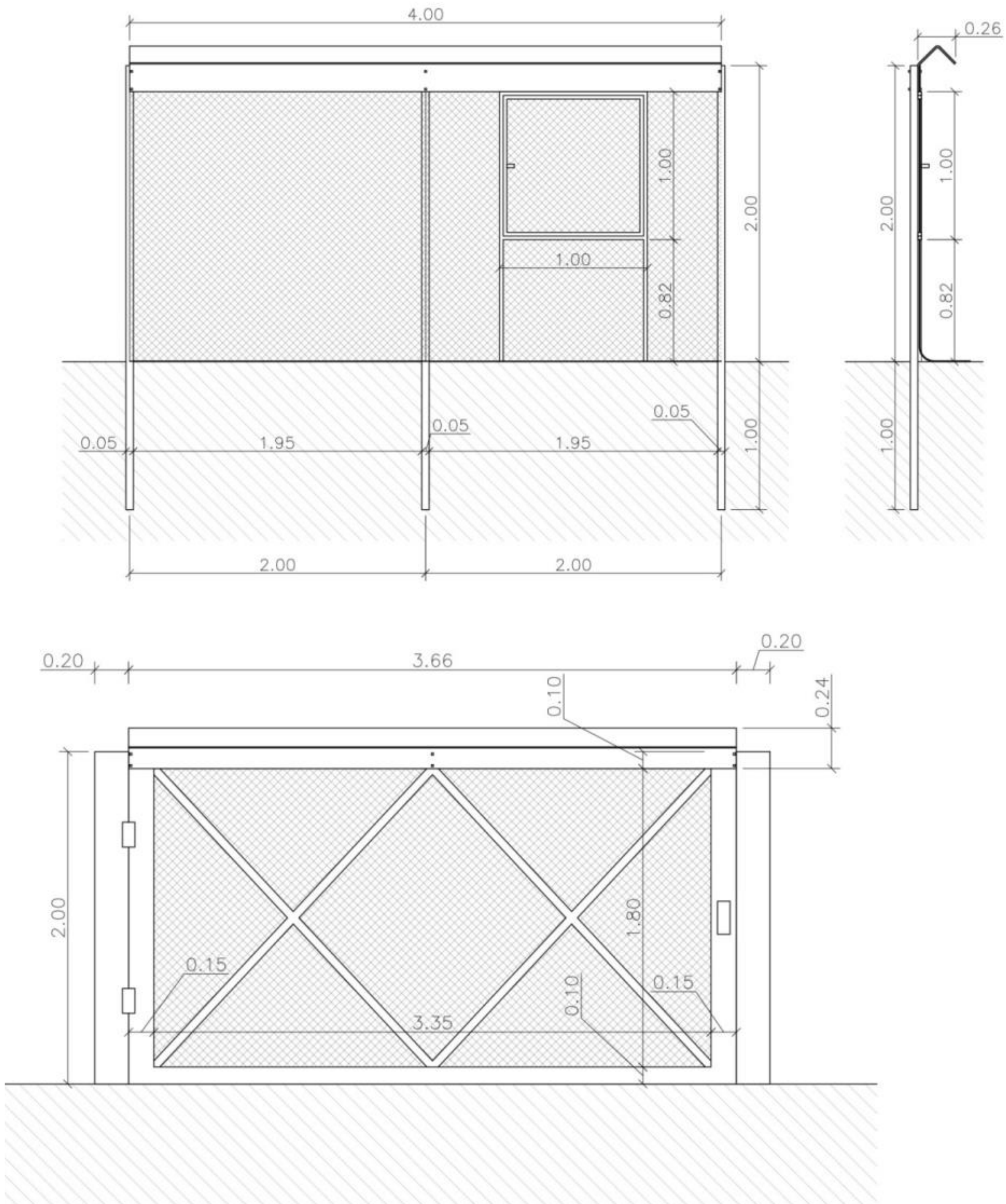

Figure 13: Predator exclusion fence technical specifications. Measurements are in meters.

Figure 14: Nihoku pedestrian gate (left) and culvert (right). The culvert is shown during construction. Fence exterior is on the right; mesh was placed over the inside of the culvert opening to prevent debris from getting into the culvert and to prevent rodents from entering.

5.4 Contract and selection of fence vendor

Three local fence contractors were approached and asked to provide cost estimates for construction of the fence at Nihoku. In the end, only one contractor submitted a bid (the other two declined to bid) and that contractor, JBH Ltd., was selected. JBH Ltd. assisted Xcluder in constructing the Kaʻena Point predator fence and thus was familiar with the technology and specific needs of such a project.

Construction needed to occur within a narrow three-month summer window in order to avoid the Nēnē breeding season at Nihoku, and having an explicit contract with deadlines was needed. Based on past experiences of contracting for other fences, the following were added as clauses (in addition to those outlined in Young et al. 2012):

1. Contractor was to supply all fasteners in the same metal grade (304 stainless) as the fence components. This clause gives the contractor some flexibility to select the best fastener for each scenario and thus reduce construction time.
2. Contractor was required to remove all construction waste.
3. Monetary penalties of $500/day were written into the contract for not completing the project on time, given the time constraints related to the Nēnē breeding season.
4. Re-negotiation of the contract price (up or down) if the final fence length varied by more than 5% of the estimated length.

5. Withholding of 50% of the contract value until completion and final inspection of fence have been signed off by an independent third party verifying that the fence has been built to specification.
6. A 30-day window to fix any construction deficiencies.

For this project, the contractor was also required to provide a complete parts list, including item description, material, manufacturer, and part number in a spreadsheet, and also a written maintenance manual, repair kit parts list, and one day of on the ground training for managers. The combination of these contract items, coupled with suggestions made in Young et al. 2012 made for a relatively smooth construction process.

5.5 Construction logistics

Fence construction began in June 2014 and was completed in September 2014. A construction window was established during contract negotiations tied to weather, road conditions, Nēnē nesting seasons, and ideal rodent removal periods. Permit regulations also dictated construction logistics to a certain extent.

Immediately prior to construction, the fence contractor was given oral as well as written instructions by project staff on appropriate behavior on the Refuge as well as training on endangered species identification. The area where machinery was allowed was clearly flagged, and any native plants or other notable features were flagged to prevent damage to the landscape. Contractors were notified of authorized walking trails, were required to bring their own portable toilet facilities, and were required to pack out any waste daily. Finally, a physical copy of all permits was given to the contractor and they were required to have these with them at all times on the job site and abide by the conditions set forth in the permits at all times.

The project consisted of the following stages of work:

- Clearing of fence-line (removing vegetation from a 3-4-meter wide swath, with machinery if possible or else by hand with chainsaws and hand tools)
- Fence platform formation (earthworks, drainage works, and culverts) with use of heavy equipment
- Installation of posts
- Attachment of hood sections
- Attachment of mesh (including ground pinning/cementing)
- Installation of culverts
- Installation of gates

For the most part, construction went as planned with no major issues encountered. Following construction, rubber water guides were installed along areas of the fence line with the steepest slope to divert water flow away from the fence and minimize erosion where bare soil was exposed. Pili grass (*Heteropogon contortus*) seed was also planted in these areas to enhance soil stabilization.

5.6 Maintenance

Based on discussions with other predator fence project managers, annual maintenance cost for materials is estimated to be 1% of the initial cost of the fence (e.g., $150,000 material cost = $1,500 per year in parts), plus labor. The extra 5% of materials from the original order can be used for repairs for the first few years. The staff time required to monitor the fence varies, but a monthly inspection on foot is recommended, with repairs on an as-needed basis.

To date, maintenance issues have been relatively minor for this fence both as a result of improvements made to the design and materials, and because it is still relatively new. The cost estimates provided above have been relatively accurate, and perhaps an overestimation of the initial maintenance costs. The two issues that have been encountered were with the vehicle gate and the steep slopes around the culvert. The ground under the gates settled after construction which put stress on the gate hinges and made it difficult to close. This was fixed by adjusting the hinges and ensuring everything is properly lubricated.

For future projects, the following are recommended for designing and implementing a fence monitoring program. While it may not be possible to implement all of these suggestions at all sites, they provide a foundation of the factors that should be considered when managing predator exclusion fences.

- An individual within the agency responsible for management at the site should be established as the primary point of contact for each fence. This individual would be in charge of scheduling maintenance and monitoring visits (even if they are not the one performing them) and would serve as a point of contact for anyone who needs to report a breach or any other relevant observations on the fence.

- A risk analysis of each fence should be undertaken regularly (e.g., during each regular monitoring visit) to identify possible areas of weakness. This analysis should identify possible reinvasion sites, such as at culverts, gates, overhanging trees, steep slopes, areas prone to high winds or rock falls, or in areas of public access. These sites should be inspected carefully during maintenance visits.

- To assist in having breaches reported in a timely manner, signs should be placed at high-risk areas and access points that provide contact information for whom to call in the event that a maintenance issue or predator is noticed. Fence posts also should be tagged with a unique number so that anyone reporting a breach can identify the location easily (e.g. fence panel #180). These can either be engraved into the fence posts or added as separate tags or labels.

- Storing fence repair supplies in the vicinity of high-risk areas can help to facilitate rapid repairs, particularly for mesh damage, which can often be fixed quickly by hand. Using the woven mesh in particular has an advantage in that a single spare wire can usually be woven into the fence to repair a hole.

- All fences need to be physically inspected on a regular basis. How regularly this is done depends on the risks prevalent on the site. Inspection may need to be monthly for some fences vs. quarterly for others. Specific recommendations for each fence are made in the implementation plan below. Factors that affect risk of breaches and pest reinvasion include:

public access and potential for vandalism and accidental damage; the nature and size of animals adjacent to the fence; proximity, extent, and size of adjacent trees; regularity and severity of flooding; regularity of people entering and leaving the fenced area; difficulty in eradicating pests within the fence following a reinvasion; and the value and sensitivity of the resources being protected by the fence.

• A physical fence inspection should be undertaken on foot where possible. Walking along the fence line allows the observer to view and inspect the fence closely and directly. Inspections should be periodically undertaken from both sides of the fence. When inspecting, there are four components to look at: hood, posts and stays, skirt, and mesh. The hood should be examined for excess lichen growth which can facilitate cats climbing over, corrosion at seams, attachment points, bends, and for scratches indicative of cats attempting to jump over. If scratches are noticed, the area should be examined to determine if there are jump points. Posts and stays should be examined for corrosion and loose attachments. Mesh should be examined for breaks in welds or links, corrosion or abrasion, and separation at the seams and attachment points. The skirt should be examined to ensure that there aren't any punctures, it is secured to the ground, not eroded underneath, and that the lip is not curling up and allowing pests to dig under.

• The duration between physical inspections can be increased by the installation of electronic surveillance systems. Solar-powered systems can detect open gates and fence damage, the location along the fence, and the extent of the damage and report it back to a control board or phone electronically. These are optional features that can notify managers immediately of an open gate or tree-fall, but do have additional costs and maintenance associated with them.

• When a fence breach occurs, it is important that any pests that enter the fence are detected quickly. If a breach goes unnoticed for some time and there is no pest detection program in place, it may become necessary to re-eradicate the pest species from the entire fenced area. The best way to detect pest intrusions is to establish a network of bait stations, traps, or tracking tunnels around the inside of the fence line and also either a grid of bait stations throughout the protected area or at least scattered stations in strategic locations. Such a grid of bait stations or traps was established previously to achieve complete pest eradication; retention of the station grid will assist with the early detection of any re-invaders. The grid need not be active at any given time, but having infrastructure in place will help to ensure a timely response.

• For budgeting purposes, it is estimated that during the first five years of the fence, minimal materials cost will be needed as extra materials ordered at the time of construction will be used for physical repairs. After year five, fence managers at other sites budget up to 1% of the capital fence cost per year to dedicate towards maintenance.

5.7 Design improvements

While the design for the Nihoku fence was conceptually the same as that for the Kaʻena Point fence, several changes were made (in addition to the gates described above) to reduce maintenance needs, cost, and facilitate construction.

The mesh used at Nihoku was a mini-chain link compared to the welded rectangular mesh used at Kaʻena Point. While both have comparable openings and are tested to exclude mice, the advantages of the chain link were that:

1. It came in 10m long rolls that could be woven together at vertical seams thus making the entire fence seamless and reducing weak points where two panels were joined together.
2. The rolls were 2.35m wide, which was wide enough to form the vertical fence and the horizontal underground skirt, thereby eliminating the horizontal seam that was present on the Kaʻena fence where two 1-m wide rolls were attached together to form a 2m high fence. This seam was particularly problematic at Kaʻena Point and has required constant maintenance.
3. Chain link is much more flexible to allow for contouring along hillsides and is less susceptible to breakage because it is not as taught as the woven mesh. This flexibility also eliminated the need for tension wires to hold the stiff welded panels taught.

Minor modifications also were made to the hood design. The main change was to use an uncoated hood product, and to eliminate the curved lip under the hood edge which collected water at Kaʻena Point. Despite costing the same, the new hood design used at Nihoku is more effective, requires less maintenance, and makes the fence slightly higher (since it curves up rather than down) thus increasing its effectiveness. An uncoated hood was requested for this project so that corrosion could be monitored more easily. The coated hood at Kaʻena Point was not stainless steel and rusted through within four years. However, since it was coated, the rust was not apparent until it had corroded all the way through the hood. The Nihoku hood, aside from being 304-grade stainless steel to increase its resistance to corrosion, was left uncoated so that any rust progression could be monitored more closely. However, a 200-m section of the Nihoku fence eventually was painted dark green after a neighboring resident complained of the bright metal reflection that could be seen off the hood into his home.

In addition to the contract and design changes already discussed, future fences could be improved by using treated wooden posts to allow for attachment flexibility with the mesh attachment, and by having a double door vehicle gate rather than a single large gate. The stress put on the single set of hinges across the 12-foot span for the vehicle gate was high. By having two doors that join at the center, less stress would be placed on the hinges, which would reduce maintenance and make the door easier to operate.

6 PREDATOR MONITORING AND ERADICATION PLAN

6.1 Introduction

All mammals in the Hawaiian Islands except the Hawaiian monk seal (*Monachus schauinslandi*) and the Hawaiian hoary bat (*Lasiurus cinereus semotus*) were introduced by people, some intentionally for food, pets, or biocontrol agents, and others as accidental stowaways (Tomich 1986). Because Hawaiʻi is so isolated from continental areas, the native plants and animals that evolved in the islands are naïve to mammalian predators and often lack defenses against them (Salo et. al. 2007, Sih et. al. 2009, VanderWerf 2012). Polynesians colonized the Hawaiian Islands about 800 years ago (Rieth et. al. 2011) and brought with them several destructive predators including the Pacific rat (*Rattus exulans*), domestic dog (*Canis familiaris*), and domestic pig (*Sus scrofa*) (Kirch 1982, Burney et. al. 2001). Introduction of alien predators accelerated with the arrival of Europeans starting in 1778, including the black or ship rat (*R. rattus*), Norway rat (*R. norvegicus*), domestic cat (*Felis silvestris*), small Indian mongoose (*Herpestes auropunctatus*), house mouse (*Mus musculus*), and European wild boar.

Predators, particularly black rats, are the single greatest threat to seabirds worldwide (Jones et. al. 2008). Feral cats and small Indian mongooses are known to be serious predators of seabirds on O`ahu and elsewhere in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002). Although mongoose do not appear to be established on Kauaʻi yet (Duffy and Capece 2014; Duffy et al. 2015), cats are a significant predator of Newell's Shearwater and Hawaiian Petrel on Kauaʻi, including in the source colonies for the translocation project (Raine et al. 2017a&b). Rodents, including black rats and Pacific rats, are known to prey on seabirds throughout the Hawaiian Islands, including Kauaʻi (Fleet 1972, Woodward 1972, Smith et. al. 2006, Raine et. al. 2017). Rats and house mice (*Mus musculus*) have also been documented to consume native plants, their seeds, and invertebrates (Shiels 2010). There are many examples in which eradication or control of predators has resulted in recovery of native species in Hawai`i (Hodges and Nagata 2001, Smith et. al. 2002, VanderWerf and Smith 2002, VanderWerf 2009, Marie et al. 2014, VanderWerf et al. 2014) and around the world (Côté and Sutherland 1997, Butchart et. al. 2006, Howald et. al. 2007). Three non-native predatory mammal species are regularly present at Nihoku: feral cats, black rats, and house mice.

Feral cats are present at Nihoku year-round and have caused substantial damage to seabird populations at KPWNR in the past. Dietary analysis of feral cats caught at Kaʻena Point on Oʻahu (a similar seabird colony) indicates that both seabirds and rodents are significant components of their diet (Lohr et al. 2013). Rats and mice are thought to be important ecosystem modifiers at Nihoku due to their consumption of prey at all levels of the food chain, from plants through birds. Rodents and cats therefore were the primary target of the Nihoku predator removal plan. Experience from other eradication attempts suggested that while mice do not pose the greatest risk for ecological restoration, they can be the most difficult species to eradicate due to their small home ranges, which require a higher bait application rate (VanderWerf et al. 2014).

The objectives of designing the predator removal program were to select the most effective method(s) available while considering the pest species present, the tools legally available for use, and the timeline and funding available. It is possible that the methods chosen do not reflect the most universally effective methods employed in other countries or states, but were the ones that were most feasible given the scope and constraints on this project. It should be noted that Barn Owls are a known predator of both NESH and HAPE, but will not be excluded with the fence and thus will be controlled on a semi-permanent basis. To inform these efforts, predators were monitored quarterly for two years in order to obtain an understanding of population densities and approximate home range sizes of species within the Nihoku project area.

6.2 Pre-eradication pest monitoring methods

Rodent monitoring was conducted from 2012-2014. Population data were collected by spacing rat snap traps (in Nēnē-exclusion boxes) on grid points (N=24) and mouse live traps on all grid points and then every 25 m between grid points (N=42). Traps were set seasonally (quarterly) for three nights after three nights of pre-baiting with peanut butter to acclimate them to the presence of the traps. Beginning in winter 2013, tracking tunnels were set quarterly for 24 hours with peanut-butter baited ink cards during the pre-baiting period.

To estimate rodent home range size, live traps were deployed during the November and March monitoring events to capture live rodents for tracking purposes. Haguruma brand live cage traps were used for rats and Eaton brand repeater mouse traps were used for mice. Both trap types were baited with peanut butter. All rodents captured were sexed, weighed, and identified to species. A small spool of white thread was glued to the back of each rodent captured. Spools used with rats weighed less than 2g and held up to 200m of thread; much smaller spools were used for mice. The end of the thread was tied to a piece of vegetation and the rodents were released. Two or three days later), GPS tracks of the path of the rodents were taken by following the thread. Maximum distance travelled was measured for each animal, and substrate and habitat type also were noted. From those distances, a minimum convex polygon was calculated within ArcGIS. Minimum convex polygons draw the boundaries of a home range from a set of location data is to construct the smallest possible convex polygon around the data.

Beginning in March 2013, cat monitoring and trapping was undertaken to determine their density using Bushnell trail cameras paired with 10 Havahart traps set at strategic locations (Figure 15). Trap locations were selected based on repeatedly noted cat sign (footprints, scat, predation). Traps and cameras were set four nights per week and baited with a rotation of vienna sausage, dried cuttlefish, pureed 'potted' meat, and soft cat food.

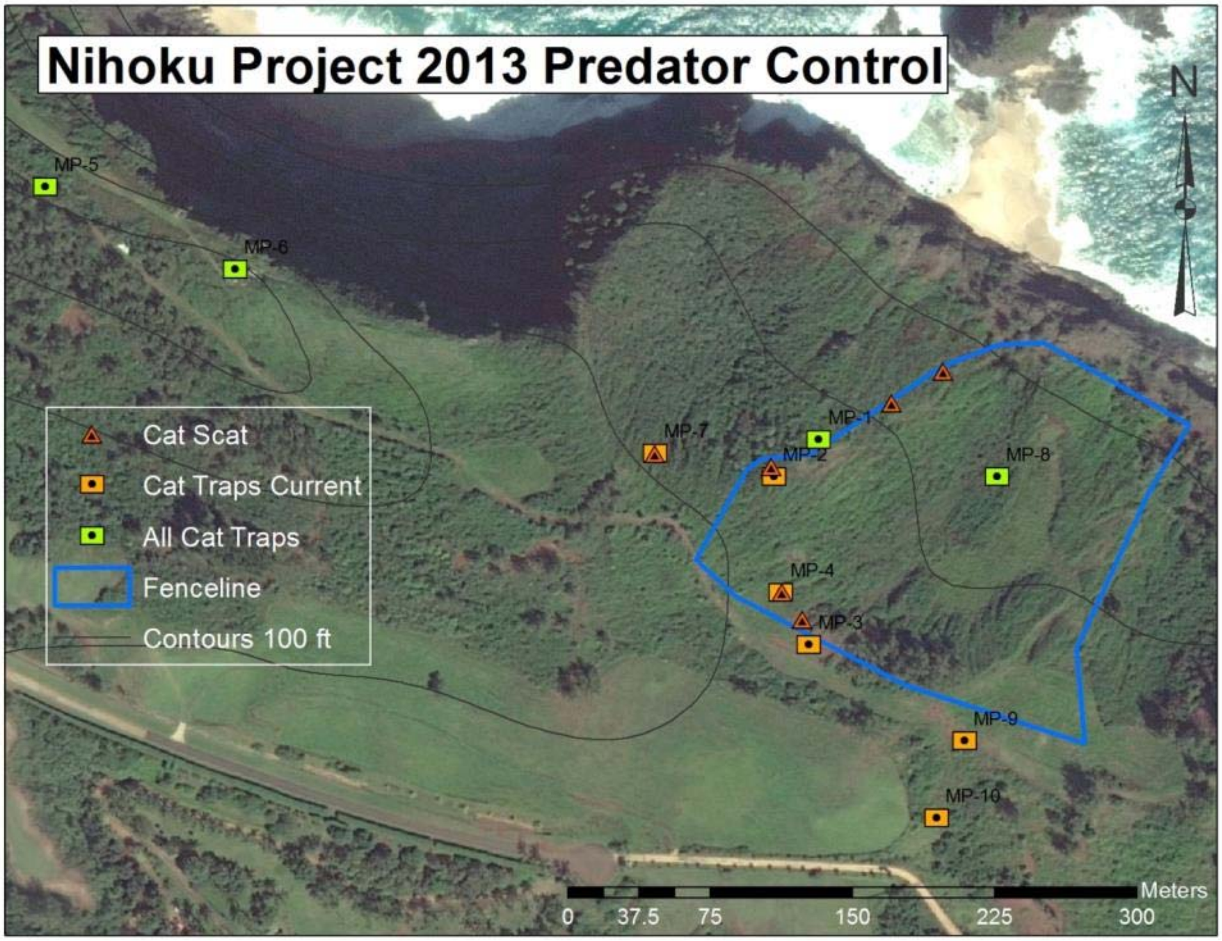

Figure 15: Nihoku cat control points.

6.3 Monitoring results and discussion

The rodent species detected were house mouse and black rat; no Polynesian rats were found. The catch rates varied seasonally, with the low point for mice in the winter and the low points for rats in the spring and summer (Figure 16). Despite the seasonal variation of both species, both measures of relative abundance were low indicating that densities likely were low.

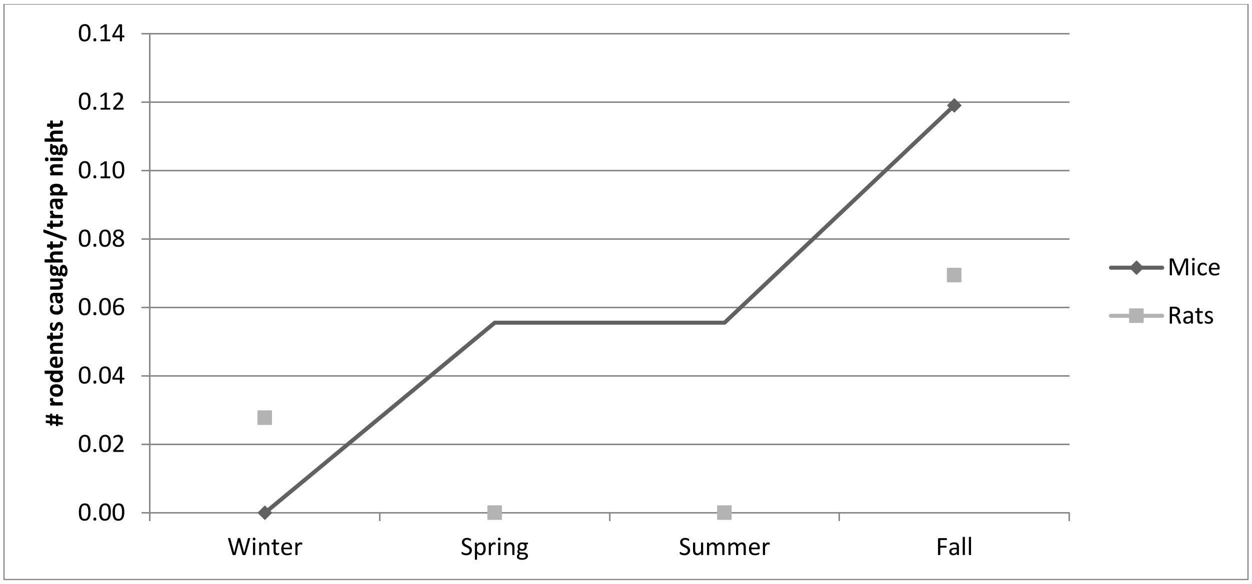

Figure 16: Frequency of rodent captures/ trap night by season.

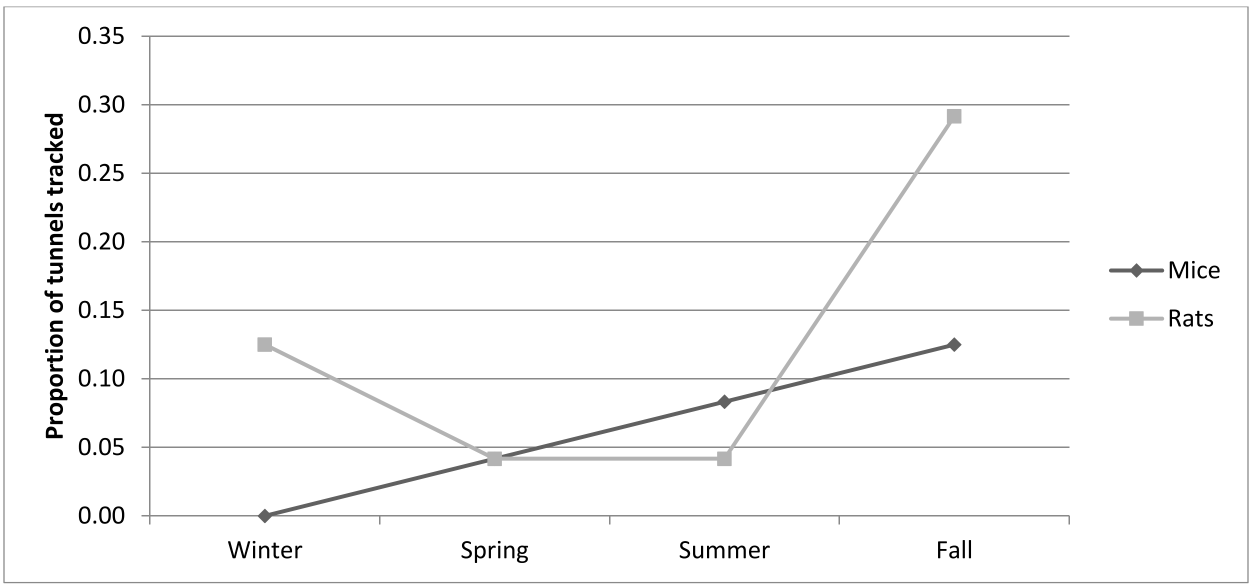

Figure 17: Frequency of tracking tunnel rodent detections by season**.**

A total of nine mice were tracked for home range estimation; two in the fall and seven in the spring. Rats were more difficult to catch in the live traps; three rats were tracked during the fall event and only one was tracked during the spring. Mice traveled an average maximum radius of 14 m (46 ft) with the spools of thread (range 7.1-29.4 m; Figure 18), resulting in an approximate home range size estimate of 0.015 ha (1565 ft^2; Figure 19). Rats traveled an average maximum radius of 28m (92 ft), for an estimated home range size of 0.021 ha (2214 ft^2). For eradication purposes, this corresponds with trap or bait station spacing of 12 m (40 ft) for mice and 15 m or 50 ft for rats, which would be a high-density trap placement. Typically, rodents in a high density situation will have smaller home ranges, however, in this case, the home ranges appear to be small and the densities low. It is possible that the poor habitat in the area has contributed to low densities for rodents and does not reflect high rates of intraspecific competition.

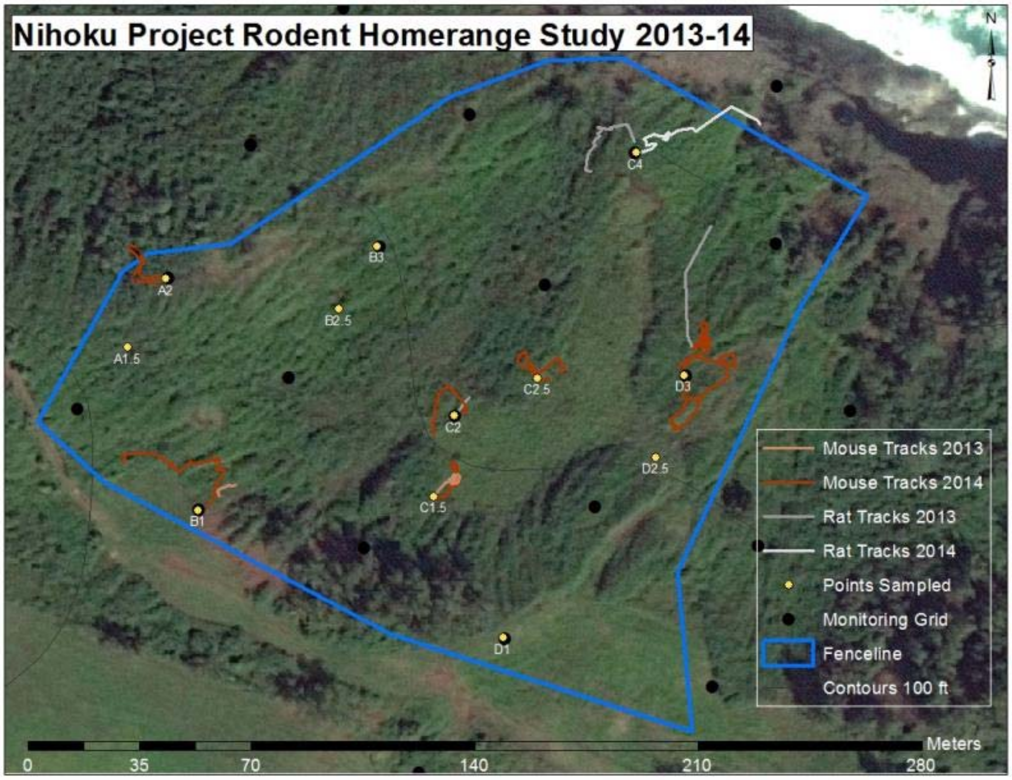

Figure 18: Rodent travel distances within the proposed fence area.

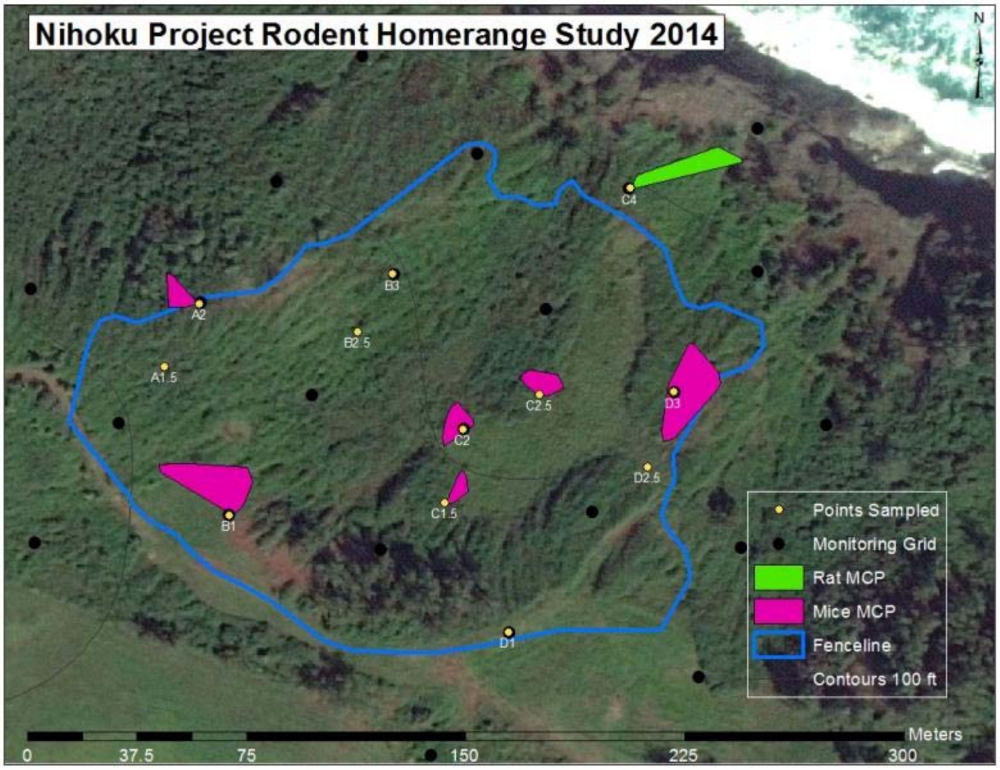

Figure 19: Minimum convex polygons depicting approximate rodent home range sizes within the final fenced area.

Seventeen cats were trapped, resulting in 0.0175 cats/trap night (17 cats/970 cage trap nights), indicating that cats were at low density in the area. No seasonal patterns were detected in cat abundance and cats were present year-round. Necropsy of three of the cats revealed moderate fat content, a full stomach containing small feathers, hair, insect exoskeleton, a few small bone fragments, fish pieces, and worms, and that specimens were not reproductively active. Feathers did not appear to be from seabirds; however, stomach contents were frozen and stored for possible further inspection.

6.4 Eradication plan outline

Based on our data, the most effective methods of predator removal were determined to be:
1) Live trapping for any remaining cats;
2) Diphacinone poison in bait stations on a 25-m grid for black rats and mice (only 50-m spacing is required for rats); and
3) If baiting alone did not result in eradication of mice, a combination of the 25-m diphacinone bait station grid and mouse traps on a 12.5-m grid.

Since the rodent tracking data indicated there was rodent breeding year-round, control operations were scheduled to begin immediately after fence construction to avoid any predation on Nēnē or Albatross nesting in the fenced area. Since the fence was completed in the fall, which corresponded to the lowest productivity point in the mouse breeding season, and a decline in rat abundance, this was a logical choice.

Diphacinone has been used to control rodents in Hawaiian coastal habitats (VanderWerf and Young 2014, F. Duvall pers. comm.) and was used to successfully eradicate Pacific rats on Mokapu Islet off of Molokaʻi (Dunlevy & Scarf 2007) and black rats at Kaʻena Point (Young et al. 2013). Diphacinone also has been used to eradicate black rats in a variety of locations worldwide (see Donlan et al. 2003, Witmer et al. 2007 for examples), though it appears to be less effective than brodificoum, particularly for mice (Parkes et al. 2010). However, diphacinone was the only poison approved for conservation purposes in Hawaiʻi, and thus was the only option available for this project. The decision to wait to conduct trapping for mice was based on the relatively low density of the animals, the low risk for being seabird predators, and the possibility that prolonged application of bait in bait stations would be sufficient.

Rodents were targeted with Ramik mini-bars® (HACCO Inc., Randolph, Wisconsin, USA) containing 0.005% diphacinone placed in tamper-resistant Protecta ® plastic bait stations (Bell Laboratories, Madison, Wisconsin, USA) to shield them from rain and reduce the risk of poisoning to non-target species. Bait stations were placed in a 25-m grid pattern throughout the fenced area and filled with up to 16 1-oz blocks per station. Bait stations were serviced twice per week during the first month, and after that frequency was adjusted based on levels of take to ensure that an adequate supply of bait was available at all times. Eradication was achieved for both rodent species in a five-month period with bait alone.

7 HABITAT RESTORATION

7.1 Introduction

Ecological restoration is the process of assisting the recovery of ecosystems that are damaged, degraded, or destroyed (Society for Ecological Restoration International 2004). For the Nihoku project, the goals of the restoration were framed in the context of building an ecological community comprised of native species, based on the limited historical knowledge of the coastal and lowland plant communities of Kauaʻi outlined in Bruggeman and Castillo (1999). More than one third (300+) plant species in Hawaiʻi are listed as threatened or endangered under the Endangered Species Act and species found in coastal shrublands and low elevation forests are particularly rare due to the higher degree of development and human habitation along coastlines. Only 11% of lowland mesic and dry native plant communities remain intact on Kauaʻi, compared to 22% for all of the Hawaiian Islands combined (The Nature Conservancy 1998). Thus restoring and providing safe areas for coastal native plants on Kauaʻi is of high priority to preserve these rare ecosystems.

KPNWR encompasses 65 ha (160 ac) of coastal sea bluff and, while managed largely for seabirds and Nēnē, contains important remnant coastal ecosystems (USFWS 2016). The Nihoku project site is composed of approximately six acres within KPNWR, just south of Makapili Rock and east of Crater Hill. The botanical surveys conducted at Nihoku, and described above, revealed that virtually the entire area (95%) was comprised of non-native species and was devoid of any burrow nesting seabirds. As a result, a restoration plan was developed in order to ensure the area was made suitable for both HAPE and NESH to be translocated there and to provide optimal forage for Nēnē. What is presented below are the techniques used and results obtained after implementation of that plan.

Purpose:
The goals of the restoration effort for Nihoku were to make the habitat suitable for currently nesting bird species, and to make the habitat suitable as a translocation site for NESH and HAPE by removing invasive species and out-planting with native species. This project also accomplished the following Refuge specific restoration goals (Bruegmann and Castillo 1999; USFWS 2016):

- Protect, enhance, and manage the coastal ecosystem to meet the life-history needs of migratory seabirds and threatened and endangered species;
- Restore and/or enhance and manage populations of migratory seabirds and threatened and endangered species.

Site characteristics
The Nihoku project site faces the ocean, on sloping land (averaging 22% slope, ranging to nearly 40% slope) above steep sea cliffs. The elevation range of the project site is approximately 42-102 m (140-335 ft) above mean sea level. The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) conducted a soil survey for an approximately 8-acre area surrounding the project site, in which the vast majority of the project area is composed of

soils categorized as Lihue silty clay, with the remaining area made up of rock outcrop (NRCS 2013). The project area receives approximately 150 cm (60 in) of annual rainfall, with higher rainfall during the winter months (Giambelluca et al. 1986). This is supported by 189 days of data collected at the Nihoku weather station (avg. 0.16 inches/day, est. 59.81 inches/year). There are no natural waterways, such as streams, within the project site; only swales that appear to have intermittently flowing water under high rainfall conditions. The Pacific Ocean is adjacent to the project area at the base of Northern steep cliffs.

Plant composition in the immediate project area was 95% invasive species, with Christmas berry being the dominant species at >50% cover across all canopy levels. Native plant species present include naupaka (*Scaevola taccada)*, ʻūlei (*Osteomeles anthyllidifolia)* and hala (*Pandanus tectorius)*; no listed native species were present. Most vegetation at the site was low in stature (<3m in height) and aside from a small grassy patch in the center, relatively uniform in composition, particularly in the canopy strata. While this site was being used by a small number of breeding Nēnē and Laysan Albatrosses, it is not being used by any burrowing seabirds as it likely is not suitable habitat for them in its current state. In planning for the ideal characteristics of the site for both Nēnē and seabirds, attention was paid to the current habitat used by each species.

Seabird and Nēnē habitat preferences

The breeding habitat of extant Newell's Shearwater populations described by Ainley et al. 1997 are characterized by steep (65˚) slopes with densely matted uluhe fern (*Dicranopteris linearis*) at higher elevations (525-4000'). Several fossil records of this species exist at low elevation indicating they once nested closer to the coastline (Pyle and Pyle 2017), but the majority of fossil evidence is at higher elevations than the project site. At KPNWR, the nesting pairs of NESH (thought to have descended from a cross-fostering experiment) breed in a combination of artificial nest boxes placed under vegetation (typically naupaka) and in naturally excavated tunnels under hala and naupaka leaf litter. Their current distribution and habitat 'preferences' are thought to be an artifact of range constriction as a result of predation and habitat destruction, i.e., only the most inaccessible colonies are left and the current nesting site characteristics reflect this rather than their true preference.

Hawaiian Petrel habitat preferences are described by Simons et al. (1998) as being sub-humid, subalpine dry habitat with <10% vegetation cover. On Kauaʻi they are found typically found in steep montane areas, where they nest under native species such as uluhe & ʻōhiʻa (*Metrosideros polymorpha*). Fossil evidence indicates that Hawaiian Petrels were once one of the most abundant seabird species in the Hawaiian Islands with numerous colony sites at low elevation (Olson and James 1982a, 1982b, Monitz 1997). Even more so than NESH, their current distribution and habitat characteristics are likely an artifact of a significantly reduced population size as a result of human consumption, habitat loss, and the introduction of mammalian predators. Our limited ability to observe habitat preference by these species in an environment free from such pressures may suggest that what we deem to be optimal habitat is merely all that's left.

In numerous seabird translocation projects undertaken on related Procellariform species in New Zealand over the last twenty years, the problem of actual vs. artificial habitat preference has been addressed by re-creating the physical condition of the burrows themselves (length, depth, temperature, substrate, and humidity) and canopy cover (open, shrubby, full canopy etc.) as much as possible at the sites where birds have been translocated, but not worrying extensively about the precise plant species composition. Many of the sites in New Zealand that were visited as a training exercise for this project leave non-native understory grass species for easy maintenance, and focus on the larger shrub/canopy layer when undertaking restoration, if restoration is done at all. As such, we feel that the approach taken at Nihoku of partial restoration was adequate to prepare the site for seabird translocations, and has the added benefit of improving the habitat for existing native bird species while reduced maintenance needs, such as mowing/weeding.

Adding to the complexity of the restoration at the site is the fact that it must also serve as forage for Nēnē in addition to nesting habitat for seabirds. Habitat types frequently used by Nēnē at KPNWR include grasslands dominated by introduced species e.g., saltgrass (*Distichlis spicata*), Kikuyu grass (*Cenchrus clandestinus*), open-understory shrublands (e.g., naupaka, koa haole (*Leucaena leucocephala*)), and sea cliffs (USFWS 2016). Nēnē build nests on the ground, usually under woody and herbaceous plants with an open canopy. Nesting habitats range widely but generally are associated with woody vegetation. Species composition varies by availability; in lowlands on Kauaʻi both native (e.g., naupaka, pōhinahina) and non-native (e.g., lantana (*Lantana camara)*, Christmas berry, koa haole, Guinea grass (*Megathyrsus maximus*)) plants are used (Mitchell 2013). In many areas Nēnē feed on cultivated grasses. The species selected for this project not only provide suitable seabird habitat, but also provide suitable Nēnē forage.

Given that non-native vegetation was not part of the original habitat of Nihoku, it is expected that the restoration activities will ultimately be beneficial for soils in returning soil chemistry to a previous state. Moreover, if the restored native coastal habitat encourages more nesting seabirds, this would increase the amount of guano input into soils. It is anticipated that this would be a beneficial effect that could assist in restoring nutrient cycles and other ecosystem processes. Overall, effects from habitat restoration are anticipated to be positive in the long term, despite short term disturbance (Mitchell 2013).

7.2 Methods

Timeline and sequence

The timing of restoration activities was selected for logistical reasons in year one in order to ensure that predators had been removed, but prior to the seabird translocation. As a result of these constraints, clearing and planting occurred in October 2015, which also corresponded to the onset of the rainy season. Restoration work in subsequent years occurred in late May or early June in order to avoid the Nēnē breeding season. During each restoration phase, invasive species were cleared in a 1-2 week period, and native plants that had been grown offsite were immediately outplanted after clearing had been completed to stabilize the soil. Thus the restoration activities were done in a relatively short period of time each year.

Clearing methods

Clearing methods varied somewhat by year as past experiences informed future events, so they are presented chronologically. In summary, a combination of mechanical removal with heavy machinery and herbicide was used to clear up to one acre of invasive weeds each year.

In October 2015, Christmas berry, the dominant invasive, was mechanically removed with a five ton excavator with a mulching head, followed by application of 17% Garlon 4 Ultra specialty herbicide (manufactured by Dow Agro Sciences) in biodiesel on the stump, leaving the root system in place to maintain soil integrity while the plants died. This method has been used in multiple restoration projects in Hawaiʻi with proven success. Non-native grasses were mowed to keep their stature short, and any other woody vegetation was cut and treated with Garlon. Large scale clearing took approximately two weeks and was done in the center of the fenced area to clear the slopes most suitable for seabird habitat first.

In June 2016, protocols were changed somewhat and a hydroax was used to remove Christmasberry by chipping it down to the stump and leaving the root system in place to maintain soil integrity while the plants died. Garlon was applied the next day and minimal Christmasberry sprouting has been observed to date. This method took three days and was approximately 60% less expensive than using an excavator and required less labor.

For the June 2017 clearing, the same protocols as 2016 were used to clear just under 0.4 ha (one acre) of invasive weeds. While these methods have been mostly successfully at keeping Christmasberry out of the area, we will likely experiment with pre-treating the Christmasberry with Garlon prior to cutting and chipping in 2018.

During all clearing events, best management practices were incorporated to minimize the potential for erosion and included: avoiding the use of heavy equipment in the steeper and more erosion-prone portion of the project area, phasing restoration over multiple years to reduce exposed ground areas, avoiding earthwork in inclement weather, using vegetative buffers for erosion control and soil stabilization, and re-vegetating of bare areas with native coastal plants in the days immediately after clearing had taken place.

Irrigation system

To ensure that a high proportion of native plants that were out-planted survived, a drip-irrigation and water catchment system was installed in November 2015. An existing 2,500 gallon catchment tank was re-located from Crater Hill to inside the fenced area and a corrugated roof was built on top to catch rain. An extensive drip irrigation network was placed throughout the planting area and set on a timer to water at dawn and dusk. The system was designed so that the hoses and pipes could be re-located as new restoration areas are planned within the fence each year. The irrigation lines were moved each year in the weeks after out planting to provide water support for the new seedlings.

Native plant propagation and out planting

The native plant species chosen to plant (Table 3) were selected based on historical and current distribution of suitable native coastal plants, recommendations by Bruegmann and Castillo (1999) in the KPNWR restoration plan, as well as species that provide seabird habitat and Nēnē forage. The native plants are low-in-stature, thus making burrow excavation easier for the birds, while simultaneously being low-maintenance and providing forage for Nēnē.

Plants grown for this project were produced from seed to maximize genetic diversity of each species. Propagules were collected in areas near the site or from similar and appropriate habitat on Kauaʻi. Seeds were sown on fine black cinder then transplanted into a custom blend potting mix of coco coir and perlite. Once seeds were established in their pots they were set up in a full sun part of the nursery to harden them. Irrigation was reduced to acclimate the plants to drier conditions to enhance survivorship after they were out planted.

Table 3: Plant species and quantity planted at Nihoku from 2015-2017.

Species scientific name	Hawaiian name	# planted
Artemisia australis	Ahinahina	94
Bidens sandwicensis	Koʻokoʻolau	43
Boerhavia repens	Anena	45
Canavalia kauaiensis	Kauaʻi Jackbean	94
Capparis sandwicense	Maia Pilo	50
Carex wahuensis	ʻUki ʻUki	1,444
Chenopodium oahuense	Alaweo	541
Colobrina asiatica	Anapanapa	375
Cyperus javanicus	Ahuawa	1145
Dodonaea sp.		124
Dodonaea viscosa	Aʻalii	200
Erythrina sandwicensis	Wiliwili	5
Euphorbia celastroides	ʻAkoko	239
Fimbristylis cymosa	Mauʻu ʻAkiʻaki	1038
Gossypium tomentosum	Mao	56
Heteropogon contortus	Pili	1198
Jacquemontia ovalifolia	Pau O Hiʻiaka	504
Kadua littoralis	Manono	55
Lipochaeta connata	Nehe	219
Lipochaeta succulenta	Nehe	93
Lycium sandwicense	Ohelo Kai	380
Myoporum sandwicense	Naio	231
Nototrichium sandwicense	Kului	161
Osteomeles anthyllidifolia	ʻŪlei	738
Pandanus tectorius	Hala	13
Peperomia blanda	Alaʻala	56

Plumago zeylanica	Hilieʻe	588
Pritchardia hillebrandii	Loʻulu Lelo	2
Psydrax odorata	Alaheʻe	146
Rumex albescens	Huʻahuʻakō	56
Scaevola taccada	Naupaka	450
Sida fallax	Ilima	244
Sporobolus virginicus	ʻAki ʻAki	5,566
Vigna marina	Nanea	273
Vitex rotundifolia	Pohinahina	1124

Propagation of seedlings was done by the National Tropical Botanical Garden (NTBG) at their Lawai nursery and followed sterile growing procedures to reduce the chance of introducing pests to the area. All biological content brought onto the site for restoration followed the Hawaiʻi rare plant restoration group (HRPRG) sanitation guidelines to prevent the spread of, or introduction of invasive species and pathogens (guidelines can be downloaded here: http://hrprg2.webnode.com/recommended-guidelines/phytosanitation-standards-and-guidelines/).

Plants were grown in a covered area isolated from weed species by at least a six foot buffer, including root systems. Growing media was sterile and from the approved growing media list provided by HRPRG, and tools used were disinfected regularly before use. Plants grown were inspected prior to being brought on-site. All species were subjected to a hardiness test before large scale out-planting.

Plants were out-planted in the 2015 restoration area in late October 2015 and again in June 2016 and 2017. During the 2016 and 2017 restoration activities, out planting was done by volunteer groups of 25 individuals over two days with guidance on placement from NTBG staff. Shrubs were spaced throughout the artificial burrow area to help produce shade and reduce the temperature in the burrows. Grasses and sedges were predominantly planted in the flatter areas below the artificial burrows to provide forage for Nēnē.

During the 2017 out planting, tropical fire ants were noticed on the ground at the NTBG nursery near plants that were being loaded to take to the Nihoku the same day. At the time that the ants were noticed, more than half of the 7,800 plants had already been placed at Nihoku. A rapid fire ant survey using spam deployed on wax paper for one hour was done in the trucks containing all the plants, and over 25% of the area at Nihoku; no fire ants were detected on either the newly arrived plants, nor the plants already on-site. As a precaution, all arriving plants and the newly cleared area were treated with granular Amdro. Follow up surveys were done site wide at Nihoku as well as at the NTBG nursery in September 2017. While no fire ants were detected at Nihoku, there were in fact fire ants detected at the nursery. As a result, biosecurity protocols at both the nursery and Nihoku were revisited in order to prevent the spread of invertebrate pests to the area.

7.3 Outcomes

Almost 1.2 ha (3 ac) were cleared of invasive weeds and close to 18,000 native plants representing 36 species were out-planted in the first three years of restoration at Nihoku. While there was some mortality associated with trampling around the artificial burrows and Nēnē browsing, it is estimated that greater than 50% of outplanted seedlings survived and are covering the majority of the cleared area. Active weeding is done quarterly to ensure that restoration areas remain native-dominated. In future years, more shrubs will be planted for better cover, and an attempt will be made to determine a better age for outplanting key Nēnē forage species so that the Nēnē don't inadvertently kill the plants (from over-browsing) before they establish. In total, approximately 40% of the project area was restored from 2015-2017, and restoration efforts will continue in future years.

Figure 20: Nihoku restoration areas, the yellow line indicates the area cleared and revegetated in 2015, the red line indicates the area cleared in 2016. On the right are native plants from the 2015 planting cohort.

Figure 21: 2017 Nihoku restoration areas before planting (left) and during (right).

8 SEABIRD TRANSLOCATION PLAN

This section covers the seabird translocation plan that was implemented, but does not include final results from the translocation itself.

8.1 Introduction

Translocation as a tool for seabird conservation

Birds in the Order Procellariiformes exhibit strong natal philopatry and high nest-site fidelity. These behavioral traits, along with a protracted nesting period and ground nesting habit, result in great vulnerability to predation by introduced mammals and exploitation by humans at the breeding colonies (Croxall et al. 2012). This vulnerability has led to the extirpation of many island populations of Shearwaters and Petrels around the world and made the consequences of stochastic events such as hurricanes, volcanic eruptions, epizootics, or fires at the remaining safe breeding sites much more significant (Jones et al. 2008, Croxall et al. 2012).

Translocation of birds to restore former breeding colonies or to create new colonies that are protected is a strategy that is being used as a conservation measure with increasing frequency, particularly in situations where social attraction techniques are not adequate on their own. Guidelines for the appropriateness, planning, implementation, and monitoring of such actions have been written for the Agreement on the Conservation of Albatrosses and Petrels (ACAP; Gummer et al. 2013) and similar guidelines were adopted by the IUCN Species Survival Commission in 2012 (http://www.issg.org/pdf/publications/Translocation-Guidelines-2012.pdf). The key methods employed to establish new colonies of burrow-nesting seabirds are acoustic attraction, provision of artificial burrows, and chick translocation.

Translocations involving hand-rearing of burrow-nesting Procellariiforms have been undertaken around the world, but particularly in New Zealand since the early 1990s (Bell et al. 2005, Miskelly and Taylor 2004, Carlisle et al. 2012). Eight species from four different genera had been translocated by 2008 (Miskelly et al. 2009) and several more species have been translocated since (Gummer 2013; T. Ward-Smith, pers. comm.) with each success building upon the last. Furthermore, translocations have been undertaken successfully for highly endangered Procellariiforms including Bermuda Cahow (*P. cahow)* and New Zealand Taiko (*P. magenta)*, where the world population has numbered fewer than 100 breeding pairs. Techniques have been developed for most of these species to a level where health issues are minimal and all transferred chicks fledge at body sizes similar to or exceeding those of naturally-raised chicks (Gummer 2013). Transferring Procellariiform chicks to a new colony site is just the beginning of a long process of colony establishment that depends on survival of the translocated birds, their recruitment to the new colony site, and the social attraction of other pre-breeding individuals that will accelerate the growth of the colony into a viable population.

While successes in early years of translocation development varied (Miskelly et al. 2009), recent years have seen successes as measured by recruitment of translocated chicks to the translocation site for a variety of species. In the Chatham Island Taiko, 60% of the 21 chicks transferred over 2007 and 2008 have been recaptured as adults (M. Bell, Chatham Islands Taiko

Trust, pers. comm. 2013), and up to 20% of translocated cohorts of Chatham and Pycroft's Petrels (*P. axillaris* and *P. pycrofti)*, translocated in the early-mid 2000s have returned to their respective release sites as adults (H. Gummer and G. Taylor, pers. comm.). Miskelly and Gummer (2013) reported that 20 of 240 Fairy Prions *(Pachyptila turtur*) transferred by 2004 were recovered at the release site despite 25 translocated birds being attracted back to the abundant source population. In addition, there has been some recruitment of non-translocated birds at new colony sites of multiple species through the use of acoustic attraction (H. Gummer, pers. comm.). Miskelly and Taylor (2004) reported that 17% of Common Diving-Petrels (*Pelecanoides urinatrix*) transferred in the late 1990s were recovered at the release site. That project has also shown the highest recruitment rate of non-translocated birds compared to all other New Zealand species, with 80 immigrants recorded within 11 years of the first chick translocation (Miskelly et al. 2009). During the three years of HAPE translocations to Nihoku, 98% (49/50) of chicks survived to successfully fledge. In summary, the numerous well-documented efforts that have been undertaken over the last 20 years have laid a solid foundation for translocating new species on islands outside of New Zealand.

In Hawaiʻi, recovery plans for the threatened Newell's Shearwater and the endangered Hawaiian Petrel specifically list translocation as a highly ranked recovery action. The purpose of this section is to outline the steps required to initiate translocation for Hawaiʻi's two endemic seabirds. The results of the translocation itself will be presented a separate manuscript in the future.

Newell's Shearwater biology

Newell's Shearwater is a threatened subspecies that is endemic to the Hawaiian Islands. It is closely related to the Townsend's Shearwater (*Puffinus a. auricularis*) found in the eastern Pacific. Newell's Shearwaters are a medium-sized Shearwater (391 g; King and Gould 1967). They are black above with a white belly, throat, and underwings, and a distinctive white patch on the flanks. Newell's Shearwaters are highly pelagic and forage over deep waters. They range throughout the tropical Eastern Pacific up to 3,000 miles from the Hawaiian Islands south to the Equatorial Countercurrent (Ainley et al. 1997). Their primary prey are ommastrephid flying squid (99%) and flying fish (*Exocoetus* sp.; Ainley et al. 2014), which are taken by pursuit plunging up to 30m, and scavenging, often in association with tuna and other sub-surface predators.

The population of NESH was estimated to be 84,000 birds including 14,600 breeding pairs in the 1990's (Cooper and Day 1994, Spear et al. 1995, Ainley et al. 1997), and approximately 27,011 birds in 2006 (Joyce 2013). Newell's Shearwaters are now primarily restricted to Kauaʻi which supports ~ 90% of the breeding population; very small numbers may also breed on Lehua Islet, Oʻahu, Molokaʻi, Maui and Hawaiʻi Island (Ainley et al. 1997, Reynolds and Ritchotte 1997, VanderWerf et al. 2007). The population on Kauaʻi is thought to have declined by over 94% from 1993-2013, based on radar and fallout data, indicating that the current population is likely much lower (Raine et al. 2017), although accurate numbers and trend indicators are difficult to obtain due to the inaccessibility of breeding colonies. Identified causes of the decline include urbanization including collisions with utility lines and light attraction and subsequent disorientation/fallout, depredation by introduced predators, habitat loss and degradation, , and natural catastrophes (Ainley et al. 1997, Raine et al. 2017).

Newell's Shearwaters are at least loosely colonial and nest in burrows, crevices, or under vegetation. On Kauaʻi, they breed in two habitat types: 1) high elevation, steep, wet montane forest dominated by native vegetation with an uluhe fern understory) and 2) steep dry cliffs (predominantly along the Na Pali coast). Newell's Shearwaters breed from April to November (Ainley et al. 1997) and are K-selected species, are characterized by a long lifespan (at least 20 years), low fecundity (one chick per year), and delayed recruitment (3-7 years; Ainley et al. 1997, Simons and Hodges 1998). Pairs are monogamous and show a high degree of nest site fidelity. A single egg is laid in a burrow or on the ground and parental care is equally distributed between the sexes. The incubation period is 62 days and the chick-rearing period is 92 days. Chicks are fed a regurgitated mixture of squid and fish; of samples regurgitated at burrow entrances during one study (N=9), squid were the only prey item (Ainley et al. 1997). Fledglings collected dead under power lines from 1993-94 (N=19) and 2001-2009 (N=79) had their stomach contents analyzed to determine their diet (Ainley et al. 2014). Their diets were 94-99% squid, dominated by ommastrephid (flying) squid (37-57%) and cranchiid squid (7-16%). Fish comprised 0.1-4% of their diet, with the primary species being *Exocoetus* flyingfish. Chicks are fed every 1-3 days by their parents (Ainley et al. 1997; Ainley et al. 2014). Imprinting on the natal site appears to occur after the date of the chick's first emergence from the burrow, which, based on remote camera data is 14.9±1.8 days before fledging (n=9 days, range 7-25) (Kauaʻi Endangered Seabird Recovery Project (KESRP; unpubl. data). Average fledging mass of chicks is 430g and fledging occurs at ~86 days of age based on data gathered from 2003-2005 and in 2014 at Kīlauea Point National Wildlife Refuge (KPNWR; USFWS unpubl. data; PRC unpubl. data).

Threats to NESH are many and varied. Predation from non-native animals on the breeding colonies, including feral cats, feral pigs, rats and Barn Owls have all been documented (Ainley et al. 1997, Raine et al. 2017). Additionally, the presence of small Indian mongooses on Kauaʻi was confirmed recently when two animals were captured in May and June 2012 near the airport and the harbor (Honolulu Star-Advertiser 2012; Duffy et al. 2015). Numerous other sightings have been reported but have not been confirmed. If this predator were to become established on Kauaʻi it would likely be catastrophic for NESH.

Light attraction and collision with artificial structures (fallout) is also a large source of mortality for NESH. On Kauaʻi, more than 32,000 Newell's Shearwaters have been collected by SOS as victims of fallout from 1979-2008, with the numbers decreasing over time in tandem with an overall population collapse (Day et al. 2003, Raine et al. 2017). Fledglings are the main victim of light attraction and fall-out because it is thought that they use the moon and stars to guide them to the ocean on their maiden flight out to sea and thus become confused when other sources of light are present. Collision with artificial structures, predominantly power lines, is also a major source of mortality for adults, particularly breeding adults moving to and from montane breeding colonies to the sea (KESRP unpub data; Raine et al. 2017). Habitat loss is often compounded with predation from non-native animals as reduction in dense native canopy cover can provide access for predators into breeding colonies (Raine et al. 2017). Finally, NESH are likely susceptible to marine-based threats, but little is known about threats in the marine environment. Newell's Shearwaters depend on tuna to force prey within reach (Harrison 1990). Tuna schools in eastern tropical Pacific are the target of widespread and efficient commercial fisheries, and several tuna species now are considered to be in jeopardy (IUCN 1996). Determining possible food web impacts remains key, as will the impacts of a warming ocean on their prey distribution (USFWS 2013). Ingestion of plastic may also be a problem for this species, although ingestion rates were much lower than for Wedge-tailed Shearwater (Kain et al. 2016).

As a result of the suite of threats that have been observed to impact the species over many decades, NESH were listed as threatened under the U.S. Endangered Species Act (ESA) in 1975 (USFWS 1983). Conservation actions were begun in the 1970's, most notably the Save our Shearwaters (SOS) program, in which the public was encouraged to bring fallout birds to rehabilitation facilities. Predator control, habitat restoration and other conservation measures have followed in recent years (KESRP unpub data).

At KPNWR, a single record of NESH nesting at the site exists from 1945 (Pyle and Pyle 2017). In response to declines in the montane colonies, in 1978 and 1980, 65 and 25 NESH eggs were translocated to Kīlauea Point and Mokuʻaeʻae Island (just offshore of KPNWR), respectively, and cross-fostered by Wedge-tailed Shearwater (WTSH) pairs in an attempt to establish a NESH colony at a protected site. Seventy-nine percent of these eggs hatched and 94% of the chicks fledged (Byrd et al. 1984) and several pairs of NESH now breed at KPNWR today. These NESH pairs are assumed to be descendants of the original cross-fostered chicks as well as new recruits attracted to the acoustic attraction system (USFWS pers. comm.). The current breeding habitat at Kīlauea Point is open-canopy hala forest with a naupaka understory. Between one and three pairs were known to breed at the Refuge since the 1970's, but with the advent of a social attraction project at the site in 2007 the number of known nest sites increased to 22, 11 of which were active in 2013, 11 in 2014, nine in 2015 and nine in 2016 (KESRP unpubl. data). Three chicks hatched and banded on Refuge in 1997, 2006, and 2009 have returned as breeders or prospectors. All nests are located on the parcel of the Refuge that contains the lighthouse and administration buildings and is open to the public.

In recent years, WTSH appear to have actively displaced several NESH pairs at KPNWR – with two NESH pairs being displaced in 2013, seven in 2015 and eight in 2016 by incubating WTSH (KESRP unpub data). It is thought that the two species may compete for nesting space at lower elevations. These observations could partly explain the paucity of NESH in the coastal fossil record relative to WTSH (Olson and James 1982a and 1982b). Being the larger and earlier arriving species, WTSH often are the winner in these confrontations, and it is unknown whether they simply displace NESH adults from preferred burrows, or if they inflict harm on the adults themselves. Recent survey work by KESRP using burrow cameras at KPNWR has recorded aggressive encounters between WTSH and NESH, with WTSH charging NESH with wings outstretched and chasing them away from previously occupied burrows (KESRP unpub data).

Additional conservation actions are needed to help counter the ongoing decline in Newell's Shearwater numbers. Managing threats on their remote colonies is critical, but is also logistically challenging and costly. Creating (and augmenting) colonies at sites that are easier to access and have been secured against predators is however an additional method for ensuring the on-going persistence of this specie and is a high priority conservation action.

Hawaiian Petrel biology
The Hawaiian Petrel, one of the larger *Pterodroma* Petrels (434g; Simons 1985), was formerly treated as a subspecies of *P. phaeopygia* and was formerly known as the Dark-rumped Petrel (USFWS 1983) until it was reclassified as a full species due to differences in morphology, vocalization and genetics from birds in the Galapagos Islands (Tomkins and Milne 1991). Hawaiian Petrels previously had a widespread prehistoric distribution throughout the Hawaiian Islands, including low elevation coastal plains on Oʻahu, Kauaʻi (such as Makauwahi Caves), and other islands (Olson and James 1982). Today, the breeding population is estimated to be 6,500-8,300 pairs with a total population of ~19,000 (Spear et al. 1995, Ainley et al. 1997), and approximately 52,186 in 2006 (Joyce 2013). On Kauaʻi, the population has declined by 78% between 1993 and 2013 (Raine et al 2017) and is thought to be as a result of collisions with power lines, fallout associated with light attraction, predation on the breeding colonies by introduced mammals and Barn Owls, , and habitat loss (Raine et al 2017). On Kauaʻi only a few HAPE are collected each year during the fallout period, but it is not clear whether this is because they are less susceptible than NESH to light attraction or because their main breeding areas are less affected by light pollution. Hawaiian Petrels were listed as endangered under the ESA in 1967.

Hawaiian Petrels are known to breed on Hawaiʻi Island, Maui, Lanaʻi and Kauaʻi, with a small, unconfirmed colony on Molokaʻi (Ainley et al. 1997, Penniman et al. 2008). Known breeding habitat varies. On Haleakalā (Maui) and Mauna Loa (Hawaiʻi) Hawaiian Petrels breed in open, rocky subalpine habitat at high-elevation. On Lanaʻi, Kauaʻi, West Maui and Molokaʻi, they breed in wet montane forest with dense uluhe fern, similar to NESH (VanZant et al 2014). While at sea during the breeding season, Hawaiian Petrels undertake long-distance, clockwise looping foraging trips over large areas of the North Pacific, sometimes traveling up to 10,000 miles in a single trip (Adams and Flora 2010; KESRP unpublished data). When not breeding, they range widely over the central tropical Pacific (Simons and Hodges1998). Their diet has been extensively studied and is composed primarily of squid (50-75% of volume), followed by a suite of reef fishes that possess pelagic juvenile stages (Simons 1985). Based on the prey species and their behavior, they are assumed to be primarily nocturnal foragers.

Hawaiian Petrels are also a K-selected species and are characterized by a long lifespan (up to 35 years), low fecundity (one chick per year), and delayed recruitment (5-6 years; Simons and Hodges 1998). Most pairs show a high degree of nest site fidelity and often remain with the same mate for consecutive years. A single egg is laid in a burrow or on the ground and parental care is equally distributed between the sexes. The incubation and chick-rearing periods are 55 and 110 days, respectively with some variation in phenology between islands. Chicks are fed an average of 35.6 g of regurgitated squid, fish and stomach oil during the last three weeks of the rearing period, and larger amounts, 55.4-63.3 g, earlier in the rearing period (Simons 1985). Imprinting on the natal site appears to occur after the chick's first emergence from the burrow, which on Kauaʻi is 15.8±0.94 days before fledging (n=22, min=7, max=29; KESRP unpub data). Average fledging mass of chicks on Maui is 434g, which is similar to adult weights (424g; Simons 1985), though it should be noted that birds from Kauaʻi appear to be smaller in build than those from Maui (Judge et al. 2014). Average wing cord at fledging for birds nesting on Kauaʻi is 281.36 ± 10.90 mm (Judge et al. 2014).

Managing threats on their remote colonies is critical, but is also logistically challenging and costly. Creating (and augmenting) colonies in easier to access, safe locations is therefore an important complementary conservation strategy. Although HAPE have not been documented to breed at KPNWR, the restored portions of the Refuge (such as that within the fenced area) provides habitat that is comparable to what would have been found in their historic coastal range. The presence of HAPE in the fossil layer indicates that this species was formerly numerous on the coastal plains of Oʻahu and Kauaʻi.

This plan has been developed specifically for translocating NESH and HAPE from nesting sites on Kauaʻi where predation is occurring, to the predator exclusion fence area at Nihoku within KPNWR. This plan outlines the information necessary to conduct the translocation.

8.2 TRANSLOCATION SITE PREPARATION

Translocation site selection and preparation considerations

Conservation practitioners are obligated to ensure that a proposed translocation site is safe and under a land management regime that ideally provides protection in perpetuity with a management plan in place. Based on guidelines set out by the population and conservation status working group of the Agreement on the Conservation of Albatrosses and Petrels (ACAP; Gummer et al. 2013), a translocation site should fulfill the following criteria:

- A suitable geographic site with respect to topography, access to the ocean, strength and direction of prevailing winds, ease of take-off and landing, nesting substrate, reasonable distance to adequate foraging grounds, and sufficient elevation to preclude periodic inundation from storm waves;
- Free of predators and invasive species harmful to Procellariiforms, or fenced (prior to translocations) to exclude such species, or a regular control program to remove those detrimental species;
- Surveyed prior to the translocation for the presence of any endemic species (flora or fauna) that could potentially be disturbed by the project, or that could influence the success of colony establishment;
- Adjacent to a cliff, elevated above the surroundings, or relatively free of man-made or natural obstructions that could inhibit fledging and arrivals and departures of adults;
- Relatively accessible to biologists, to facilitate delivery of supplies and monitoring;
- Designated for long-term conservation use;

- A site for which other conflicting uses (e.g. local fishing, aircraft operations, city lights, busy roads, and antennae, etc.) have been considered and conflict avoidance measures are feasible;
- Be free of, or have minimal, known human threats to the species (such as light attraction or power lines) within its immediate vicinity.

Site preparation

Ideally, the site selected for the translocation should already have substrate and vegetation structure preferred by the species to be translocated. If there are plants that create collision hazards or block the wind and cause over-heating by preventing convective cooling, they should be removed. For burrow-nesting species, artificial burrows need to be installed to accommodate translocated chicks and to provide suitable nesting sites for prospecting adults.

It is also important to have a sound system (solar-powered) continuously playing species-specific calls from existing breeding colonies. While decoys are not commonly used for burrowing seabirds, they may help attract birds to the area (this is currently being trialed by First Wind for both NESH and HAPE at two predator exclusion fenced enclosures in Maui at Makmakaʻole). The decoys and sound system serve two purposes: (1) They provide visual and auditory stimuli to the developing chicks, which may allow them to re-locate the site when they attain breeding age; and (2) The calls and visual cues may attract others of the species to the site. Juveniles that were not reared at the site and have not yet bred may choose to breed at the site, thereby helping to increase the population.

Nihoku site selection

The site selected for Hawaiʻi's first translocation of listed seabirds is the Nihoku section of Kīlauea Point National Wildlife Refuge. This site fulfills all of the criteria described above. Kīlauea Point National Wildlife Refuge was set aside in perpetuity in 1985 by the federal government "to preserve and enhance seabird nesting colonies and was expanded in 1988 to include Crater Hill and Mōkōlea Point" (USFWS). Located at the northern tip of the island of Kauaʻi, the 203 acre Kīlauea Point National Wildlife Refuge is home to thousands of nesting seabirds, including Laysan Albatrosses (*Phoebastria immutabilis)*, Red-footed Boobies (*Sula sula)*, Red-tailed Tropicbirds (*Phaethon rubricauda*) and White-tailed Tropicbirds (*P. lepturus*), Wedge-tailed Shearwaters (*Puffinus pacificus)* and several pairs of Newell's Shearwater as well as numerous pairs of Nēnē or Hawaiian Goose (*Branta sandvicensis*). In addition, many migratory and resident seabird species frequent the area when not nesting. The area is managed for native birds by the U.S. Fish and Wildlife Service through predator control, habitat management (both weeding and outplanting), and fencing.

The Nihoku project site consists of approximately 6.2 acres between Crater Hill and Mōkōlea Point, just south of Makapili Rock and approximately 1.5 kilometers northeast of Kīlauea town. Nihoku faces the ocean, on sloping land (approximately 23° slope) above steep sea cliffs. The elevation ranges from approximately 140 to 250 feet above mean sea level; well above all scenarios of projected sea level rise as a result of climate change. The area has a natural 'bowl' shape and the orientation facing towards the ocean and prevailing northeast winds make it an ideal location for birds to be directed straight out to sea. The natural cliffs and ridgelines made it ideal to tuck a fence behind to reduce the possibility of birds colliding with the fence, to facilitate take-off for flight and to reduce light pollution from private residences adjacent to the Refuge. It was also a relatively simple location on which to build a fence and conduct a translocation due to easy access from a nearby road.

Nihoku site preparation

Site preparation at Nihoku consisted of three phases: fence construction, predator removal, and habitat restoration. Those activities have been discussed in detailed earlier in the document, but are summarized below for ease of accessibility.

Fence construction was done by a contractor specializing in fence construction took three months. Immediately after fence construction, all remaining invasive mammalian pests were removed. Based on monitoring results and regulatory restrictions, a combination of diphacinone in bait boxes spaced 25m apart and multiple-catch mouse traps was used to eradicate rodents, and live traps were used to remove cats. These methods were successfully used to eradicate all mammalian pests from a pest-exclusion fenced area at Kaʻena Point in 2011 (Young et al. 2013). Following fence construction, just under three acres (45%) of the project area was cleared of invasive alien plants and suitable native species were out-planted.

Standard artificial burrow designs used in New Zealand for similar Procellariformes species are 5-sided wooden boxes (four sides plus a lid) with open bottoms and corrugated plastic PVC tubes for burrow entrances. A similar design is used for NESH, but with a lighter weight plastic that has been used for the tropical nesting Bermuda Cahow and Audubon's Shearwater in the Carribean.

Figure 22: Nihoku artificial burrows prior to being installed.

The nest boxes that were used were manufactured by the Bermuda Audubon Society with 0.3 cm thick High Density Polyethylene (HDPE) and fabricated in a size for accommodating all burrow/cavity nesting seabirds in the weight range 250 – 600g (see attached specifications). HDPE is chemically inert and very durable and the thickness is strong enough to resist warping or physical damage from trampling, tree-fall and rock-fall in most circumstances, especially when buried in soil substrate. The burrows (pictured above) are square boxes measuring 50 x 50 cm and are 38 cm high. They have hinged lids for easy access and a modular tunnel component that can be cut to any length and with 225˚ angled sleeves to allow the tunnel to make turns (to keep out light). The opening of the tunnel is 15cm in diameter.

Burrows were installed in 2015 and were dug into the ground so that just the lid was exposed. The lids were painted white and had holes drilled in the side to allow for airflow. Finally, sandbags were placed on burrow lids to reduce thermal fluctuations. Temperatures were monitored for several weeks, and by painting, drilling and covering the lids, we reduced the average temperature by 2°C, and most importantly reduced the upper end of the range from 30°C to 25°C. Temperature monitoring continued during the initial HAPE translocation and all chicks appeared to thermoregulate normally within this temperature range. The burrow floor, which is open to the ground, was covered with a layer of tumbled pea gravel topped with wood shavings to prevent flooding and mud accumulation.

Interactions and impacts with other species

Based on the species currently present in the project area, with the exception of Barn Owls and Wedge-tailed Shearwater, no negative interactions are anticipated between NESH or HAPE and any other animal or plant in the fenced area site. The successful establishment of these seabirds in the site would likely increase soil fertility, with benefits for a wide range of species. However, the presence of Barn Owls at the site is a concern since they cannot be excluded from the area and are known seabird predators. During the translocation period and ideally throughout the life of this project, Barn Owl control would be implemented to prevent any of the fledglings from being taken by Owls. Control during the recruitment period is done on an as-needed basis.

While there are no WTSH nesting currently in the project area, they do nest nearby (closest colony is <250m and one pair is immediately outside the fenced area) and it is possible that once the habitat has been prepared and artificial burrows are installed, that the area may become attractive for this species and that they may move into the project area. Wedge-tailed Shearwaters have been known to displace NESH from breeding burrows (USFWS &KESRP unpub data) and potentially inflict harm on NESH adults. To prevent WTSH from displacing returning NESH and HAPE chicks, artificial burrow entrances are blocked until the beginning of the NESH arrival period (early April) since WTSH tend to arrive on the breeding colonies earlier than NESH. It is hoped that this action will discourage WTSH from nesting in the artificial burrows to reduce potential interactions between the two species at the site. In the event that all artificial burrows are occupied, additional burrows will be installed on an as-needed basis if birds will not use the naturally occurring features at the site. Removal or relocation of WTSH may need to be considered if WTSH pose a problem.

8.3 SOURCE SITE SELECTION

Surveys to locate potential donor colonies

From 2012-2017, KESRP undertook a series of surveys at known NESH and HAPE breeding sites to locate potential donor colonies for this project. These surveys were initially undertaken at colonies which were considered to have the highest threat of extirpation – due to fallout, power line collision, predation, and habitat loss as well as the colony at KPNWR due to its proximity to the Nihoku site.

Surveys at these sites were conducted using a standardized auditory survey protocol developed by KESRP, with 2 hour evening surveys beginning at sunset and 1.5 hour morning surveys beginning 2 hours before sunrise. Surveys were conducted during the peak breeding season when birds are most vocal – June to beginning of September. Surveys were accompanied by burrow searches in areas where the highest levels of ground calling activity were identified.

In 2012, a total of 167 surveys were conducted at five colonies – KPNWR, Makaleha, Kahili/Kalaheo, North Fork Wailua and Koluahonu. The highest call rate was found at the North Fork Wailua Colony (an average of 217 calls/ hour), and the lowest at the Koluahonu Colony (56 calls/ hour). Three new burrows were located in the Kahili region, one at the Kalaheo colony and 11 burrows were found to be active in KPNWR. Additionally, locations of high calling rates or potential ground calling were identified at all sites.

In 2013, the focus shifted somewhat. As well as undertaking surveys at five low elevation sites with high risk of colony extirpation, three higher-elevation sites were also included. These areas had known colonies of both NESH and HAPE, and had higher levels of activity when compared with the low elevation sites and had active colony management. These sites were included in the surveys due to the low success of locating nest sites in the low elevation sites (and that there were very few birds left at these sites). As with 2012, KPNWR was also included in the surveys. A total of 165 surveys were therefore conducted at nine colonies in 2013 - KPNWR, Makaleha, Kahili/Kalaheo, North Fork Wailua, Koluahonu, Sleeping Giant, Upper Limahuli Preserve and Hono o Na Pali North Bog. The highest call rate was found at one of the higher elevation sites, Upper Limahuli Preserve (an average of 363 calls/ hour), and the lowest at the Koluahonu Colony (79 calls/ hour) and KPNWR (77 calls/hour).

In 2014, due to the very low number of burrows located in colonies with a high risk of extirpation, surveys focused on higher elevation sites with large concentrations of birds as well as KPNWR. A small number of surveys were also undertaken at North Fork Wailua, Kahili and Kapalaoa. At the end of this period, all sites surveyed over the last three years were considered for feasibility for a translocation project. These were ranked on the following criteria: (i) presence of breeding colony, (ii) known burrows present, (iii) threat level, (iv) on-site predator control and (v) accessibility. For Hawaiian Petrel, the four sites that scored the highest ranking were (in descending order): Pihea (HNP), Upper Limahuli Preserve, North Bog (HNP) and Hanakapia'i. For Newell's Shearwater, the four sites that scored the highest ranking were (in descending order): Kīlauea Point NWR, Upper Limahuli Preserve, Pohakea (HNP) and Kahili.

Potential effects of removal

The proposed removal of up to 90 NESH and HAPE chicks from up to four colonies (with a minimum of 158 active nests) over a five year period (10-20 per year depending on the year) will likely have minimal impacts on the local, or species level populations. The largest colonies (Upper Limahuli Preserve and North Bog) had a minimum of 82 NESH and 79 HAPE known burrows and in 2015 produced a minimum of 60 chicks. If one considers the number of known NESH and HAPE burrows in these two colonies and assumes all are active in the first year of translocation then the proposed total take of 10 nestlings based on 2015 numbers is a small proportion (12.2-12.7%) of total production at those sites. However, Upper Limahuli Preserve is a very important colony and under its current management regime (presently via funding from the Kauaʻi Island Utility Cooperative {KIUC}) has a very high reproductive success rate. Therefore, chicks would not only come from this site - under the proposed removal regime for the translocation project only 3-4 nestlings would be removed from each site – in which case 4 nestlings would represent 4.9-5.1% of total known burrows at any one site. It should also be noted that new burrows are found each year (i.e., in 2015 a further 18 NESH burrows were located at Upper Limahuli Preserve alone) and therefore there are almost certainly many more birds breeding within the selected donor areas. Thus, the proportion of chicks removed is likely much lower.

Considering the small number of chicks taken out of any colony in a given year, coupled with the use of different burrows in different years (i.e., chicks would not be removed from the same burrow in consecutive years if at all possible), it is unlikely that this will have a measurable impact on the local, or species level population of NESH or HAPE since the vast majority of the translocation chicks are expected to fledge. In other species, much higher proportions of nestlings are removed from the colonies for conservation purposes. In the critically endangered Cahow and in the Taiko, 100% of the chicks produced for the species are removed each year to start a new colony (since both species are restricted to a single colony; Carlisle et al. 2012).

It is important to consider predation levels at current colonies. In areas where no predator control is occurring, predation levels of breeding seabirds and their chicks can be extremely high. For example, several historical NESH colonies on Kaua'i (such as Makaleha and Koluahonu) have been depleted to the point of near-extirpation in the last decade. Makaleha in particular is an interesting case as this site has only been monitored using helicopter-deployed song meters and auditory surveys from a ridge on the other side of the valley, so there has been no human ingress to this site at all and no management. In the span of ten years this site has gone from having call rates as high as Upper Limahuli to having call rates that are sporadic at best (Raine *pers comm*). Ainley et al. (1995) reported 23 NESH killed by cats in the Kahaleo colony in 1993 alone and Jones (2000) found that New Zealand Shearwater colonies would disappear within the next 20-40 years on the mainland of New Zealand without significant management actions to eliminate predation by introduced mammals. Chicks that would be removed and hand-reared at a translocation site would likely have higher survival than chicks from sites without predator control. Furthermore, monitoring of predation levels of nesting endangered seabirds in areas on Kaua'i where predator control is currently on-going has revealed that while significantly reduced, predation of chicks - in particular by feral cats, pigs and Black Rats - is still an issue (KESRP unpub data). For example, at North Bog in Hono o Na Pali NARS, 25% of all monitored NESH chicks were killed by rats in 2013 and 9.2% in 2014 (KESRP unpub data). Cats continue to predate upon both species at all sites every year, with cat predation events recorded in all three Hono o Na Pali sites in 2014 and 2015. Cat depredation has been particular bad on Newell's Shearwater at Pohakea, for example. Therefore, survival to fledgling of birds in these colonies is already reduced. With the above being the case, the removal of three or four chicks in a given year from several different colonies, regardless of whether predator control is occurring, is unlikely to cause any issues with the overall recruitment of source colonies since a portion of the translocation chicks would not have survived to fledge in the source colonies regardless.

Another concern is the potential desertion of breeding pairs from burrows where chicks have been removed for translocation purposes. This has not been a serious issue in previous projects. In a number of other translocation studies (Miskelley et al. 2009); adults return the following year despite the removal of their chick prior to fledging. There is also some suggestion in related species that breeding pairs whose chicks die (or in the case of translocation are removed) may have a higher survival rate as they are able to spend more time foraging for self-maintenance compared to pairs with an active chick (VanderWerf & Young 2011). In NESH burrows currently monitored on Kauaʻi, breeding pairs return in subsequent years after their chicks have been depredated and successfully fledge young in the following year (KESRP unpub data), and initial observations indicate parents whose chicks have been removed for translocation also return

The translocation to Nihoku is also likely to be neutral from a genetic perspective since very few seabirds (or land birds) have distinct genetic structure of populations on the same island. It is likely that many NESH populations on Kauaʻi were at one point continuous and are only now discrete as a result of habitat fragmentation and population declines (Olson and James 1982a and 1982b). Potential impacts of human visitation at source colonies that could be considered are damage to nesting habitat by repeat visits, disturbance resulting in temporary or permanent burrow desertion by adults (although this has never been recorded in areas currently monitored on Kauaʻi at a frequency of up to eight visits per year), and the creation of trails to burrows that could be used by introduced predators. These potential impacts are minimized by:

- Following existing trails whenever possible, taking care to avoid creating new trails;
- Concentrating only on areas where predator control is on-going, so that animals that may be attracted to the area will have reduced impacts;
- Repairing all burrows damaged accidentally by trampling;
- Minimizing the number of visits to each burrow and using burrow cameras to help assess viability of any given burrow for use as a source bird for translocation; and
- Using a team of two trained people on nestling collection trips to minimize disturbance levels.

8.4 COLLECTION AND REMOVAL OF DONOR CHICKS

Age at translocation

Age of the chick at translocation is an important variable that needs to be optimized to allow chicks the longest time possible with their natural parents for species imprinting, transfer of gut flora, and expert parental care without losing the opportunity for the chicks to imprint on the translocation site and increase the probability that they will eventually recruit to the new site. In addition to thermoregulatory and nutritional benefits, it is possible that rearing by parent birds for the first month minimizes the chance that the chicks will imprint on humans, and allows transfer of parents' stomach oil (and possibly unknown species-specific micronutrients or antibodies) to the very young chicks.

Burrow-nesting seabird chicks are thought to gain cues from their surroundings during the emergence period shortly before fledging, and then use that information to imprint on their natal colony (location imprinting). Chicks that have never ventured outside natal burrows can be successfully translocated to a new colony location. Success is optimized if chicks spend the greater proportion of the rearing period with parents before being moved.

For NESH, age of first emergence is 14.9±1.8 days before fledging (n=9, min=7, max 25) (KESRP unpub data). Based on morphometric measurements collected (USFWS unpub data, PRC unpub data), this would appear to be when at a minimum mass of 400g and wing cord of 189mm, or a ratio of 2.1 mass/wing cord. This occurs in mid-late September based on on-going data collection at active burrows using Reconyx cameras. Trips are made to source colonies in mid to late September, and cameras are checked to see whether the chicks have emerged. Those that have not emerged, and appear to be in good health are selected.

For HAPE, age of first emergence is 15.8±0.94 days before fledging (n=22, min=7, max=29) (KESRP unpub data). This occurs in late October to beginning of November based on on-going data collection at active burrows using Reconyx cameras. Trips are made to source colonies in mid-October, and cameras are checked to see whether the chicks have emerged. Those that have not emerged, and appear to be in good health are selected.

Number of chicks in each translocation cohort, and number of cohorts
Factors important in choosing a cohort size for a chick translocation are genetics, rate of growth of the new colony, size of the source colony and the practical limitations of logistical capability and labor to care for the translocated chicks. Since these translocations involve only chicks of long-lived birds, it is unlikely that taking the proposed number of the chicks from the parent colony will affect the viability of that source population as it might have if one moved adult animals.

In New Zealand, for established translocation programs for burrowing species, a maximum of 100 chicks a year is considered appropriate to transfer for project totals of up to 500 birds over a five year period. The recommended number of chicks to transfer to a new site in the first year of a project is generally 50 chicks if the team is new to seabird translocations, and/or there are anticipated logistical issues to resolve at the release site (Gummer 2013). If the species has never been translocated before, a trial transfer of a small number of chicks (e.g., ≤10) may be appropriate to test artificial burrow design and hand-rearing methods. The conservative approach of up to 10 chicks in year one is what was used with both species.

Translocation projects ideally should span several years to increase the genetic heterogeneity of the translocated population, to accelerate the development of a natural population age structure at the new site, to increase the size of the translocation group within the staff capabilities for chick rearing, and to “spread the risk” associated with environmental stochasticity. Transferring a minimum of 200 chicks of burrow-nesting species over a 3−4 year period has now been tested on several projects in New Zealand. With increased confidence in techniques, it is now considered advantageous to move more than this to increase the pool of birds returning to the establishing colony site and the encounter rate of conspecifics, which is thought to be important in encouraging adults to settle there (Gummer 2013). Supplementary translocations in later years may also need to be considered to achieve this goal. It should be noted that even with the expertise to manage large numbers of birds on the translocation site, it is unlikely that enough suitable donor burrows will be located for such large cohorts. Thus, more transfers of smaller cohorts may be necessary to achieve the same objective.

For the first year of NESH and HAPE translocations, 10 chicks will be removed and transferred to Nihoku following recommendations developed in New Zealand for new translocation projects. If fledging exceeded 70%, then up to 20 birds would be moved in years 2-5 for a total of 50-90 birds. Considering the rarity of these species, available nesting burrows in multiple colonies will be one of the main limiting factors in any given year. If fledging is below 50% in any given year, the project will be re-evaluated before proceeding. If fledging criteria are not met at any stage, numbers will not be increased until those numbers are met. The number of birds may also depend on whether additional suitable donor burrows can be located. The goal of this project is to transfer a minimum of 50 and up to 90 chicks over a five year period.

Pre-capture monitoring

All potential source colonies are being monitored on a regular basis by the KESRP. Ten monitoring trips are carried out to these sites each year and are undertaken once a month. Trips are made, based on the following schedule: (i) pre-arrival, to deploy cameras and song meters (late February), (ii) arrival on breeding colonies (March), (iii) arrival of NESH (April), (iv) incubation period (1 or 2 trips in June-July), (v) early chick-rearing period (1 or 2 trips in August-September), (vi) fledging or late chick-rearing period for NESH in October and (vii) fledging or late chick-rearing period for HAPE in November. This schedule is flexible depending on logistical considerations and project priorities.

During each visit, identified burrows are inspected to assess breeding status as per the standardized protocols outlined below. At all times, care is taken to minimize damage to surrounding vegetation and burrow structure through careful approach to and from the burrow site, with staff paying particular attention to vegetation and potential areas where the ground could collapse.

At each check, notes are made on any signs of activity within or around the nest. This includes (i) the presence of adult, egg or chick, (ii) scent, signs of digging or trampling, and/or (iii) presence of feathers, guano or egg shell. A note is also be made as to whether or not it was possible to see to the back of the burrow (e.g. was the burrow fully inspected, or was there a possibility that something was missed). Any signs of predation (such as a dead adult or chick in front of burrow or inside burrow), or the presence of scat/droppings/prints that indicate a predator has been in the vicinity of the nest, are also recorded.

A sub-set of burrows (30) are also monitored by cameras (Reconyx Hyperfire PC900). These cameras are mounted on poles located 3-10ft away from the burrow entrance and set on a rapid fire setting (motion sensor activated, with a trigger speed of 1.5sec). 8GB SD cards are used to record photographs, and these (along with the rechargeable batteries) are switched out on each visit to ensure continuous coverage over the season. If a burrow fails during the season or the chick successfully fledges, then the camera is moved to a new active burrow until the breeding season is over.

At the end of the season, a final status is assigned to each nest using the following categories:

- *Active, breeding confirmed* – breeding was confirmed as having been initiated during the season through the presence of an egg or chick. For this category, the outcome is noted as either:
    - *Success* – Nest successfully fledged a chick. As the site is remote and not visited regularly enough to actually see the chick fledge, a successful fledging is

considered in the following scenario – A chick was confirmed in burrow up until typical fledging month (November/early December) and on the following check (i) the presence of small amounts of down outside the nest site indicate that the chick was active outside the burrow and subsequently fledged and/or (ii) there are no signs of predation or predator presence. Burrows with cameras provide information on exact fledging date and time. Translocated chicks would be considered as being in this category for the purposes of colony monitoring.

  - *Failure* – Nest did not fledge a chick. The failure stage (egg or chick) and cause of failure (predation of chick or egg, abandonment, predation of breeding adult, etc.) is recorded where known. Burrows with cameras can provide information on predation events and predator visitations pertinent to nest failure.
  - *Outcome Unknown*- Breeding was confirmed at the site, however no subsequent visits were made, no visits were made late enough in the season to confirm fledging, or signs were inconclusive. Only a very small number of burrows fit into this category as every effort is made to assess the final status of all burrows.
- *Active, unknown* – the presence of an adult bird, or signs of an adult bird (guano, feathers, trampling, etc.) indicate that a bird was present during the breeding season but it was not possible to confirm whether breeding occurred and failed or breeding was never initiated. Either way no chick fledged. Situations like this arise in instances where (i) it was not possible to examine the back of the nesting chamber due to the structure of the burrow, (ii) an adult bird was confirmed in the burrow during the incubation period, but it was not possible to determine if it was incubating an egg, or (iii) the burrow is discovered late in the breeding season and, as it was not therefore monitored during the egg-laying period, it is not clear if breeding had been initiated (even if eggshell fragments are recorded, as they could have been from previous seasons).
- *Active, not productive* - the presence of an adult bird, or signs of an adult bird (guano, feathers, trampling, etc.) indicate that a bird was present during the breeding season but burrow inspections reveal that no breeding took place (i.e. no egg was ever laid).
- *Prospecting* – bird(s) recorded visiting nest, but signs are indicative that these are prospecting and not breeding birds. Examples would be new excavations within a previously inactive burrow, a single visit during the breeding season to a previously inactive burrow, a visit to a burrow where both adults had been confirmed killed the year before, or the preliminary excavation of a burrow-like structure combined with the confirmed presence of a seabird.
- *Inactive* – no sign that the burrow has been visited in that breeding season.

Additional visits are made to the sites each year to actively search for new burrows. Burrows that are found during these trips are added to the overall monitored group of burrows at the site, as detailed above.

Selection of individual chicks to be moved

Chicks selected for translocation will be chicks that appear healthy and in good condition and are in burrows where they can be safely (and easily) removed. Chicks fledging in optimum condition have an improved chance of surviving and returning as adults. Ideally, chicks will meet species-specific criteria on the day of transfer (Gummer 2013), and thus, a combination of wing cord and mass measurements will be used to select chicks if enough burrows exist to allow for selection criteria to be implemented (see below for target measurements). Setting a transfer wing-length range ensures that only chicks of appropriate age are taken. Setting minimum transfer weights for different wing-length groupings ensures chicks can recover weight lost during transfer and while adapting to the hand-rearing diet, and still fledge in optimum condition. In addition, it is vital that chicks have not emerged at the source colony yet for even a single night to avoid imprinting on their natal site. Since all potential donor burrows will be monitored with cameras, it will be known if the chick has emerged.

Due to the limited number of burrows available from which to select chicks, every effort will be made to select chicks that meet the age (size) criteria set above. In the event that there are not enough burrows to choose from, we will select burrows where the chicks a) are reachable by hand from the burrow entrance and b) have not yet emerged from their burrow based on nest camera information/data.

Over multiple transfer years, efforts will be made to maximize representation of different parents from different parts of the source colony. This prevents the same adult pair from being targeted for chick removal in subsequent years, potentially disrupting their pair bond by forcing them to 'fail' multiple times in their breeding attempts. Therefore, burrows that were used for a translocation in the previous breeding season will not be used in a second consecutive season but may be used every other season if necessary.

Chick capture and transport
Minimizing the risks of overheating and injury in the carrying containers, and stress from unfamiliar stimuli, are major considerations for the chick capture and transport phase. The transfer box design used for most burrow-nesting Petrel transfers in New Zealand is based on a standard pet (cat) box (Gummer 2013) and will be used for both NESH and HAPE. There must be enough space and ventilation to avoid overheating issues, and to minimize wing and tail feather damage of the more advanced chicks. Boxes will also be heat-reflective, dark inside to reduce chick stress levels, and have padded flooring (yoga mats) that provides grip and absorption of waste or regurgitant. Since only a small number of chicks will be taken, one box per chick will be used. Chicks will be removed by hand from the burrow, and placed into transfer boxes. Boxes will then be loaded into the cabin of the helicopter and secured to a seat for flight using rope. Once they have arrived at the Princeville airport (~15 minute flight from the natal colonies), they will be transferred into a vehicle and likewise secured into a passenger seat for transfer to the translocation site (~30 minute drive). It is expected that birds will be in their transfer boxes for 4 hours maximum and every effort will be made to ensure that transfer time is as short as possible. Upon arrival at Nihoku, each chick will be banded to help with individual identification and future recaptures as adults on the site.

Post-collection donor colony monitoring
Each year, all of the colonies being used as source colonies will be monitored to assess potential effects of the translocation of chicks on the future breeding efforts of donor burrows. For birds

that are transferred from areas already under management and monitoring regimes, all burrows will already be monitored ten times spanning the breeding season to assess whether the burrow is active, breeding has been initiated, whether a chick has hatched and whether a chick has fledged (see pre-collection monitoring for details). As all burrows are given a unique identification tag, the progress of each burrow in any given season is known. It will therefore be possible to assess whether burrows used as donor burrows in the previous season show any change in productivity in the following year. If a negative effect is noted, then the translocation protocols will be re-assessed. All burrows used as donor burrows in 2015 were active in 2016 and the same was true in 2017 for donor burrows in 2016 (KESRP, unpub data).

8.5 CHICK CARE AT THE NEW COLONY SITE

Burrow blockage procedures

In order to ensure that newly translocated chicks do not wander out of the burrow prematurely, entrances will be blocked on both ends of the entrance tube. The interior entrance to the burrow chamber from the tube will be blocked with a square panel of metal mesh screening to allow airflow, and the exterior entrance will likewise be blocked with a similar mesh screen to allow for airflow. Because of the curve in the burrow tunnel, light penetration into the burrow chamber is minimal. A double-sided blocking procedure is done to ensure that chicks do not get trapped in the tunnel if they attempt to leave the burrow by blocking both entrances to the tunnel. The exterior entrance block is to prevent newly emerged chicks from adjacent burrows wandering into the burrow opening and similarly are unable to turn around when they reach the interior chamber mesh screening.

Burrow blocks will be removed on an individual basis depending on chick developmental stage and proximity to fledging. Blocks will not be removed until NESH chicks have reached the minimum wing cord length required to fledge.

- Wing length: ≥220 mm
- Weight: ≥350 g
- Down cover: Not exceeding 60% (looking down on chick from above)
- Wing growth rate: Slowed from up to 9 mm/day, down to <5 mm/day

For HAPE, Criteria are as follows based on 90 day old chicks (~1 month prior to fledging) from Simons 1985 and Judge et al 2014:

- Wing length: ≥170 mm
- Weight: ≥500 g
- Down cover: Not exceeding 60% (looking down on chick from above)
- Wing growth rate: Slowed from up to 9 mm/day, down to <5 mm/day

Down cover should not be relied on as a sole guide to gate removal as it can be prematurely lost on the transfer day, or through handling, especially in wet weather. Down coverage is recorded by visually estimating the percentage of down left when looking down on the chick from above. Down-cover percentage is used as a cue to preventing premature blockade removal; chicks with ≥60% estimated cover are not allowed to emerge, especially if they are lighter in weight, as they are considered to be too far from fledging and may be compromised without further meals if they disappeared.

Blocking the entrances of burrows will also be undertaken prior to the NESH breeding season to minimize the possibility that WTSH will take over the nesting sites. Burrows will be blocked once all birds have fledged and will remain blocked until the start of the HAPE breeding season at the beginning of March and will have cameras deployed on them to determine if WTSH are actively investigating the burrows.

Diet and feeding procedures
All meals will be prepared off-site either at a private residence with access to electricity and water, or at the Refuge headquarters. All meals will be prepared at room temperature and transported to the translocation site in a cooler each day and all clean-up will be done at the same location to maintain hygienic standards (outlined below).

<u>Recipe</u>
Previous projects in New Zealand have used 1 (106 g) tin Brunswick™ sardines (89%) in soy oil (10%) (including oil contents), one-third Mazuri™ Vita-zu bird tablet (vitamin supplement) coupled with 50 ml cold (boiled > 3 min) water. This diet is stable at room temperature (prior to preparation) and is easy to obtain and bring into the field. It also was the clear winner in a feeding trial conducted by Miskelley et al. (2009) of translocation projects in New Zealand.

<u>Preparing food:</u>
Mazuri tablets (or portions of tablets) will be crushed to as fine a powder as possible. The tablets do not dissolve, so crushing to a fine dust allows the vitamins to be equally distributed in the mixture. If making four tins of fish (700ml total volume), 200 ml cold (boiled > 3 mins) water (or unflavored pedialyte) will be placed in a blender with two tins of fish and blended until runny (at least 30 sec). A third tin of chopped fish (or equal mass of fresh fish) will then be added and blended until runny. Vitamin powder will then be added through hole in lid while blender running at low speed. The fourth tin of chopped fish will be added and blended until smooth. The mixture will be kept cold until immediately before feeding.

Food will be warmed immediately (<10 min) before feeding to prevent bacterial build up. Temperature will be tested on with a thermometer and will not exceed 33°C (cold mix e.g. <30°C may be rejected by chick; hot mix e.g. >35°C may damage chick's internal tissues). Food temperature will be monitored regularly (aiming for ~ 33ºC) and stirred with a spoon before drawing up food (the thick part of the mix can settle).

<u>Retrieving chicks from burrows:</u>
The methods outlined below are for two-person teams (a feeder permanently at the feeding station located by the artificial burrows and a handler/runner collecting, holding and returning

chicks). Prior to starting feeding for the day, complete rounds of all occupied burrows to check on welfare of all birds will occur. Each burrow will be visited in numerical order (to ensure all are checked), and the overall welfare of the chick will be checked in addition to signs of regurgitation in burrow, or abnormal excrement, and for any signs of digging in blockaded burrows. Any missing chicks will be searched for, including in un-occupied artificial burrows, in the event that they wander into an adjacent burrow.

Chicks will be processed in the following order:

1. Extract from burrow
2. Weigh (to obtain pre-feed or base weight)
3. Check band
4. Measure wing length (right wing) if wing measuring day
5. Any other handling (e.g. physical examination, down coverage estimates)
6. Feed (recording amount delivered in ml; no post-feed weight required)
7. Return to burrow

When birds are removed, they will be placed in a carrying box. Carrier boxes will have a clothes pin that is attached from each burrow with the burrow number on it to ensure birds are placed back in their proper burrow. After feeding, the chick is returned to its burrow and the clothes pin is clipped to its burrow lid. This helps to prevent confusion during feeding and eliminates the carrier's need to remember which burrow their chick came from.

Feeding chicks:

All feeding will be done on a clean surface (folding table) located in the shade above the colony. On rainy days, a pop-up tent will be erected to provide cover. The handler will hold the chick firmly on a surface (with towel) with a loose hand grip—the chick must not be tightly gripped or it will not feed properly and the crop area in particular needs to be unrestricted. The feeder will hold open the bill (mainly grasping the upper bill), stretching the head and neck out (at approx. 30–40º angle from the horizontal). With other hand holding the syringe, the feeder inserts the crop tube to the back and side of the throat (to keep airway clear). Food delivery will be at least 30 seconds for a 40 g batch, with at least one rest approximately half way (c. 20 ml) through syringe load to check for any signs of meal rejection. Food delivery will stop at the pre-determined amount or earlier if there are signs of food coming back up throat. The bill will be immediately released as the crop tube is withdrawn, so that if there is any regurgitation the food can be projected clear of the plumage and risk of aspirating food is reduced.

Figure 22: Demonstration of proper feeding technique, and apparatus from the 2015 HAPE translocation to KPNWR.

After feeding, the chick will be cleaned with a soft tissue so that there is no food on the bill or plumage. Soiling of the plumage with foreign materials can disrupt water-proofing and insulation. Particular attention will be paid to the base of the bill where food can build up and form a crust if not cleaned away. The amount of food actually taken by a chick will be recorded. Any details regarding food delivery e.g. regurgitation, overflow, appears full, difficult feeder requiring plenty of breaks, resists food, good feed etc. will be recorded to help with the planning of subsequent meal sizes.

Chicks will be fed amounts according to their weights on the day after transfer. Chicks will be fed up to 15% of their body weight on any given day, and food consumption will be adjusted to mimic the natural growth curve in wild chicks of each species.

Sterilization procedures

Maintaining sterile conditions for husbandry tasks will be crucial to preventing infections in the transferred chicks. Food storage, preparation and cleaning will all occur at the Refuge where there will be access to electricity, a sink and refrigerator; meals will be carried in a cooler to Nihoku immediately prior to feeding. Microshields™ chlorhexidine (5%) will be used for all disinfecting tasks. All feeding and food prep instruments and tools will be disinfected using chlorhexidine and rinsed using boiled water prior to commencing feeding. Each individual bird will have its own sterile syringe and stomach tube each day to avoid cross-contamination between feedings. All work surfaces will be wiped down with kitchen towels and disinfectant spray (or leftover sterilizing solution), or with antibacterial surface wipes both before and after feedings. Any weigh boxes that have been used will be washed, rinsed, and set out to dry.

Chick health and morphometric monitoring

As well as the physical health check made prior to transfer, a full physical examination will be given when chicks arrive at the release site, and at any point thereafter where there is unexpected and/or unusual chick behavior or posture. The Short-tailed Albatross (*Phoebastria albatrus*) translocation team collected blood samples to compare 9 different blood chemistry parameters with the same ones in naturally reared chicks (Deguchi *et al.* 2012a, b) and to characterize the effects of transmitter attachment and handling on hand-reared chicks. These measures provided insight into health status and body condition of the artificially reared birds. The results found better nutritional status in hand-reared birds than those raised by wild parents but evidence of possible muscle damage or capture myopathy in birds handled for transmitter attachment. At a minimum, NESH chicks to be transferred will have baseline blood panels and disease screening conducted on the day of transfer, and then again close to fledging.

All efforts will be made to minimize regurgitation, and to handle chicks in such a way that regurgitant can be projected away from the body. Regurgitation can have serious consequences, including soiling of plumage spoiling water-proofing and insulation; possible asphyxiation; and, aspiration of food particles leading to respiratory illness. Burrows will be carefully inspected for signs of regurgitation, especially while chicks adjust to a new diet and feeding regime, and to ensure chicks are passing normal feces and urates.

Other serious health issues that staff will be aware of include: ventriculitis/proventriculitis injury (caused by gut stasis or food contamination); aspiration of food (caused by regurgitation or poor feeding technique); and dehydration and heat stress. Appropriate first-aid treatment will be available if chicks injure themselves during the emergence period (see veterinary care and necropsy section).

Aside from basic health checks, one of the most important measurements that will be used in decision-making will be chick mass. Chicks will be weighed by placing them in a tared weigh box onto a table-top scale. The box will be cleaned between each chick measurement. Weight will be recorded in grams. Wing measurements may be made every 2-3 days to assist with planning meals and gate removal. Wing measurements will be taken at the following intervals and done less frequently than weight since a higher chance of injury is associated with wing measurements:

- Day of transfer in natal colony
- Soon after transfer on translocation site
- When wings are predicted to be around 210 mm in length for NESH/ 270mm for HAPE (based on a daily growth rate of up to 8 mm/day);
- 3–5 days later to determine the wing growth rate once chicks had reached or exceeded 220 or 275mm (to help schedule blockade removal).
- On alternate days, once blockades are removed to record departure wing lengths. Wing measurements can stop being measured once three measurements read the same (i.e. wing has stopped growing).

- Younger chicks can also be measured at opportunistic intervals, to monitor progress,

To measure wing length, birds will be kept in bags (to keep calm), and the right wing will be removed to measure—straightened and flattened to record maximum wing chord. Whenever possible, this measurement will be done by the same person to reduce inter-observer bias. If the potential exists for two observers to take measurements, they will be calibrated against each other to apply any needed corrections to the data.

Fledging criteria

Chicks of New Zealand species are not allowed to exit burrows before they have reached the minimum known first emergence wing-length for the species (emerging species), or are just short of the minimum known fledging wing-length (species fledging on the first night outside the burrow). Burrow blockade removal strategies have been developed to ensure that chicks do not leave the burrow prematurely and still have a good chance of fledging, even if at the lower end of the target fledging weight range for the species. Secondary criteria are species-specific and include weight, wing-growth rates and down coverage (Gummer 2013).

These strategies are necessary since it can be difficult to find chicks that have left their burrows. Lighter chicks that need to be fed daily are at the greatest risk if they can no longer receive meals, and some species are more prone to disappearing than others (e.g. Fluttering Shearwaters, *Puffinus gavia*; Gummer and Adams 2010). For both species, fledging criteria will be a combination of the measurements described below, a slowing of wing growth and reduced down.

Veterinary needs and necropsy protocols

Veterinary care will be provided locally by Dr. Joanne Woltman, DVM at Kaua'i Veterinary Clinic and all efforts will be made to stabilize chicks in the field so that they can remain at the translocation site. In the event that a chick cannot be stabilized in the field, it will be sent to the Save our Shearwaters facility at the Kaua'i Humane Society in Lihue for intensive care. Any chicks that expire during the process will be sent to Dr. Work at USGS for a full necropsy to determine the cause of death.

8.6 TRANSLOCATION ASSESSMENT

Measuring success

Establishment or restoration of colonies of Procellariiforms is a long-term commitment and markers of success will be incremental. Milestones that can be quantified include:

- Proportion of chicks that survive capture and transfer to new site
- Proportion of chicks that fledge from the colony
- Body condition of fledged chicks
- Proportion of translocated chicks that return to the new colony from which they fledged
- Number of prospecting birds fledged from other colonies that visit the translocation site.
- Number of those birds fledged from other sites that recruit to the new colony.

- Reproductive performance (hatching success, fledging success) of birds breeding in the new colony.
- Natural recruitment of chicks raised completely in the new colony
- Annual population growth within new colony

Most projects involving transfers of burrow nesting species in New Zealand have employed most, if not all, of the methods described above to monitor their success.

Monitoring success at Nihoku

Success at Nihoku will be monitored at various stages of the project. Items 1-3 from Table 4 below will be measured in each year during the translocation itself. Items 4-8 will be measured over time- starting 3-5 years after the first translocation cohort fledges (i.e. after sufficient time has passed for birds to return to the site as adults). If birds are identified during these checks, the burrows will be regularly monitored through the duration of the breeding season. It is hoped that by year five, there will be at least one active breeding pair at the site.

	Success Metric	**Nihoku Target**
1	% chicks that survive capture and transfer to new site	90% year one; 100% afterwards
2	Body condition of fledged chicks	Wing and mass measurements ≥ wild chicks
3	% chicks that fledge from the new colony	70% year one; 80% afterwards
4	% translocated chicks that return to the new colony (by age four)	NESH: ≥ 15% (estimated return rate of existing KPNWR colony)- 40% (cumulative survival rate from 0-4 years from Greisemer and Holmes 2011) HAPE: ≥ 27% (rate of survival in unprotected colonies)
5	# birds fledged from other colonies that visit the translocation site	>0 (i.e. any visitors considered successful)
6	# birds fledged from other sites that recruit to the new colony	>0 (i.e. any new recruits considered successful)
7	Reproductive performance of birds breeding in the new colony.	Reproductive success ≥ wild colonies with predation (NESH: 0.2-0.5; Greisemer and Holmes 2011); HAPE (39-61%; Simons 1985)
8	Natural recruitment of chicks raised completely in the new colony	NESH: ≥15% (estimated return rate of existing KPNWR colony) - 33% (rate of survival in unprotected colonies from Greisemer and Holmes 2011) and by year 6

		HAPE: ≥ 27% (rate of survival in unprotected colonies) and by year 10

Table 4: Metrics of success and targets used to determine translocation outcomes.

9 CONCLUSIONS

9.1 Summary

As with any multi-phase project that invokes contemporary techniques at the forefront of island conservation, there are lessons learned along the way that can serve future projects. The goals of this report were not only to document the process that this project went through, but also to provide some constructive suggestions for future projects so that others can learn from both what was and was not done correctly. As time passes, future publications will be put out on the ultimate results of the translocation as well as the results of ecosystem recovery.

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