Habitat suitability assessment for listed seabirds in the main Hawaiian Islands

November 2016

Prepared by:
Dr. Lindsay Young and Dr. Eric VanderWerf
Pacific Rim Conservation
PO Box 61827
Honolulu, HI, 96839

Cover photo. Song meter deployment site: Mount Kaala, Oahu

TABLE OF CONTENTS

EXECUTIVE SUMMARY:

Hawaii's only two endemic seabirds, the Newell's shearwater (*Puffinus newelli*; NESH) and Hawaiian petrel (*Pterodroma sandwichensis*; HAPE), and the Band-rumped storm petrel (*Oceanodroma castro*: BANP) are all listed under the endangered species act. Threats to all species include light attraction and fallout, collision with power lines, predation, and habitat degradation. Programs are already underway to mitigate light attraction, fallout and collision, but additional work is needed to provide protection from predation on the montane breeding colonies and/or determine areas that may be suitable for the creation of new breeding colonies. To accomplish this, in 2015 the USFWS produced a seabird habitat suitability model that identified the potential locations across the state where all three seabird species might be found. However, since many of the sites identified by the model had not been assessed on the ground for the presence of birds, and their potential to serve as management sites, it was recommended that those sites be ground-truthed. The results of that exercise (combining habitat and light suitability modeling with ground truthing) are presented below.

Table 1. Summary of sites visited, fence suitability, and presence of birds

Island	**# Sites visited on foot**	**# sites assessed aerially**	**# fenceable sites**	**# songmeters deployed**	**# sites with seabirds detected**
Oahu	3	0	1	3	1 (NESH)
Molokai	4	8	2	12	1 (NESH)
Maui	3	17	0	20	7 (HAPE&NESH)
Hawaii	3	0	1	3	3 (all three species)

A total of 13 sites were visited on foot, and an additional 23 were assessed aerially for a total of 38 locations assessed across four islands. Sites that were deemed accessible and/or possibly suitable for predator proof fencing were visited on-foot. In performing the on-the-ground surveys, attention was paid to not only whether the area was fenceable, but also to whether the terrain lent itself to rodent eradication using bait-stations. Habitat assessments were done and included a generalized habitat description (e.g., dominant vegetation, topographic and biotic complexity etc), and an assessment of whether the area appeared to be suitable for nesting seabirds. During ground visits, searches for signs of active nesting for NESH, HAPE, and BANP were done. A total of 38 songmeters were deployed across the four islands and recorded for anywhere from 8-12 weeks for each unit.

Birds were detected on all islands, but in variable densities. On Molokai, this consisted of a single call of a NESH that may have been just transiting the area and was not near a site that could be fenced. On Oahu birds were detected at one sites- three calls on the same night near Mt. Kaala. On Hawaii Island NESH and HAPE were detected in variable densities at two of the sites. However, the birds appeared to be transiting the area and nesting on the sheer cliffs just outside the area. At the third sites on Hawaii Island, HAPE were detected in very high densities, and BANP in densities high enough to suggest breeding. Both species had been previously observed on the ground at this site, which is also suitable for fencing and further management should be pursued at this site. On Maui HAPE were detected at six sites, once of which in high enough call rates to suggest breeding. NESH were detected at two sites- one site was the likely HAPE breeding location, and another single call at a second location.

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). 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 (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 (*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 Hawai‘i and elsewhere (Ziegler 2002, Reaser et al. 2007). Hawaii's only two endemic seabirds, the Newell's shearwater (*Puffinus newelli*; NESH) and Hawaiian petrel (*Pterodroma sandwichensis*; HAPE) are also listed under the endangered species act (USFWS 1983), as is a third nesting seabird, the Band-rumped Storm Petrel (*Oceanodroma castro;* BANP). Threats to these species include light attraction and fallout, collision with power lines, predation, and habitat degradation (Ainley et al. 2001). These pressures have resulted in a serious decline in all three species, particularly for NESH. Using at sea counts, Spear et al. (1995) estimated the number of NESH at~84,000 in the early 1990s, the number of NESH has since fallen drastically. Recent ornithological radar surveys, combined with returns of downed birds to the Save Our Shearwaters (SOS) program, show an apparent decline of 75% from 1993 to 2008 (Holmes, pers. comm. 2010), resulting in a current population estimate of 21,000 NESH. In order to mitigate this decline, effective and pro-active threat abatement is necessary to recover this species.

Newell's Shearwaters, HAPE and BANP are at least loosely colonial and nest in burrows, crevices or under vegetation. All three species breed in at least two habitat types: 1) high elevation, steep, wet montane forest dominated by native vegetation (ōhi‘a (*Metrosideros polymorpha*) forest with an uluhe fern (*Dicranopteris linearis*) understory) and 2) steep dry cliffs. In addition to those sites HAPE and BANP breed in open, rocky subalpine habitat at high-elevation. Historically, both NESH and HAPE bred from sea level all the way up to alpine peaks, so their current nesting habitat is likely dimished in terms of locations and diversity of types of ecosystems compared to historical nesting sites. Their almost exclusive presence at high elevations makes implementing conservation measures challenging.

In New Zealand and Australia, predator exclusion fencing, i.e., fencing designed to keep all non-flighted terrestrial vertebrates out of an area, has been used widely with extraordinary results (Day & MacGibbon 2002). The fencing excludes animals as small as two-day old mice, and prevents animals from digging under or climbing over the fence. Research undertaken in 2002 (MacGibbon and Calvert 2002) and completed in March 2011 (Burgett et al. 2007) has shown that these fences can be designed to exclude all of the mammalian pests present in Hawai‘i. 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 Hawai‘i (Day & MacGibbon 2002; Young et al. 2012 and 2013). Resource managers in New Zealand have built more than 52 predator fences that protect more than 10,000 hectares and five fences have recently been built in Hawai‘i to date. In New Zealand, these fenced areas are now refuges for a majority of the endangered species. Protection of Hawaii's listed seabirds on their nesting grounds and reduction of collision and lighting hazards are high priority recovery actions. 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.

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 Hawai‘i, 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). However, before attempting this, the rugged montane areas where all three species nest need to be assessed on a site by site basis to determine if fencing is feasible.

For this study we proposed a ground validation of a Habitat Suitability Model (HSM) developed by the US Fish and Wildlife Service (USFWS) combined with an initial assessment of whether areas suggested by the model contained nesting birds and if they were potentially fenceable. The HSM is a decision support tool to be used by conservation and ecosystem managers for planning, threat mitigation and strategic habitat prioritization to help define, and refine, current and future conservation efforts. The compilation of these two approaches will help to identify areas of conservation concern, and will allow the USFWS to model the impact of various management approaches to increase the long-term viability of the populations.
The purposes of this plan were to: 1) Visit sites proposed by the HSM to determine if the habitat was suitable based on knowledge of habitat in existing nesting colonies; 2) identify possible predator exclusion fence units put forward by the HSM and 3) Determine whether any of those units contained nesting NESH, HAPE or BANP.

METHODS

Information gathering

The project began with an initial meeting between PRC and FWS on 05-29-2015. At that meeting, methods and expectations for the project were discussed. Since the contract had not yet been officially awarded, and we were already well into the breeding season for all species, all parties agreed to postpone the field work until the summer of 2016 and spend the remaining time in 2015 gathering information. Once the HSM had been produced and potential site visit points had been identified, a meeting was scheduled with the seabird hui- a group that functions as Hawaii's listed seabird species recovery group. On 09/08/2015 a meeting was held with the seabird hui to discuss the sites proposed by the USFWS for visiting and to begin to coordinate with each island based manager on specific site visits. The outcomes from those meetings were that the following site visits would occur on each island:

1. Visit four sites on the ground on Oahu where suitable habitat occurs and previous sightings of either NESH or HAPE have been made.
2. Visit four sites on Hawaii Island- one in the National Park and three within Puu Oumi Natural Area Reserve in the Kohala Range in coordination with the National Park Service and the Hawaii Natural Area Reserves staff
3. Visit six sites on Maui on both east and west Maui in coordination with the Maui Nui Seabird Recovery Project.
4. Visit six sites on Molokai, also in coordination with the Maui Nui Seabird Recovery Project and several landowners.

On each island, the sites that were selected for visitation in coordination with local biologists, would first be flown over by helicopter to determine the highest suitability areas to visit on foot. Once the precise locations to be visited had been confirmed, sites were visited on the ground where anywhere from 1-4 days was spent at each location assessing the habitat and searching for the presence of birds (described in more detail below). During all visits, GPS tracks were taken of areas visited. Specific methods employed on the site visits are described below.

Aerial habitat surveys

All sites on each island were first flown over via helicopter to make a cursory determination of whether they could be accessed on foot, what the general habitat conditions were, and if they appeared to be suitable locations for predator proof fences. During those flights, photos and GPS coordinates were taken of each HSM proposed site in order to extract information from the site once back on the ground. Sites that were determined to be poor locations for fencing from the air were deemed such because the topography was too steep or the streams were too large and no suitable natural barriers were observed that could be used to secure fence ends against predators. For the majority of sites that were eliminated, steep slopes were the main cause. If a site appeared to be fencable and accessible, it was noted and every attempt was made to visit the site on foot. Some sites that were not accessible on foot still had song meters deployed in order to determine whether any seabirds were nesting in them in order to validate the slope and aspect inputs of the HSM.

Ground-truthing

Sites that were deemed accessible and/or possibly suitable for predator proof fencing in the initial flyovers were visited on-foot whenever possible. In performing the on-the-ground surveys,

particular attention was paid to not only whether the area was fenceable, but also to whether the terrain lent itself to rodent eradication using bait-stations. Conditions that made a site fencable included a solid substrate to anchor fence posts, a grade not exceeding 50%, vegetation that could be safely cleared without impacting the forest structure or listed plant species, an absence of active streams and ground substrate suitable for burrowing seabirds (i.e. not flooded bog or solid rock). In some cases, streams that terminate with a suitable natural barrier (exposed cliff face or waterfall) can be used to secure a fence without traversing a waterway. These instances are noted in individual site descriptions below.

In addition to assessing the suitability of constructing predator proof fences, an assessment of the habitat was done. Specific habitat variables that were collected include the slope, elevation, canopy cover, dominant canopy species, percent native species and dominant ground cover. At the end, a generalized qualitative assessment of whether the area appeared to be suitable for nesting seabirds was made.

Seabird presence surveys

During ground visits, searches for signs of active nesting for NESH, HAPE, and BANP were done. These signs included droppings and presence of a burrow, smell and other signs of seabird visitation during the day, and the use of night vision and triangulation with ground calling at night. Acoustic surveys were also conducted during the evenings and mornings at any site that was visited overnight. Standardized auditory and night-vision surveys were conducted from sunset to 2 hours post-sunset (evening commute period) and from 90 minutes prior to sunrise until sunrise (morning commute period) each day during the survey period following established protocols from the Kauai Endangered Seabird Recovery Project. Data collection included recording the number, time, and flight direction of seabird targets detected visually and acoustically.

In addition to ground-based searches, passive acoustic surveys have been found to be an effective technique for detecting the presence of rare and elusive nocturnal seabirds like the Hawaiian Petrel and Newell's Shearwater (Buxton & Jones 2012; Oppel et al. 2014; Borker et al. 2015; Dufour et al. 2016). The method takes advantage of the social behavior that occurs at and around breeding aggregations, including frequent vocalizations. Automated acoustic sensors and automated acoustic classification techniques now make it possible to detect and quantify vocalizations, which contributes to identifying previously-unknown breeding sites. This automated survey approach greatly increases the spatial and temporal scale of acoustic surveys, thereby improving detection probabilities for rare and elusive species. Increased survey effort can also help increase the statistical power of long-term monitoring projects, a problem that can hamper less intensive monitoring projects (MacKenzie et al. 2002, 2005).

At sites on all islands, song meters (remote acoustic recording devices) were deployed for anywhere from 1-3 months to record auditory data. Song meters are compact, battery-operated remote acoustic sensors that record nocturnal calls during evening hours, targeting peak activity for the focal species Each song meter was programmed to record continuously for a five-hour block every evening starting at local sunset, when all three species are most vocally active. After that initial five hour recording block, the recording schedule was for one-minute every ten-minutes until dawn in order to maximize both battery life and data collection. The acoustic analyses of all field recordings were carried out with custom detection and classification tools developed by acoustic monitoring experts from Conservation Metrics (CMI). For analysis, CMI splits field recordings into two-second clips and extracts measurements of ten spectral features

found in bird calls. A classification model was then obtained for each species of interest using training and cross-validation datasets containing examples of positive sounds (i.e. petrel vocalizations) and a representative example of negative sounds from the soundscape at all survey sites. The processing algorithm learns which spectral features best differentiate target sounds from other sounds in the environment, and each model can then be applied to raw acoustic data. The models return a probability that a given two-second window contains a sound produced by the target species.

MOLOKAI RESULTS

Partners

Maui Nui Seabird Recovery Project- Jay Penniman, Becca Pederson and Che Frausto
Molokai Land Trust- Butch Haase (landowner)
Dunbar Ranch- Stephanie Dunbar (landowner)
American Bird Conservancy- Hannah Nevins (donation of song meter analysis)

Site descriptions and suitability for fencing

Twelve sites were assessed on Molokai- eight exclusively from a helicopter and four on the ground. Seven song meters were deployed- three at ground-truthed sites and four deployed aerially. While all sites had vegetation structure and habitat that appeared suitable for seabirds, only a single NESH was detected via song meters. Of the twelve total sites, only three sites were technically fenceable, and only one of the three fenceable sites would be recommendable to build for reasons described below. No birds were detected inside potential fence sites and thus these sites should be considered translocation sites rather than social attraction or colony protection site. An overview summary of the sites visited is presented below with more detailed site descriptions following. Site number corresponds to .kml location point provided by USFWS from the HSM.

Figure 1: Map of sites assessed on Molokai

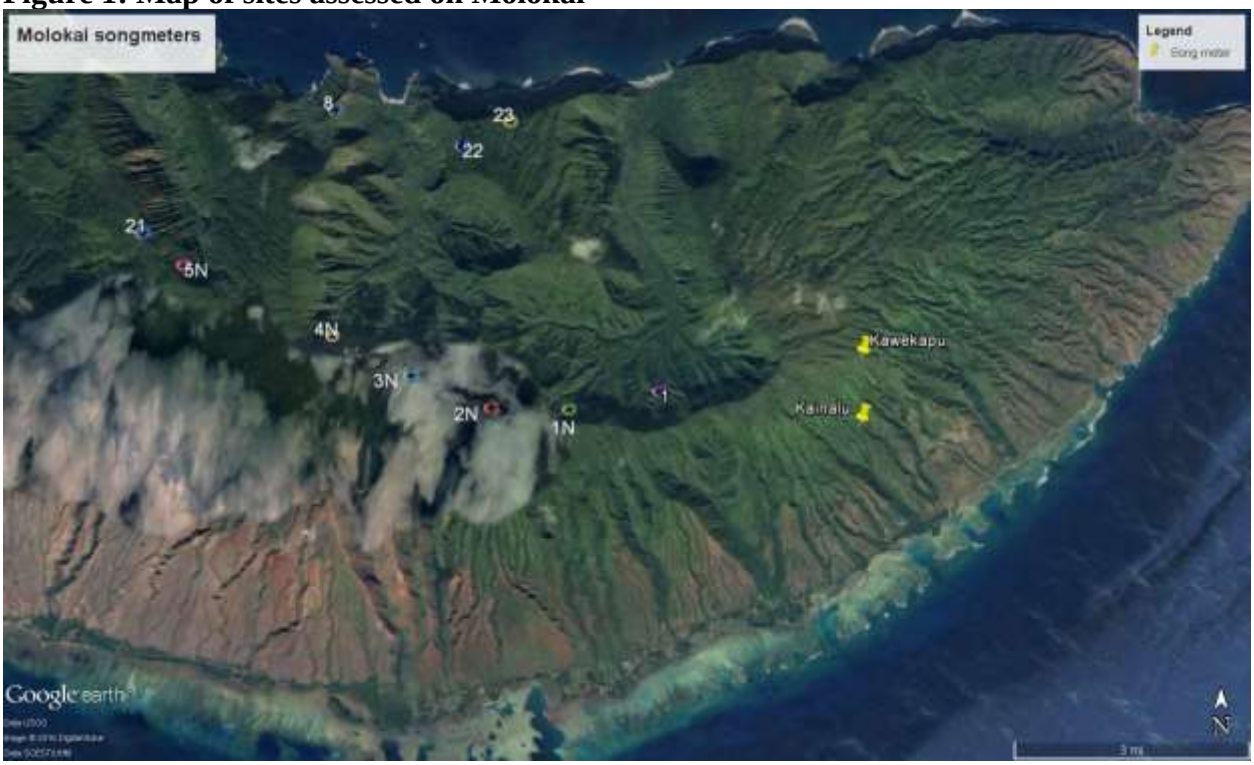

Table 2: summary of sites visited on Molokai

Site	*Model output #*	*Fenceable?*	*Seabirds detected?*	*Habitat suitable?*
Pelekunu overlook	21	Yes	No	Yes
Pelekunu Preserve	8	No	1 NESH call	Yes
Olokui	22	No	No	Yes

Olokui	23	No	No	Yes
Kainalu	None	No	No	Yes
Kawekapu	None	No	No	Yes
	1	No	No	Yes
	1N	No	No	Yes
	2N	No	No	Yes
	3N	No	No	Yes
	4N	Yes	No	Yes
	5N	Yes	No	Yes

The habitat of most sites assessed on Molokai was mesic to wet forest with an Uluhe understory and either open, or limited Ohia canopy. The slope was variable and ranged from near vertical cliffs, to gradual slopes.

Sites visited by helicopter:
Sites 1, 1N, 2N, 3N, 8, 22 and 23 when flown from the air were clearly not fenceable, nor were there any areas close to the points that were fenceable. All of the points were on steep valley walls with no practical way to enclose the area. That being said, song meters were still deployed at some of the locations (8, 22, and 23) to determine if birds are nesting in that type of habitat. Sites that were extremely steep, but had potential areas to fence immediately behind the cliffs were examined on foot whenever possible and described below.

Figure 2: Site 1 (left) and 1N (right) from the air; examples of sites that cannot be fenced because of streams (in the case of site 1) and steep terrain (site 1N).

Site 4N while not itself fenceable, had a plateau area immediately behind the pali that is almost certainly fencebale and is currently managed by The Nature Conservancy (TNC). However, the area that lends itself to fencing is very boggy and may not be suitable habitat even as a social attraction site as birds may not be able to burrow in the substrate. This site was not visited on

foot despite suitable access as further discussions with TNC are needed to gain access, and it is unclear whether it would make a suitable social attraction site due to the boggy substrate.

Figure 3: Site 4N immediately over the Pali. The habitat ranged from 100% canopy cover to full open bog at this site and was fenceable.

Sites ground-truthed on foot:
Sites 4N, 5N, and 21 were fenceable in areas immediately behind (south) of the pali and 5N and 21 were visited on foot. Site 21 had good semi-native forest that was easily fenceable and had vehicular access. The fenceline would follow an existing, newly installed ungulate fence up to a puʻu at which point it would enclose the pu`u with a steep pali immediately on one side. Based on the height of the t-posts used for the existing fence, it may be possible to retrofit or replace a section of the ungulate fence to save on materials. None of the sites detected birds on song meters deployed there and thus should be considered translocation sites rather than colony protection or social attraction.

Figure 4: Site 21 showing existing ungulate fence and habitat. Area to be enclosed would be on the right of the existing ungulate fence.

Figure 5: Site 5N showing public access and tall Eucalyptus canopy.

The area just over the pali from site 5N was also visited on foot in an area by the Waikolu lookout. The site has drive-up access and is relatively flat, but has some distinct disadvantages. There are numerous large Eucalyptus trees in the area that present a tree-fall hazard, and the location close to hunting and public vantage points could present a risk of vandalism. The habitat in the fenceable area is also sub-optimal for the birds and active restoration would need to be undertaken to make it suitable. Since it is very close to site 21, it would be recommended to begin with site 21 before considering this location.

Figure 6: Song meter deployment and habitat at Dunbar Ranch

The Dunbar Property, also known as Kainalu Ranch, was visited on foot and a song meter deployed (see figure 5 above), but no birds were detected. The site where the song meter was deployed was not feasible as a fence location due to the presence of several actively flowing streams.

The ridge adjacent to the Dunbar property, Kawekapu, owned by Molokai Land Trust was visited on foot and had a song meter deployed**.** The findings are the same as the Dunbar property- it is not feasible as a fence location due to the presence of actively flowing streams. There is the possibility of enclosing the entire drainage running along ridges from both landowners from almost summit to southern Makai boundary, but a fence in that area would be many kilometers in size and to date, available rodent eradication methods for an area that size are not feasible in Hawaii. Given that no birds were detected on either property, they are not currently recommended as possible fencing locations.

Presence of birds

No birds were detected visually or on the ground at any site during ground searches. However, a single Newell's Shearwater was detected via songmeters at Pelekunu. Seven song meters were deployed on Molokai using in-kind funding from the American Bird Conservancy. Five of the seven deployed sensors were recovered and one sensor failed four days into the monitoring period, likely due to battery failure. Two sensors had microphone quality problems, resulting in loss of data. These types of problems have been known to occur with song meters in the past, and are likely due to the deteriorating effects of weather and moisture on microphone components.

No Hawaiian Petrel or Band-rumped Storm-Petrel were detected using auditory monitoring. However, this is not conclusive proof of the absence of these species in the survey area, and it is worth noting that birds may be present on Molokaʻi in other areas that were not surveyed. Newell's Shearwaters were detected at one site: number eight within the Pelekunu Preserve Area. This was a single calling event on July 14, at 22:40. Notably, this was near the end of survey effort for this round, at one of the two survey sites with the greatest amount of

high-quality recording data. This detection was a single calling event of less than 6 seconds duration, so we were not able to determine any information about behavior. The analyst suggested it was likely a flight call given the short duration and not likely to be ground calling. Ground-calling would be an indicator of nest activity, but flight calling could be done by adults returning to feed chicks at nests during this time of the season.

The confirmed Newell's Shearwater call was rated with a high level of confidence by CMI's detection models (more than 95%). This indicates that the models were performing well in the Molokaʻi soundscape, despite being trained with data from other Hawaiian islands. All signs indicate that the detection models were performing well, and would have detected other Newell's Shearwater activity if it were present.

Habitat suitability

All sites contained suitable habitat at the points identified by the HSM. Most contained a majority of native plants and faced a northern exposure giving birds clear access to the prevailing winds as well as the ocean. However, the majority of sites fell on extremely steep slopes that were not suitable for implementing active management and predator control. At some sites that were only assessed aerially, it was not possible to conduct an accurate assessment of groundcover or % native species present, and thus those fields have been left blank. A summary of habitat variables is presented below in table 3.

Table 3: Summary of habitat variables for sites across Molokai

Site	*% Slope*	*Elevation (m)*	*% Canopy cover*	*Canopy species*	*% native*	*Groundcover*
8	54.7	427	20	Open Ohia Forest	<50	?
22	41.59	981	60	Open Ohia Forest		Uluhe
23	22.57	925	30	Open Ohia Forest		Uluhe
Dunbar- Kainalu	30	2240	15	Open Ohia Forest	95	Uluhe
MLT- Kawekapu	30	2240	20	Open Ohia Forest	95	Uluhe
21	39.78	1066	15	Open Ohia Forest	80	Uluhe
1	28.9	525	15	Open Ohia Forest		Uluhe
1N	40.88	810	60	Open Ohia Forest		?
2N	52.71	1129	<5	Cliff vegetation	95	Uluhe
3N	50.46	1198	10	Open Ohia Forest		Uluhe
4N	62.79	820	<5	Cliff vegetation	95	Uluhe
5N	46.78	833	80	Open Ohia Forest	95	Uluhe

Conclusions

Overall, the island of Molokai contained large areas of suitable habitat for all three listed seabird species, with notable concentrations on the northern sea cliffs of the island. Unfortunately, only a single calling NESH was detected across all sites suggesting that a breeding population may no longer exist, or is in very low densities on the island. While the habitat may be suitable, there are likely predators in high enough densities to prevent nesting of all three species. There were several areas where constructing predator proof fences were possible, but none of the potential locations contained, or were near to, listed seabird locations. Given the very low density of birds, all fence sites should be treated as translocation sites since birds are not at sufficient densities in the immediately surrounding areas for social attraction to be a feasible alternative (Buxton et al. 2014). For future years, it is worth repeating and expanding these surveys to confirm the status of listed seabirds on Molokai.

OAHU RESULTS

Partners

State of Hawaii Natural Area Reserves Program- Chris Miller
Oahu Army Natural Resources Program- Phil Taylor

Site descriptions and suitability for fencing

Three sites were visited on Oahu, all of which were visited on foot, and song meters were deployed at each site. All sites had vegetation structure and habitat that appeared suitable for seabirds. NESH were detected at one of the three sites via song meters. One of the three sites was fenceable, which, unfortunately, was not a site where birds were detected. A summary of the sites is presented below.

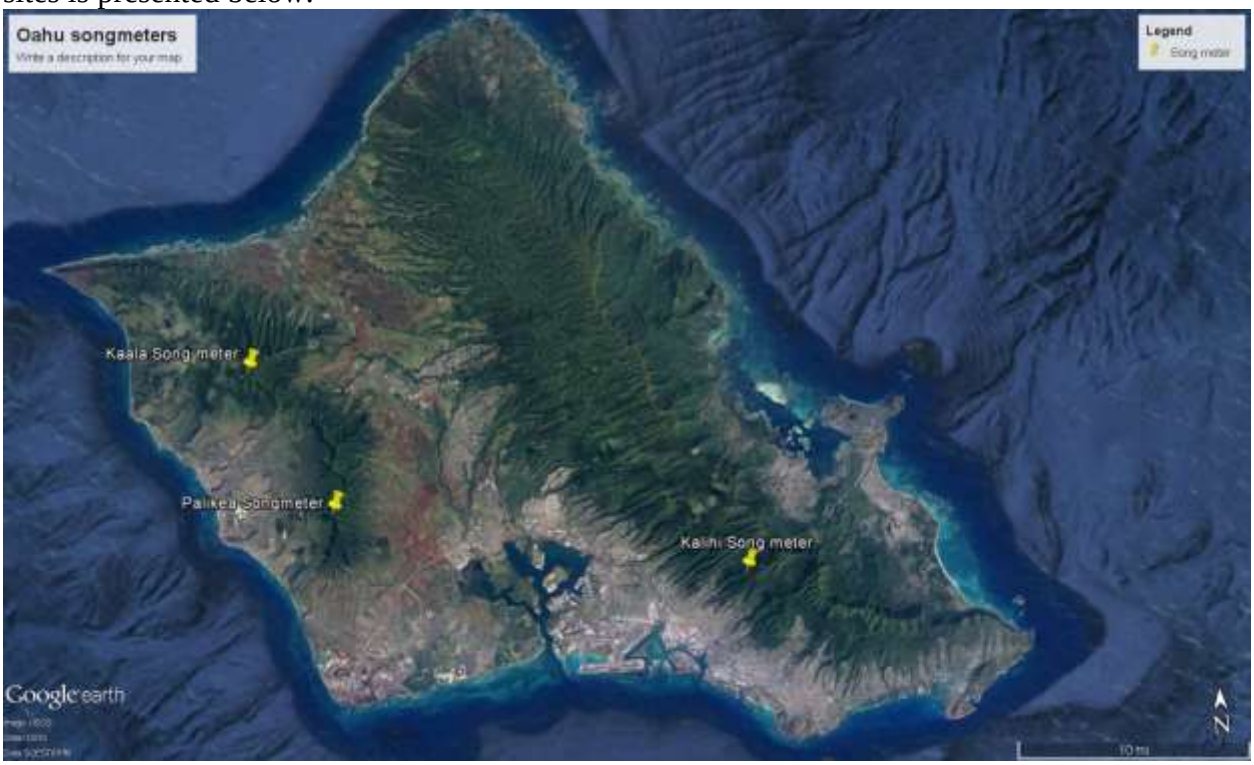

Figure 7: Map of sites assessed on Oahu

Table 4: summary of sites visited on Oahu

Site	*Model output #*	*Fenceable?*	*Seabirds detected?*	*Habitat suitable?*
Kaala	None	No	3 NESH calls on same night	Yes
Palikea	None	No	No	Yes
Kalihi	None	Yes	No	Yes

The three sites listed above were visited from 06/23/2016 to 07/06/2016 on foot. Mt. Kaala is at the northern end of the Waianae range and contains Kaala Natural Area Reserve, which is an excellent example of a native bog habitat and is known for its stunted Ohia forest and native invertebrates. While the bog habitat itself is not suitable for nesting seabirds due to the risk of burrow flooding, the deployment location was on the west side of Kaala overlooking Waianae Valley, where there is a large area of potentially suitable seabird habitat with steep, vegetated cliffs facing the ocean. Palikea is a peak at the southern end of the Waianae range and is

positioned at the top of a long the ridge separating Nanakuki and Lualualei Valleys. This area is an excellent example of native mesic forest and contains steep vegetated and non-vegetated cliffs that are potentially suitable habitat for nesting montane seabirds. Finally, Kalihi valley, adjacent to urban Honolulu, has smaller hanging valleys comprised of a sparse Ohia canopy with Uluhe understory. While Kalihi Valley appears to be an unusual choice, vocalizations of NESH flying over a neighborhood were recorded by a local resident in 2006, and several reports of downed birds exist on roads in the adjacent valleys, making it a logical place to search.

Of the three sites visited, only Kalihi Valley was suitable for predator proof fencing. Kaala and Palikea were not fenceable because of the very steep terrain. Both were on steep valley walls with no practical way to enclose the area and would require crossing larger streams. However, both sites are in locations that can be accessed by foot and doing predator control at these sites would be feasible if the birds were in fact breeding in the area. As such, management of these sites should not be ruled out completely.

Figure 8: Site at Kaala Natural Area Reserve that could not be fenced because of steep terrain.

The Kalihi site however, was fenceable as a discrete valley with a relatively small stream to enclose at the bottom.

Figure 9: Kalihi Valley site facing North East (upslope)

Figure 10: Kalihi Valley site facing South (down slope)

A fence could run along both valley ridges and terminate at the bottom resulting in a fenceline that is approximately 3,000 feet long and encloses 12 acres. While the fence is technically possible, significant urban barriers along the coastline, most notable bright lights and numerous structures, would pose a risk to birds transiting in and out of this valley if they were to be attracted to the area. Thus, while fenceable, it does not seem to be a suitable site to attract birds into due to its urban location.

Presence of birds

Song meters were deployed at each site for a minimum of two and maximum of three months. No Hawaiian Petrels or Band-rumped Storm-Petrels were detected using song meters. Newell's Shearwaters were detected with song meters at Kaala on a single night where it recorded three calls. The Newell's Shearwater calls were rated with a high level of confidence by CMI's detection models (more than 95%). This indicates that the models were performing well in the Oahu soundscape, despite being trained with data from other Hawaiian islands. All signs indicate that the detection models were performing well, and would have detected other Newell's Shearwater activity if they were present.

Table 5: Summary of song meter results from Oahu

Site	*# days deployed*	*# hours recorded*	*Date / Time*	*Minutes After Sunset*	*Number of Calls*
Kaala	78	113.34	08-02-2016 05:06:00	595	3 (NESH)
Palikea	76	110.69	N/A	N/A	0
Kalihi	66	96.01	N/A	N/A	0

Habitat suitability

All sites contained suitable habitat. Most contained a majority of native plants and faced an exposure that would give nesting seabirds clear access to the ocean. A summary of habitat variables is presented below in table 6.

Table 6: Summary of habitat variables for sites across Oahu

Site	*% Slope*	*Elevation (m)*	*% Canopy cover*	*Canopy species*	*% native*	*Groundcover*
Kaala	25	1163	75	Open Ohia	95	Multiple native
Palikea	30	947	75	Open Ohia	70	Multiple native
Kalihi	35	454	15	Open Ohia	95	Uluhe

Conclusions

One of the three sites was fenceable, which, unfortunately, was not a site where birds were detected, despite being the location where NESH had been heard in 2006. However, the detection of NESH at one of the three sites with a very limited recording window was encouraging. Even with the low number of calls, future surveys should be conducted to determine whether birds are nesting nearby and what management actions could be taken to protect any remaining breeding colonies. If NESH are still nesting on Oahu, it is at low densities that are likely in need of protection.

MAUI RESULTS

Partners

Maui Nui Seabird Recovery Project- Jay Penniman, Lynx Gallagher, Becca Pederson, and Che Frausto

Maui Land and Pineapple Company

Site descriptions and suitability for fencing

Three sites were assessed on West Maui, including one site that was assessed by helicopter and two that were visited on foot. Song meters were deployed in 20 locations, 10 each in May and July (Figure 10). All three sites assessed had vegetation structure and habitat that appeared suitable for seabirds, consisting of dense low vegetation including uluhe ferns, scattered ohia trees, and a variety of other native plants species. Of the 20 sites where song meters were deployed, HAPE were detected at six sites and NESH were detected at two sites (Table 7). One of the three sites identified by the HSM was suitable for fencing (pt. 17), but no song meter was placed there so it is unknown if any birds are present. An overview summary of the sites visited is presented below with more detailed site descriptions following. Site numbers correspond to location descriptions provided by USFWS from the HSM.

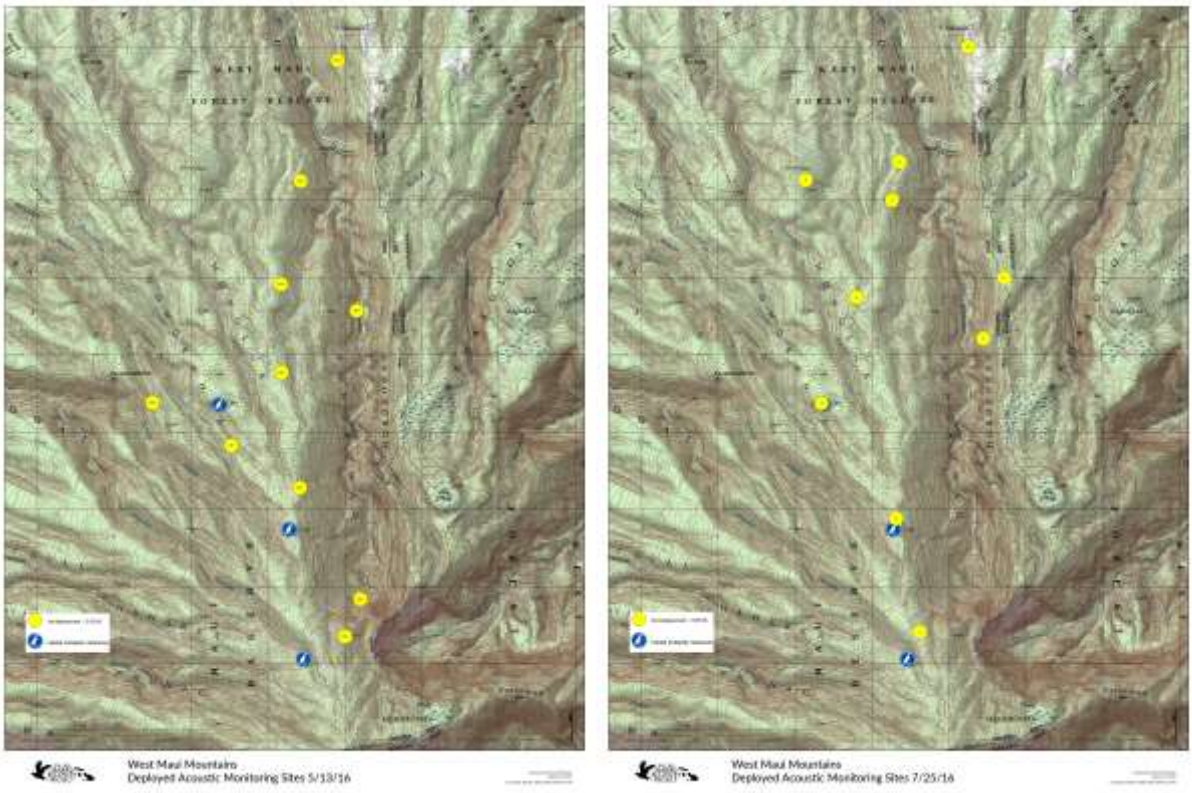

Figure 10: Map of sites assessed in the West Maui Mountains, showing the songmeter deployment points in May (left) and July (right). Blue points indicate USFWS model outputs from North to South point 2, 17 and 7.

Table 7: summary of sites visited on Maui

Song meter site	*Model output #*	*Fenceable?*	*Seabirds detected?*	*Habitat suitable?*
1	N/A	No	0	Yes
2	N/A	No	HAPE	Yes
3	N/A	No	0	Yes
4	N/A	No	HAPE	Yes
5	N/A	No	0	Yes
6	N/A	No	0	Yes
7	N/A	No	0	Yes
8	N/A	No	HAPE	Yes
9	N/A	No	HAPE & NESH	Yes
10	N/A	No	NESH	Yes
11	Close to HSM 7	Yes	0	Yes
12	Close to HSM 17	Yes	0	Yes
13	HSM2	Yes	0	Yes
14	N/A	No	0	Yes
15	N/A	No	HAPE	Yes
16	N/A	No	0	Yes
17	N/A	No	0	Yes
18	N/A	No	HAPE	Yes
19	N/A	No	0	Yes
20	N/A	No	0	Yes

Sites visited by Helicopter:

One site on West Maui identified by the HSM as potentially suitable for seabird nesting was assessed by helicopter on 15 August. The site appeared to have suitable habitat for seabirds, though it was more densely forested and contained less uluhe fern than many typical nesting sites elsewhere. The site consisted of a low hill covered in dense native forest, with scattered ohia trees up to about 8 meters tall, a diverse midstory comprised of olapa (*Cheirodendron* sp.), kolea (*Myrsine* sp.), and other small trees, and a dense ground cover of uluhe (*Dicranopteris linearis*), tree ferns other ferns, kanawao (*Broussaisia arguta*), ohelo (*Vaccinium* sp.), and numerous other forbs. It would be possible to construct a completely enclosed fence around the site, but doing so would cause substantial damage to the habitat because of the requirement for clearing the area on either side of the fence. Fencing of the site is not recommended at this time because it is not known if any seabirds occur at the site.

Figure 11: HSM 2 on West Maui. The site contained suitable seabird nesting habitat but was perhaps more densely forested than typical sites elsewhere. It was suitable for fencing but the presence of seabirds was unknown

Sites ground-truthed on foot:

Two sites on West Maui identified by the HSM as potentially suitable for seabird nesting were assessed by helicopter on 15 August 2016.

Site HSM17 (Figure x) appeared to have suitable habitat for seabirds, though it was more densely forested than many typical nesting sites elsewhere and contained no uluhe fern. The site was located on a wider section of a ridge separating two deep valleys. It was covered in dense native forest, with scattered ohia trees up to about 8 meters tall, a diverse midstory comprised of olapa (*Cheirodendron* sp.), kolea (*Myrsine* sp.), and other small trees, and a dense ground cover of uluhe (*Dicranopteris linearis*), tree ferns other ferns, kanawao (*Broussaisia arguta*), ohelo (*Vaccinium* sp.), and numerous other forbs. It would be possible to construct a completely enclosed fence around the site, but doing so would cause substantial damage to the habitat because of the requirement for clearing the area on either side of the fence. Such a fence would protect only a narrow strip of habitat along the ridge top. The slopes on each side were not steep enough to act as a natural barrier to predators, precluding construction of an effective fence that was not fully enclosed. Fencing of the site is not recommended at this time because it is not known if any seabirds occur at the site and because the effectiveness of the fence is questionable.

Site HSM17 (Figure x) appeared to have suitable habitat for seabirds and was very similar to nesting areas observed on other islands. The site was located on moderate slope and was covered in dense stunted native forest, with scattered ohia trees up to about 3 meters tall, olapa (*Cheirodendron* sp.), and other small trees, and a dense ground cover of uluhe (*Dicranopteris linearis*), tree ferns other ferns, kanawao (*Broussaisia arguta*), ohelo (*Vaccinium* sp.), and numerous other forbs. It would be possible to construct a completely enclosed fence around the site, but doing so would cause substantial damage to the habitat because of the

requirement for clearing the area on either side of the fence. Fencing of the site is not recommended at this time because it is not known if any seabirds occur at the site and because the effectiveness of the fence is questionable.

Figure 12. Two views of HSM 17. The site contained suitable seabird nesting habitat but contained little uluhe and was perhaps more densely forested than typical nesting sites elsewhere. It was suitable for fencing but the presence of seabirds was unknown.

Figure 13. Two views of HSM 7. The site contained very suitable seabird nesting and was suitable for fencing but the presence of seabirds was unknown.

Presence of birds

A total of 1258.26 hours of song meter recording were collected over 849 total survey-nights between May 13, 2016 and August 15, 2016. The first round of deployments made up 939.42 of these hours, collected over 629 survey-nights between May 13, 2016 and July 25, 2016. The second round of deployments comprised the remaining 318.84 hours, collected over 220 survey-nights between July 25, 2016 and August 15, 2016

Table 8: Summary of song meter results from Maui

SPID	*Recording Unit*	*Model output*	*# days deployed*	*Species*	*Call rate (calls/min)*
1	WM01		74	N/A	
2	WM02		45	HAPE	Single calling bout

3	WM03		44	N/A	
4	WM04		70	HAPE	0.0133 +/- 0.06
5	WM05		51	N/A	
6	WM06		74	N/A	
7	WM07		63	N/A	
8	WM08		64	HAPE	0.0593 +/- 0.1351
9	WM09		70	HAPE & NESH	HAPE- 0.6393 +/- 0.9576 NESH- 3 calls
10	WM10		74	NESH	2 calls
11	WM01	HSM 7	22	N/A	
12	WM02	HSM 17	22	N/A	
13	WM03	HSM2	22	N/A	
14	WM04		22	N/A	
15	WM05		22	HAPE	0.0119 +/- 0.0398
16	WM06		22	N/A	
17	WM07		22	N/A	
18	WM08		22	HAPE	0.004 +/-0.0182
19	WM09		22	N/A	
20	WM10		22	N/A	

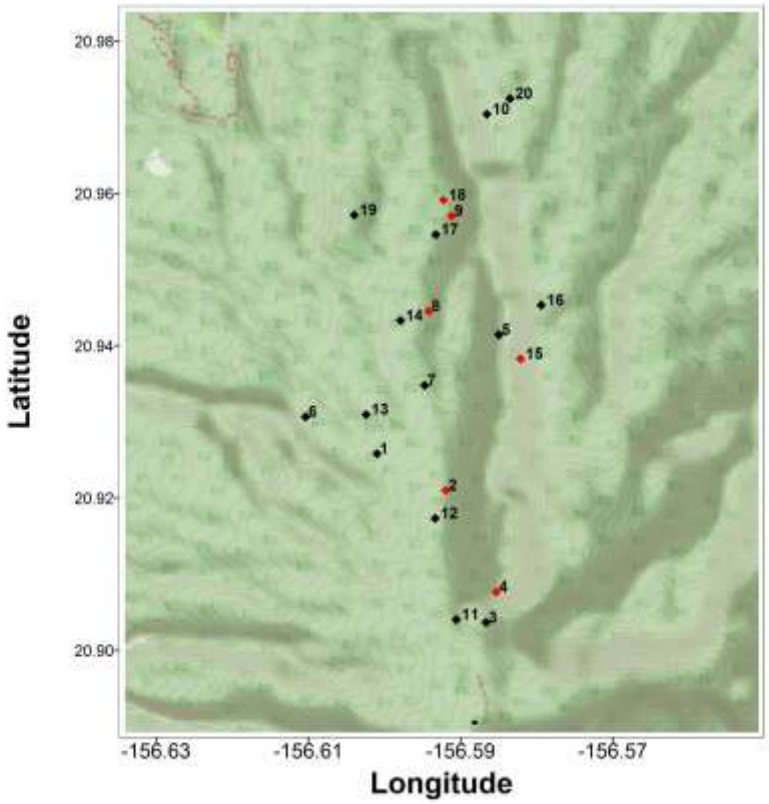

Figure 14: 20 sites surveyed for HAPE activity in the West Maui Mountains. HAPE calls were detected at red points; no HAPE calls were detected at black points.

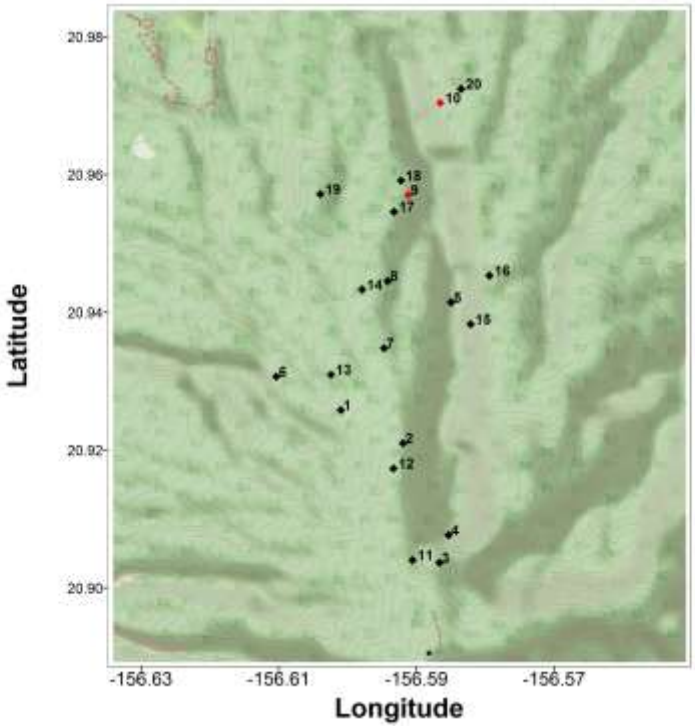

Figure 15: 20 sites surveyed for NESH activity in the West Maui Mountains. NESH calls were detected at red points; no NESH calls were detected at black points.

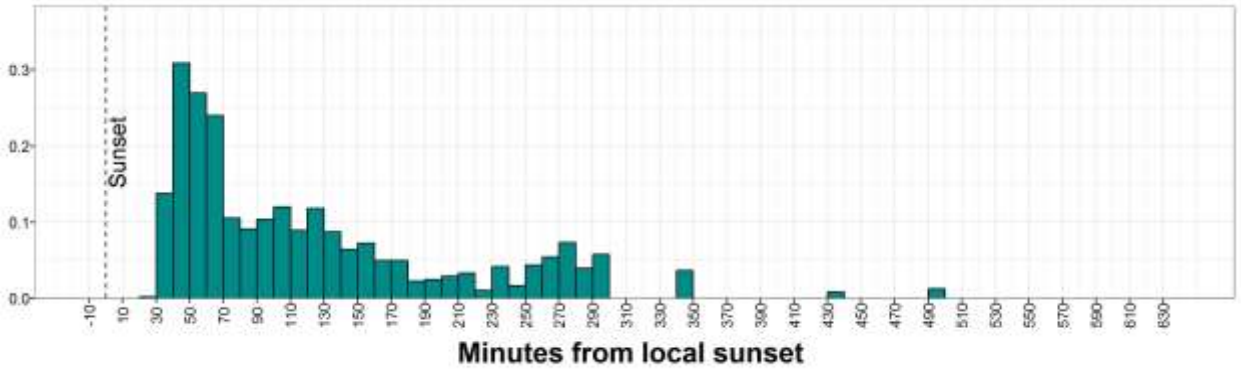

Figure 16: Mean HAPE calls per minute for active sites as a function of minutes from local sunset. Peak calling hour was between 30 and 90 minutes after sunset.

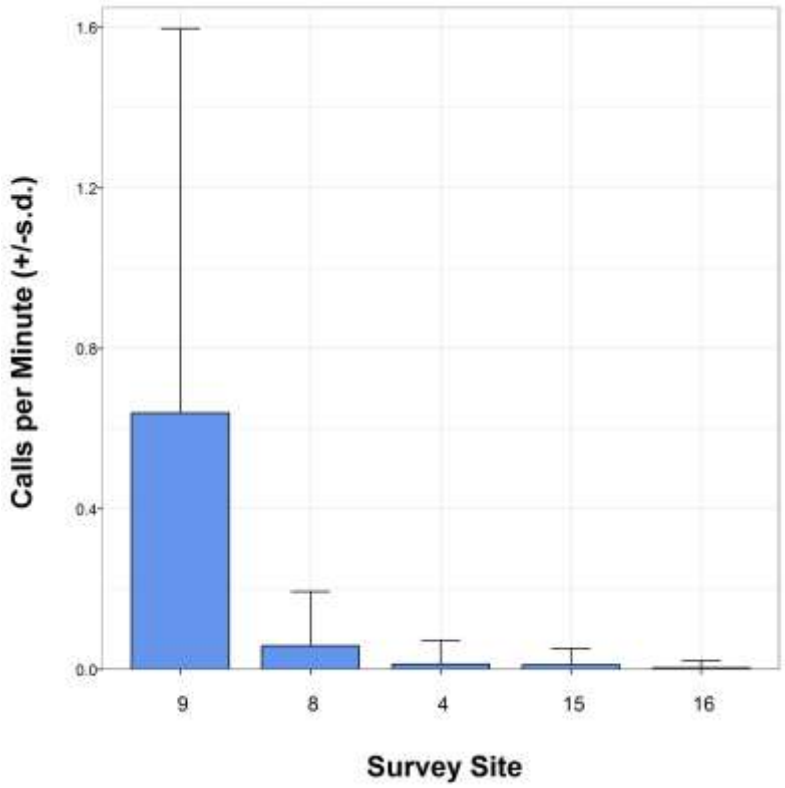

Figure 17: Mean HAPE call rate per minute during the peak calling hour for active sites during the survey period.

Auditory surveys conducted on 15 August at site WM6 detected no seabirds calls during two hours of observation. No active signs of nesting were found at sites that were visited on foot.

Habitat suitability

Table 8: Summary of habitat variables for sites visited on Maui

Site	*% Slope*	*Elevation (m)*	*% Canopy cover*	*Canopy species*	*% native*	*Groundcover*
2	0-30		90	Ohia	100	100
7	0-10		90	Ohia	100	100
17	0-45		50	Ohia, olapa	100	100

Conclusions

All three of the HSM sites appeared suitable for seabird nesting and were fenceable, but the presence of birds was unknown at those sites, and the habitat two sites was more densely forested and contained less uluhe than many typical montane seabird nesting sites on other islands. Of the 20 sites where song meters were deployed, seabirds were detected at seven sites. None of the sites are recommended for fencing at this time because they are either too steep or because the presence of seabirds in unknown. It is possible that other sites on West Maui can be identified that have seabirds and are fenceable.

HAWAII ISLAND RESULTS

Partners

Hawaii Natural Area Reserves System: Nick Agarostis and Alex Wang
Hawaii Volcanoes National Park: Kathleen Misajon
Maui Nui Seabird Recovery Project: Lynx Gallagher

Site descriptions and fenceability

Three sites were visited on the island of Hawaii, all of which were on foot, and song meters were deployed at each site. All sites had vegetation structure and habitat that appeared suitable for seabirds either immediately on the site itself, or adjacent, and all three sites detected seabirds. While only one of the three sites was fenceable, it that was the site with the highest call rates of both HAPE and BANP. An overview summary of the sites visited is presented below with more detailed site descriptions following. Site number corresponds to .kml location point provided by USFWS from the HSM for viewing in google earth.

Figure 18: Map of sites visited on Hawaii Island

Table 9: summary of sites visited on Hawaii Island

Site	*Model output #*	*Fenceable?*	*Seabirds detected?*	*Habitat suitable?*
Waimanu- Slant camp	1N	No	NESH (low) and HAPE (high)	On cliffs only
Waimanu- Poho camp	1N	No	HAPE (med)	On cliffs only
Mauna Loa	None	Yes	HAPE (high) BANP (med)	Yes

Two of the sites visited (Waimanu Slant Camp and Waimanu Poho Camp) were in Puu Oumi Natural Area Reserve at the edge of Waimanu Valley in the Kohala range. Puu Oumi reserve

covers the west upper slopes and summits of the Kohala Mountains down to the dry coastal sea cliffs. Two rare montane bogs are found at Pu‘u O ‘Umi, along with montane wet grasslands, shrublands and forests. The reserve also contains coastal dry shrublands and grasslands, intermittent stream and montane wet cliff ecosystems, and lowland wet forests and shrublands. While birds can be heard transiting a good portion of this area, it is likely that they primarily nest on the steep cliffs facing the ocean.

Figure 19: Wiew of Waimanu Valley from valley floor. N. Agorastos photo.

Figure 20: Plateau of Waimanu Valley showing boggy habitat

Mauna Loa, in contrast, is a young lava flow on Mauna Loa's sourthwest rift zone and is almost exclusively comprised of lava with minimal vegetation.

Figure 21: Song meter deployment location on the southern flank of Mauna Loa. Photograph by K. Misajon

Presence of birds

Birds were detected at all three sites, both on auditory and visual surveys as well as with song meters. Hawaiian Petrels were detected at all three sites, and NESH and BANP were each detected at one site.

Table 10: A summary songmeter effort from Hawaii Island

Site	*# days deployed*	*# hours recorded*
Waimanu- Slant	86	126.72
Waimanu- Poho camp	84	123.72
Mauna Loa	78	114.72

Auditory surveys were conducted at both Waimanu sites in May and August following protocols described above, where HAPE were detected at both sites, and NESH detected at one site. Results are presented below. On the May trip, nightly surveys were conducted from May 16-19th (four survey nights). For NESH, the total number of calls over four nights is presented, but for HAPE, a call rate/minute is presented.

Table 11: Summary of NESH detection results from Hawaii Island

Site	*Auditory Date*	*Min After Sunset*	*Auditory Total # Calls*	*Songmeter Detection Dates*	*Songmeter Time (post sunset)*	*Songmeter Call rate (#/min)*
Waimanu- Slant	May 16-19		14 over 4 days	06-13-2016 19:53:00	50	1
Waimanu- Poho	N/A	N/A	0	N/A	N/A	0
Mauna Loa	N/A	N/A	0	N/A	N/A	0

Based on songmeter data, peak calling hour for HAPE occurred in the period between 60 and 120 minutes after sunset, similar to activity patterns at other monitoring sites in Hawai‘i. Activity rates (from 60 to 120 minutes after sunset) were highest at Mauna Loa (2.70 calls/min +/- 2.76) where more than a thousand calls were detected over the survey period. A total of 20 HAPE calls were detected at the Slant Camp site, between May 18 and July 29, all between sunset and midnight (call rate = 0.0054 calls/min +/- 0.037). Only 8 total calls were detected at the Poho camp site between May 18 and July 19, all between sunset and 1:30AM (call rate =0.0029 calls/min +/- 0.015).

Table 12: Summary of HAPE detection results from auditory surveys on Hawaii Island

Site	*Auditory Date*	*Min After Sunset*	*Auditory Call rate (#/min)*	*SongmeterDetection Dates*	*Songmeter Time*	*Songmeter Call rate (#/min)*	*Songmeter Total # calls*
Waimanu-Slant	May 16-19		0.18-2.86	05/18-07/29	<12:00am	0.0054	20
Waimanu-Poho	08/09/16	0-120	35	05/18-07/19	<1:30am	0.0029	8
Mauna Loa	N/A	N/A	N/A		60-120 post	2.70	Numerous

Band-rumped Storm-petrel calls were detected only at the Mauna Loa survey site. Peak calling hour occurred between 80 and 140 minutes after sunset. During this peak calling hour, 0.4416 calls per min (+/- 0.5638 s.d.) were detected at this site. Calls were detected consistently throughout the survey period indicative of an active breeding colony at this site.

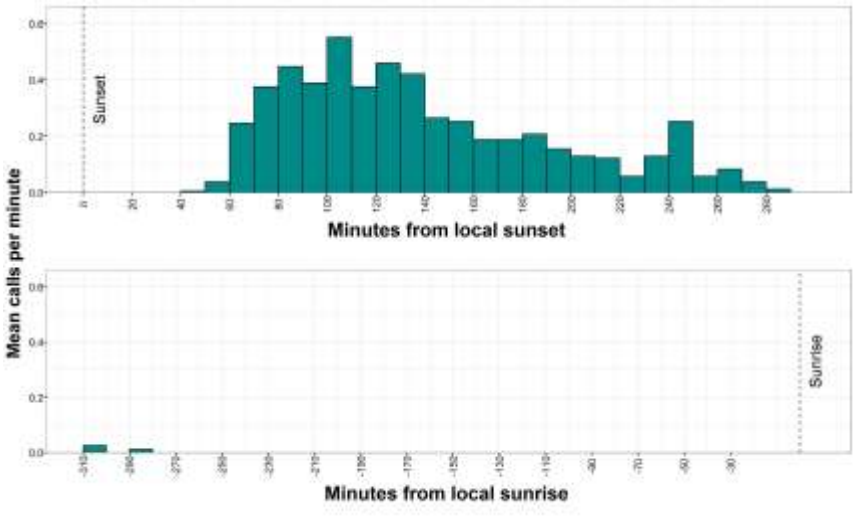

Figure 22: Mean Band-rumped Storm-petrel calls at Mauna Loa as a function of minutes from sunrise or sunset.

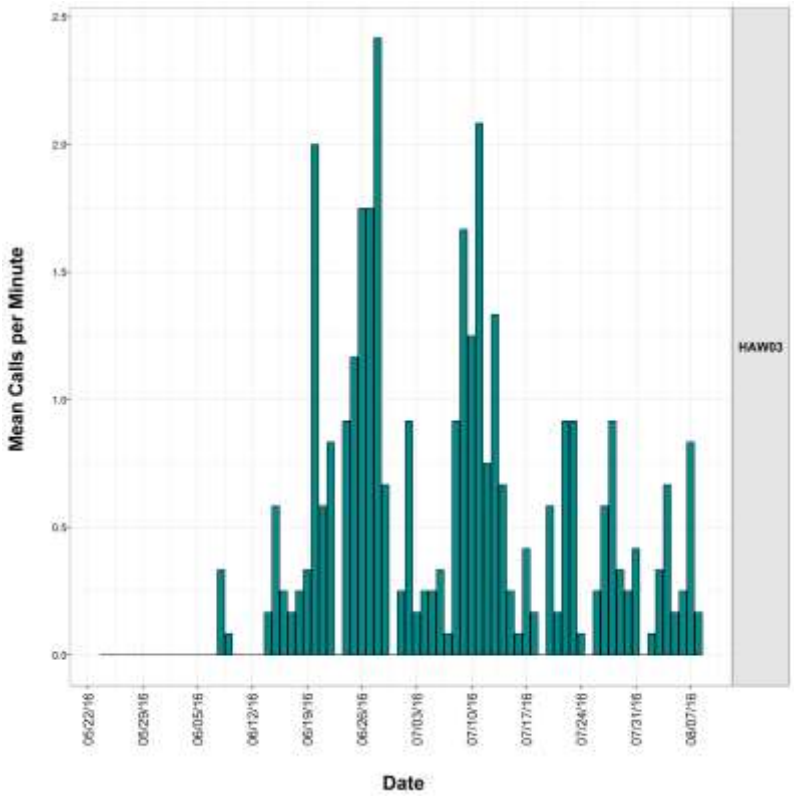

Figure 23: Mean Band-rumped Storm-petrel calls per minute at Mauna Loa

Habitat suitability

Table 13: Summary of habitat variables for sites visited on Hawaii Island

Site	*%*	*Elevation*	*% Canopy*	*Canopy*	*%*	*Groundcover*
Puu Oumi- Waimanu	0	2953	10	Open Ohia	95	Uluhe/Spagnum
Puu Oumi- Waimanu	0	3500	20	Open Ohia	95	Uluhe/Spagnum
Mauna Loa	15	1658	0	Rock	0	Lava

The habitat at Puu Oumi in the area surveyed was not itself suitable due to the extremely boggy and wet conditions that would flood any potential burrows. The birds that were detected likely nest on the large cliffs facing the ocean, or along gulches of tributary streams leading into the large cliffs that contain ample suitable habitat in the form of Uluhe understory and small caves. At Mauna Loa, the substrate was almost exclusively rock crevices which present plenty of readily made burrows for seabirds to nest in.

Conclusions

While all three sites had birds present, only the Mauna Loa site was potentially fenceable. Given the high density of both HAPE and BANP at that site, it should be a priority for future conservation measures. For Puu Oumi, more surveys should be undertaken to determine where exactly the birds are nesting to see if any management actions could be taken to protect them. If they are indeed nesting on the steep cliffs, then their habitat likely provides the best protection of all from predators.

REFERENCES

Ainley, D. G., R. Podolsky, L. DeForest, G. Spencer, and N. Nur. 2001. "The Status and Population Trends of the Newell's Shearwater on Kauai: Insights from Modeling." Studies in Avian Biology 22: 108–123.

Borker, A. L., Halbert, P., Mckown, M. W., Tershy, B. R., & Croll, D. A. (2015). A comparison of automated and traditional monitoring techniques for marbled murrelets using passive acoustic sensors. *Wildlife Society Bulletin*, 1–6. doi:10.1002/wsb.608

Burgett, J, T.D. Day, K. Day, W. Pitt, and R. Sugihara. 2007. From mice to mouflon: development and test of a complete mammalian pest barrier from Hawai`i. Hawaii Conservation Conference poster presentation.

Buxton, R. T., & Jones, I. L. (2012). Measuring nocturnal seabird activity and status using acoustic recording devices: applications for island restoration. *Journal of Field Ornithology*, *83*(1), 47–60. Retrieved from http://www.mun.ca/serg/Buxton&Jones_JFO_2012.pdf

Buxton, Rachel, C. Jones, H. Moller, and D. Towns. 2014. Drivers of Seabird Population

Recovery on New Zealand Islands after Predator Eradication. Conservation Biology.

Day, T.D., and R.J. MacGibbon. 2002. Escape behaviour and physical abilities of vertebrate pests towards electrified and non-electrified fences. XcluderTM Pest Proof Fencing Company unpublished report. 7 pp.

Dufour, O., Gineste, B., Bas, Y., Le Corre, M., & Arti??res, T. (2016). First automatic passive acoustic tool for monitoring two species of procellarides (Pterodroma baraui and Puffinus bailloni) on Reunion Island, Indian Ocean. *Ecological Informatics*, *35*, 55–60. doi:10.1016/j.ecoinf.2016.08.004

Hodges, C. S. N., and R. J. Nagata. 2001. Effects of predator control on the survival and breeding success of the endangered Hawaiian dark-rumped petrel. Studies in Avian Biology 22:308-318.

MacGibbon, R.J. and Calvert, 2002. Evaluation of the Effectiveness and Suitability of XcluderTM Pest Proof Fencing Technology as a Conservation Management Tool in Hawaii. XcluderTM Pest Proof Fencing Company unpublished report. 49 pp.

MacKenzie, D., Nichols, J., & Lachman, G. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, *83*(8), 2248–2255. Retrieved from http://www.esajournals.org/doi/abs/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2

MacKenzie, D., Nichols, J., & Sutton, N. (2005). Improving inferences in population studies of rare species that are detected imperfectly. *Ecology*, *86*(5), 1101–1113. Retrieved from http://www.esajournals.org/doi/abs/10.1890/04-1060

Oppel, S., Hervías, S., Oliveira, N., Pipa, T. T., Silva, C., Geraldes, P., … Hervias, S. (2014). Estimating population size of a nocturnal burrow-nesting seabird using acoustic monitoring and habitat mapping. *Nature Conservation*, *7*, 1–13. doi:10.3897/natureconservation.7.6890

Parkes, J., Fisher, P., & Forrester, G. 2011. Diagnosing the cause of failure to eradicate introduced rodents on islands: brodifacoum versus diphacinone and method of bait delivery. Conservation Evidence 8:100-106.

Reaser, J.K., L.A. Meyerson, Q. Cronk, M. De Poorter, L.G. Eldrege, E. Green, M. Kairo, P. Latasi, R.N. Mack, J. Mauremootoo, D. O'Dowd, W. Orapa, S. Sastroutomo, A. Saunders, C. Shine, S. Thrainsson, L.Vaiutu. 2007. *Ecological and socioeconomic impacts of invasive alien species in island ecosystems*. Environmental Conservation 34(2): 98-111.

Spear, Larry B., David G. Ainley, Nadav Nur, and Steve N. G. Howell. 1995. "Population Size and Factors Affecting At-Sea Distributions of Four Endangered Procellariids in the Tropical Pacific." The Condor 97 (3) (August 1): 613–638. doi:10.2307/1369172.

U.S. Fish and Wildlife Service. 2005. Regional seabird conservation plan, Pacific region. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, Portland Oregon. 261 pp.

United States Fish and Wildlife Service. 1983. Hawaiian Dark-Rumped Petrel and Newell's Manx Shearwater Recovery Plan. 57pp.

VanderWerf, E. A., L.C. Young, et al. 2014. Increase in Wedge-tailed Shearwaters and Changes in Soil Nutrients following Removal of Alien Mammalian Predators and Nitrogen-fixing Plants at Kaena Point, Hawaii. Restoration Ecology 22:676-684

VanderWerf, E.A. 1993. Scales of habitat selection by foraging 'Elepaio in undisturbed and human-altered Hawaiian forests. Condor 95:961-971

Young, L.C., VanderWerf, E.A., Mitchell, C., Yuen, E., Miller, C.J., Smith, D.G. and C. Swenson. 2012. The use of predator proof fencing as a management tool in the Hawaiian Islands: A case study of Ka`ena Point Natural Area Reserve. Technical Report #180 The Hawai`i-Pacific Islands Cooperative Ecosystem Studies Unit & Pacific Cooperative Studies Unit, University of Hawai`i, Honolulu, Hawai`i. 82 pp.

Young, L.C., VanderWerf, E.A., Lohr, M.T., Miller, C.J., Titmus, A.J., Peters, D., and Wilson, L. 2013. Multi-species predator eradication within a pest-proof fence at Ka`ena Point, Hawai`i. Biological Invasions 15(6): DOI 10.1007/s10530-013-0479-y

Ziegler, A.C. 2002. *Hawaiian Natural History, Ecology, and Evolution*. University of Hawai'i Press, Honolulu.