NEWELL'S SHEARWATER LANDSCAPE STRATEGY

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Honolulu, Hawaii 96850

Version 1, January 2016

CONTEXT

This document is intended for use within the Pacific Islands Fish and Wildlife Office as guidance for recovery actions, habitat conservation planning, and Endangered Species Act section 7 consultations. Threats to the Newell's shearwater (*Puffinus newelli*, NESH), including light attraction and fallout, collision with power lines, predation, and habitat degradation, have resulted in an estimated 12.8% annual decline in the period from 1993 to 2013, based on data from radar surveys (Raine *et al*., in press). Management of this species is difficult at best due to the remote rugged areas where they now occur. Further complicating recovery for this species is its relatively low reproductive output as it is late to reach sexual maturity, and produces at most one young per year (K-selected). Population growth is naturally slow, even in the absence of human-induced threats. For a review of the species' biology, see Appendix 1.

Our office developed extensive habitat suitability and population models to assist in habitat conservation planning (HCP) and the development of this recovery strategy. Previous Population Viability Analyses (PVAs) have focused extensively on deterministic meta-population models (Ainley et al. 2001a; Griesemer and Holmes 2011). These models were developed to assess the overall viability of the meta-population as it relates directly to average demographic trends without significant stochastic variation (Morris 1999). These models are extremely useful in that they identify demographic parameters sensitive to some form of modification (e.g. predation, collision etc.). The work outlined here attempts to build on the outputs and methodologies discussed extensively in Ainley et al. (2001) and Griesemer and Holmes (2011) by incorporating the most up-to-date geographic and demographic information possible, developing a geographic assessment of NESH colony sites, and creating an iteratively reproducible and update-able projection in the R statistical environment. Species-specific data in the models were from datasets with small sample sizes or short sampling periods; and thus where necessary, information from similar species were used. The models' precision will improve as more data are collected and incorporated. This plan identifies actions we can undertake in the short-term to stabilize and eventually recover NESH. Species-specific information and actual species response to threat minimization and management will guide future revisions to the models and this plan.

Because an estimated 90 percent of the NESH population occurs on Kauai and because little species information is available on islands other than Kauai, our modeling efforts and this plan focused on Kauai. Until more information is available for NESH on other islands, we recommend recovery efforts generally reflect those outlined for Kauai.

MODEL OVERVIEW

SPECIES DISTRIBUTION MODEL

We used an ensemble modeling approach to determine suitable habitat for NESH. Variables in the model include topography, slope, bioclimatic variables, light impingement, and species occurrence data (See Appendix 2 for a complete model write-up). Based upon our analyses, ~34,100 Ha of suitable habitat are available to NESH on Kauai (Figure 1), but when areas of viewable light are removed this is reduced to just ~12,000 ha (Figure 2).

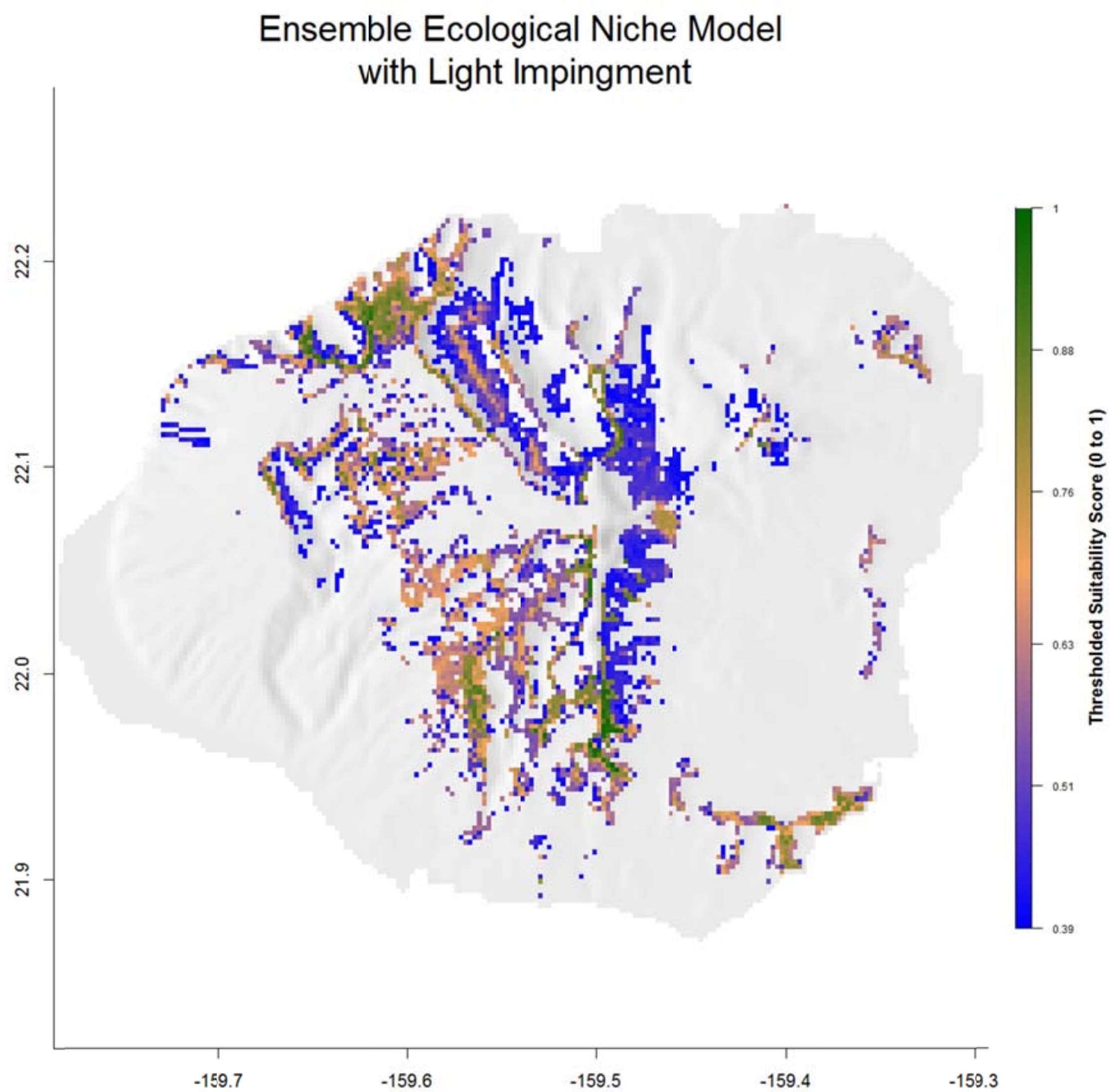


Figure 1: Model output of suitable NESH habitat on Kauai showing 34,140 ha of suitable area. Areas in green are more suitable

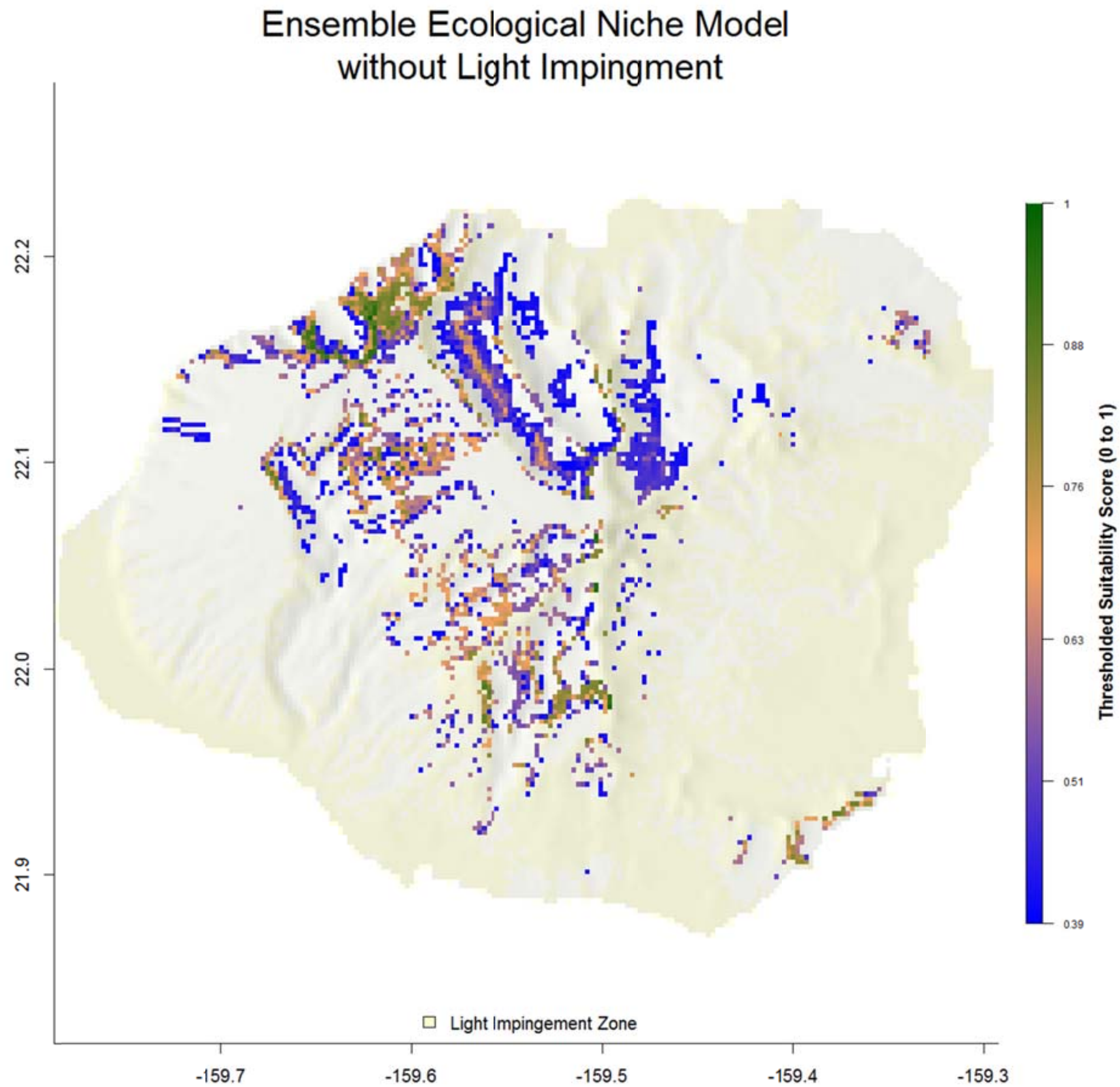


Figure 2: Model output NESH habitat on Kauai showing 12,010 ha of suitable habitat with areas of visible light removed. More suitable areas are shown in green.

Population Viability Analysis

Two variations of a population viability analysis (PVA) were conducted to evaluate the population status of NESH under a range of conditions. The **colony-based PVA** looked at the response of populations at a compiled set of NESH occupied sites representing 76 different polygons to various rates of predation, flight path and resulting power line strike, light fallout, demographic stochasticity, and extreme weather events. The range in threat values was developed to approximate the variability in known or estimated rates.
The results from these analyses were used to develop a **meta-population PVA**, which used the median of each modeled colony over each year's flight path iterations, predation, and

light fallout, predation, and strike scenarios to project the relative trend of each population polygon, as compiled into a meta-population assessment, until the year 2100. Meta-population estimates conducted without and with strikes show meta-populations across all predation and light fallout scenarios have equivalent projected ecological extinction end points, ranging from mid to end century. The projected population estimate at the end of 2100 showed either complete extinction, or a substantial population decline that is representative of ecological extinction, depending on the scenario assessed (for detailed model methods, refer to Appendix 2).

The PVA demonstrates that the NESH population will continue to decline if we take no action to manage threats. Existing threat management tools include manual predator control, predator fencing, ungulate exclusion, translocation to and social attraction in predator-free areas, minimizing the impacts of power lines and lights, and continuation of SOS Program, a recovery and rehabilitation program for downed NESH.

Use of aerial broadcast of rodenticide is currently authorized in Hawaii under certain label conditions, but most entities are waiting until a Programmatic Environmental Impact Statement (PEIS) is completed prior to using aerial application of rodenticide on their lands. The draft of the PEIS is expected to be released sometime in 2016. Aerial broadcast of rodenticide is a part of the proposed action that will be analyzed in the draft PEIS.

STRATEGY

To recover NESH on Kauai, efforts should focus on managing and enhancing extant colonies in areas with minimal light impacts, mitigating threats at the colony and those encountered while in transit to the colony, and creating new colonies through social attraction and translocation. Standardized monitoring protocols should be used to evaluate colony demographics and ensure effective management and mitigation. Further, to facilitate long-term recovery, stakeholders must have the staffing, infrastructure, and funding available to see these actions through, monitor the population's response, and modify actions as needed.

COLONY MANAGEMENT

Because light impingement has such an influence on survival, colony management should first be focused in areas of occupied suitable habitat without light impingement, see Figure 2, then other sites as opportunity and funding becomes available. At the colony, options to improve survival include predator fencing, manual predator control, ungulate fencing, and barn owl control. Optimal management scenarios will need to be determined on a site-by-site basis.

Predator Fences

Predator fencing is our most effective tool against mammalian depredation at the colony. Within the current range of NESH, topography, streams, and remoteness limit the number of sites and size of areas that can be protected with predator fences. Preliminary surveys of eight sites known to have NESH populations identified three as suitable for predator fencing; the other five were eliminated because of topography or streams (Young and VanderWerf 2014). The remaining three sites encompass a maximum of 224 ha of habitat. This effort was an initial assessment, and it is very likely that other occupied sites within the unlit habitat are suitable for predator fences. We examined this in our model, with the assumption that areas with less than 50% slope are suitable for fencing, and identified approximately 9,470 ha of suitable NESH habitat where fences may be built (Figure 3). When we looked at only sites of 10 or more contiguous hectares, approximately 7,800 ha were suitable for fencing (Figure 4). Suitability for fencing at these sites should be verified and ground-truthed. The Hawaii Division of Forestry and Wildlife's (DOFAW) Kauai Endangered Seabird Recovery Program (KESRP) continues to survey areas for NESH activity, so active sites suitable for predator fencing in addition to those identified in our model, could be identified in the coming years.

At a minimum, we recommend fencing the two sites recommended by Young and VanderWerf that have identified NESH burrows, the third site was found to have only Hawaiian petrel (*Pterodroma sandwichensis*) burrows. We also recommend fencing sites located independently by KESRP as well as sites predicted by our model and verified as occupied and suitable for fencing. These sites should be protected using manual predator control until the fences are complete. To increase recruitment once fences are complete, social attraction should be a component of the project (see below).

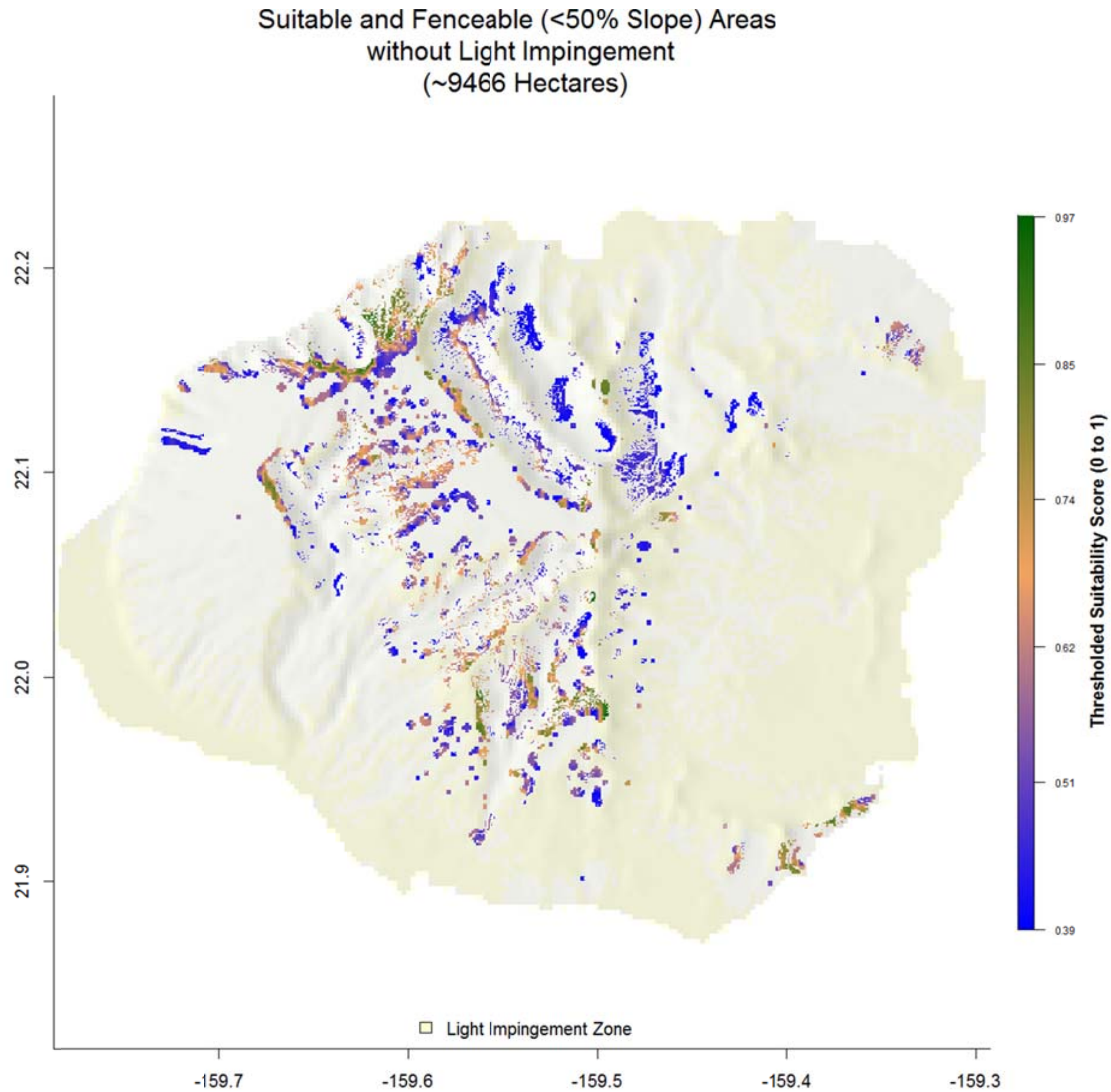


Figure 3: Suitable NESH habitat that fit criteria for predator fencing in the Habitat Suitability Model.

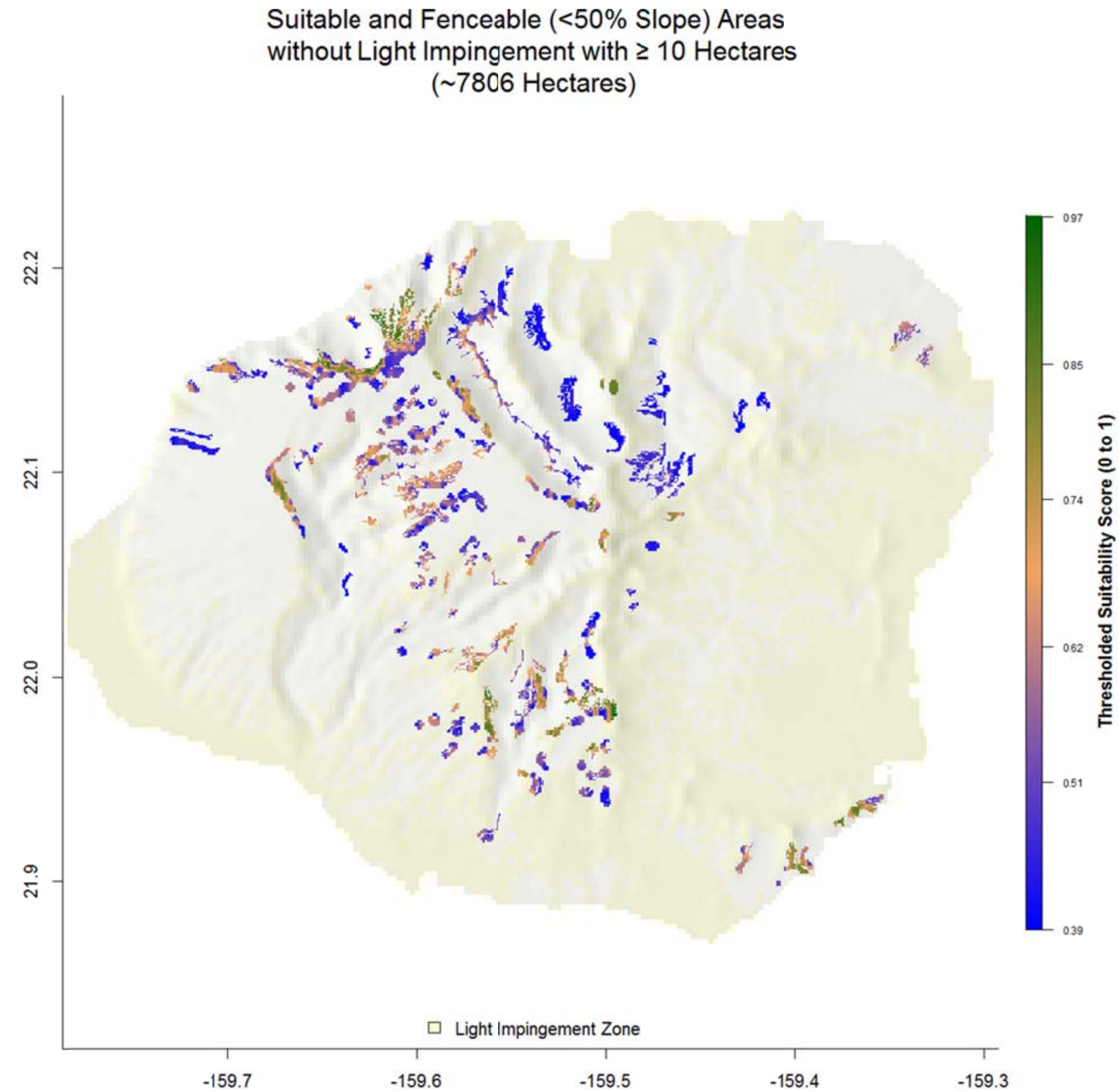


Figure 4: Suitable NESH habitat units greater than 10 ha in size that fit criteria for predator fencing in the Habitat Suitability Model.

MANUAL PREDATOR CONTROL

KESRP has located a number of colonies and monitors burrows at three sites with identified NESH burrows, and there is ongoing predator control in these areas. One site is fenced and ungulate free and the other is not. The effectiveness of manual predator control at these sites has been variable inter-annually and from site to site. Changes in predator density, modifications to control techniques, number of staff available and amount of funding, and site-specific topography and vegetation contribute to the variation in effectiveness.

Current methods used to control cats include live traps (particularly Tomahawk traps), as well as Conibear traps and leg hold traps in situations where hikers, hunters, and hunting dogs are not present. We are constrained by the interpretation of diphacinone label restrictions and thus only use mechanical methods for controlling rats in NESH colonies. Snap traps have been shown to be ineffective in reducing NESH egg and chick predation, so control using GoodNature™ traps is implemented at both managed sites. This has been found to significantly reduce black rat (*Rattus rattus*) numbers within trapping areas. Snares and various hunting techniques are utilized to reduce pig populations at the NESH unfenced site. Targeted hunts and Bal chatri traps are utilized to control Barn Owls at all sites.

Manual predator management is time-intensive, but the methods described above are currently the only means we have to reduce predation pressure. The scale at which we are managing NESH colonies is not enough to offset known threats. However, manual predator control should continue at the two managed NESH colonies, and should be implemented at other sites, prioritizing those that are suitable for predator fencing. Given the start-up time to complete a fencing project, in the absence of manual predator control it is likely that we could see serious declines in colonies at sites targeted for predator fencing as predation has been documented at all management sites and widespread predation recorded at new sites with no predator control. Implementing management at these colonies will help sustain them until the fences are completed. Once predator fences are complete, manual control efforts should be shifted to sites where predator fences are not feasible or when monitoring inside the fences indicates a need.

UNGULATE FENCING

Burrow destruction and depredation of NESH by pigs has been documented as a significant source of mortality, including substantial adult mortality at unfenced NESH colonies as adult birds are eaten if they are within the nest burrows at the time of the predation event (Raine et al. 2015, Raine and Banfield 2015a,b,c). Further, pigs and goats modify the habitat by eating and trampling native vegetation and spread invasive plants (such as guava and ginger) that can then in turn modify the habitat to the point of excluding breeding birds.

To manage depredation by pigs and habitat damage from pigs and goats, ungulate fences should be installed around those colonies where predator fences are not feasible, and manual predator management should be undertaken as described above, or using aerial broadcast of rodenticide. The Kauai Watershed Alliance (KWA) has proposed strategic fences to protect over ~5,632 ha in areas that have suitable NESH habitat (Figure 5), which will protect NESH within the area.

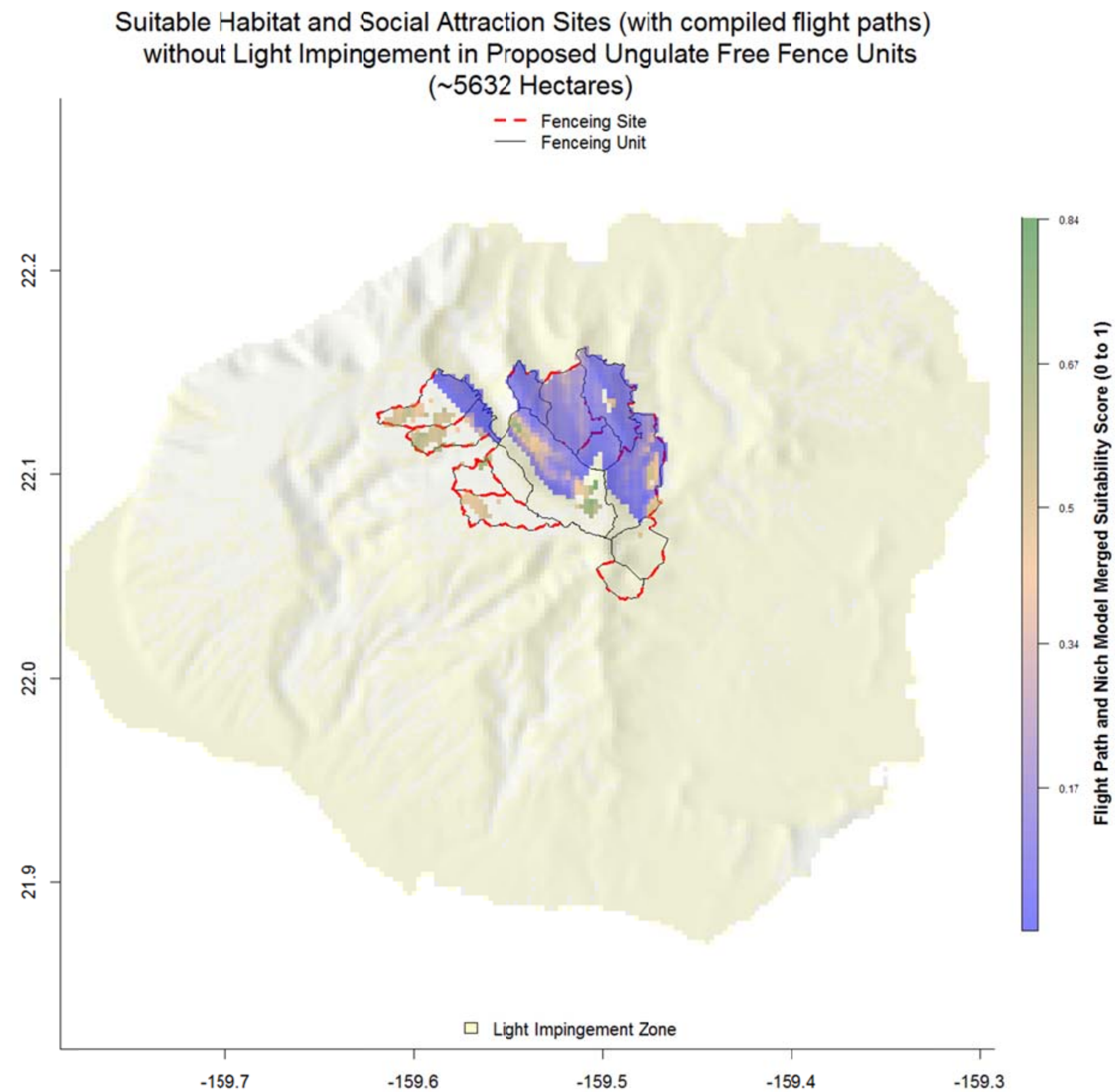


Figure 5: Overlap of suitable NESH habitat and ungulate fencing units proposed by the Kauai Watershed Alliance

Landscape Scale Rodent Control

Aerial application of rodenticide could be used at a landscape level to suppress rodent populations prior to the breeding season in areas where NESH are known or expected to occur but are inaccessible. It is anticipated that landscape scale rodent control will be part of ecosystem restoration efforts but could also be used for NESH-specific management.

On a smaller scale, a grid of GoodNature™ repeatable traps could be used to reduce rodent populations at sites that are accessible. Rodent populations could be eliminated if this technique is used in conjunction with predator-proof fencing.

Social Attraction and Translocation

The primary methods to establish new or enhance existing colonies of burrow-nesting seabirds are social attraction and translocation. Social attraction aims to lure prospecting adults and pre-breeding subadults to a protected site using a sound system and sometimes decoys (the latter an as yet unproved technique for this species). Sites are usually supplemented with artificial burrows. Translocation entails moving pre-fledged chicks to a protected site and hand-rearing them until they fledge. Translocation and social attraction can be used in combination, translocation should always include social attraction, but social attraction can be used alone in a site where birds are known to transit.

The sites identified as suitable for protection with predator fences should incorporate social attraction to increase recruitment. To further bolster population growth, predator fences with social attraction should be established in suitable but unoccupied areas where they are likely to draw individuals from unprotected populations, such as in areas adjacent to NESH colonies unsuitable for fencing, and in known NESH flyways. One of many scenarios of this model, that include a series of flight path assessments, identified almost ~6,000 ha that fit these criteria (Figure 6). Note that some sites are in low-lying coastal areas outside of the area in the north and west of Kauai known to harbor most NESH. Because these sites are dark and have direct access to the sea, we consider them suitable for translocation and social attraction. We can establish other sites in light-free coastal areas for translocation projects. Further, NESH have been documented nesting at the Kilauea Point National Wildlife Refuge, likely as a result of a social attraction project, for almost 10 years. A predator fence has been erected there, with translocation of Hawaiian petrel chicks initiated in 2015, and NESH in 2016. It is likely that sites outside those identified by our model would be suitable for social attraction if they are on a known NESH flyway.

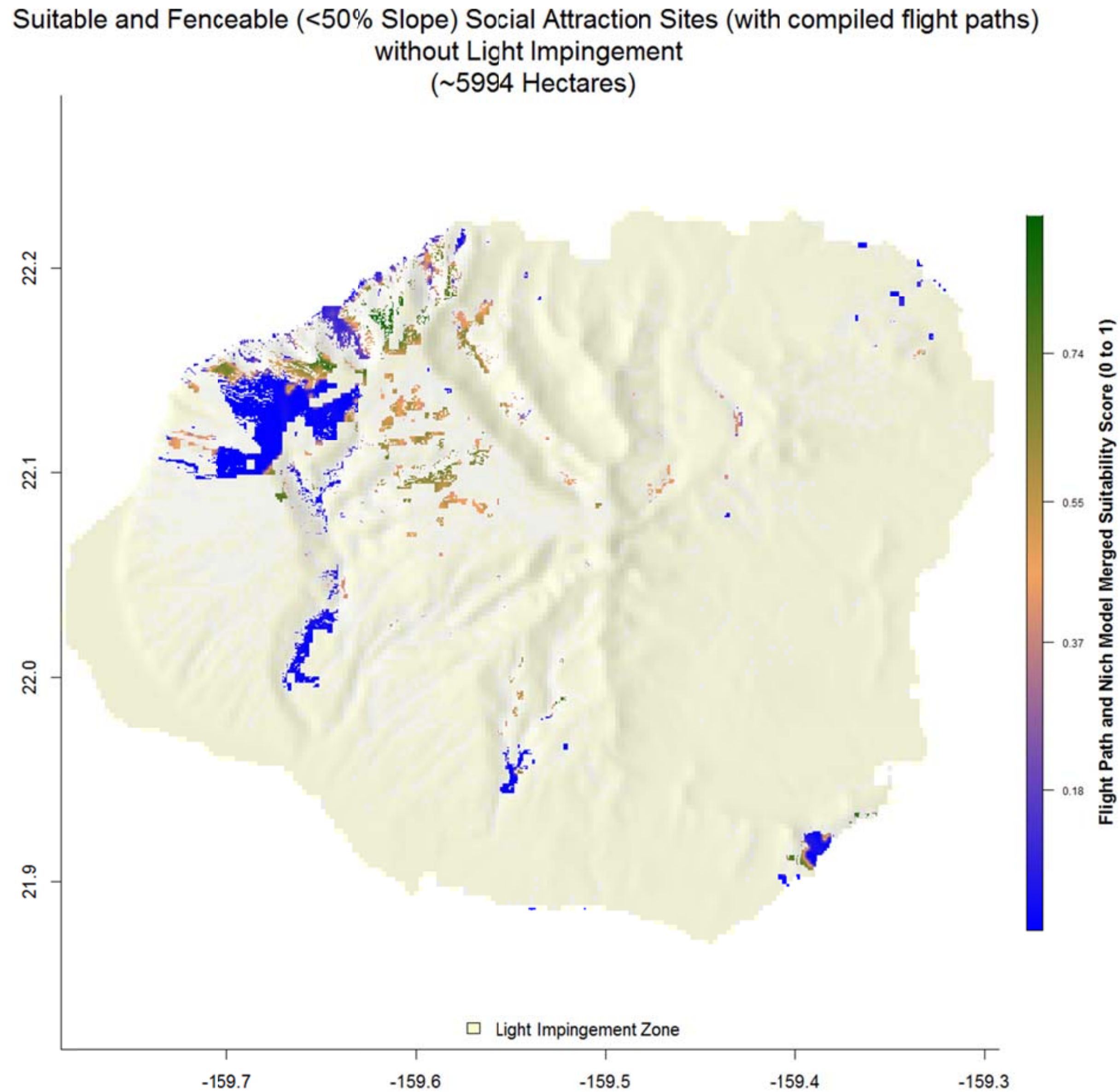


Figure 6: Potential sites for predator fences in suitable, unoccupied habitat.

THREAT MINIMIZATION AWAY FROM THE COLONY

Light attraction and collision with power lines and other anthropomorphic structures are the biggest threats to NESH on land outside of the colony. Increasing urbanization and accompanying artificial lights have resulted in substantial hurdles for fledgling NESH during their first flight to the ocean from their nesting grounds. When attracted to lights, fledglings become confused and may suffer temporary night blindness. They often fly into utility wires, poles, trees, and buildings, or become exhausted from repeated circling and fall to the ground (fallout), where they are unable to take flight and are vulnerable to predators or vehicles. A large scale fallout event at Kokee Air Force Base in 2015 also illustrated the potential for light attraction to take out breeding adults (A. Raine, pers. comm). This phenomenon appears to be restricted to bright lights in upper montane areas near breeding colonies and seems to have a limited/negligible impact along coastal areas for adults.

For adult birds transiting from the sea to the breeding colony, recent studies using acoustic monitoring devices have documented high rates of collision with power lines (Travers et al. 2014, Travers et al. 2015). As of this Feb. 2017 yearly detected strikes at a subset of monitored sites range from 995 to 1,017 strikes (2014 and 2015 respectively) as detected using this technique. The rate of ensuing injury or mortality is not known, nor is the total number of birds that collide with lines, as the study sampled just a small portion of the island's power lines. Since power line collision, even just at the monitored sites, is much greater than previously anticipated, the Service independently developed an island-wide strike estimate using data from Travers et al. 2014 so that the impact could be quantified in the PVA. This model extrapolated the probable impact of the island's network of power lines and estimated, using both biological opinion and projected/imputed strikes, that there were ~1,800 NESH adult mortalities every year due to powerline strikes (see Appendix 2 for methodology). Below we describe options to minimize or eliminate light and power line impacts.

LIGHTS

Many sources of light fallout have already been modified to minimize attraction of fledging NESH, but a standard island-wide study is needed at regular intervals to identify new locations and those that might be out of compliance. Fallout continues to be a problem. As a cost-saving measure, KIUC will be replacing most existing bulbs with LED bulbs. A study is needed to test the various types of LED bulbs available against the existing low pressure sodium bulbs to assess which is most suitable for seabirds. Once we determine what configuration has the least impact on NESH, lights should be outfitted with these bulbs, targeting the highest impact lights first. In the interim, problematic lights should be removed, turned off during the fledging season, reduced in intensity or fitted with shields to direct the light toward the ground to minimize impacts.

POWER LINES

The data gathered from Travers et al. 2014 and Travers et al. 2015 have vastly improved our knowledge of the scope of the impact of power line collision and have identified the power line segments, of those surveyed, that have the greatest impact on seabirds. Lines along Power Line Trail in the north central region of the island were responsible for 75 percent of the documented strikes in 2014 (Travers et al. 2015). This stretch of lines should be prioritized to be buried, lowered in height, modified such that the top lines are removed, re-directed (after appropriate studies to assess whether this would actually be useful) or made visible in some manner (through the use of lasers or bird diverters, both of which are being trialed by KESRP on Kauai). As additional stretches of lines are monitored each year, other high-impact zones will be identified and appropriate avoidance or minimization methods should be implemented. Reducing the impact of power lines is critically important to ensuring the continued existence of NESH on Kauai.

Save Our Shearwaters

The SOS program collects downed birds, assesses their health, and either immediately releases them, rehabilitates them for release, or euthanizes unsalvageable birds. However, we do not know the survival rate of fledglings released from the SOS program compared those that fledge without encountering artificial lights.

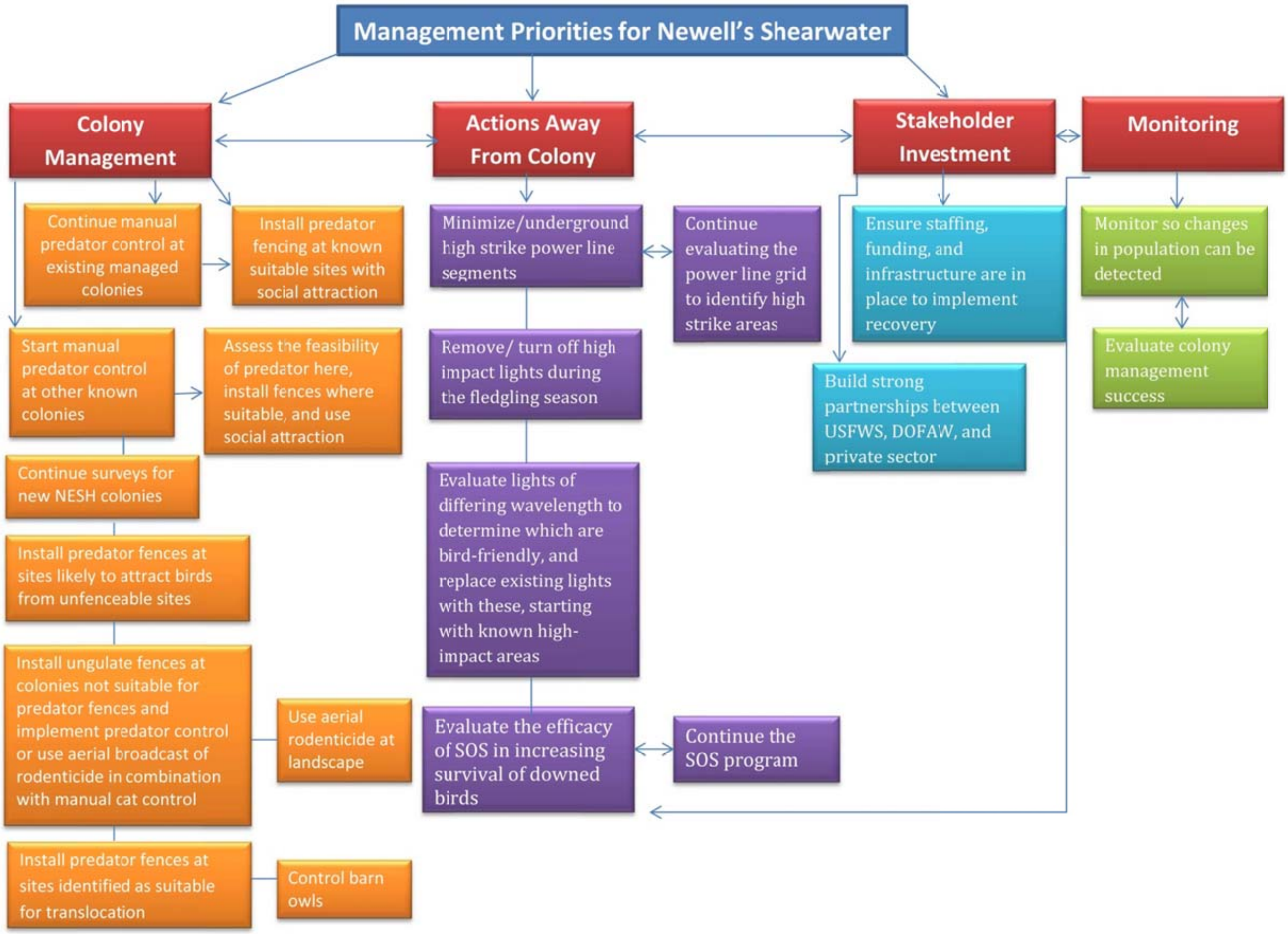
The SOS program also serves as an outreach opportunity; the public is directly involved in turning birds in to SOS, and there are educational programs such as releasing birds as part of school curriculum. This gives the public the opportunity to interact with and learn about a bird they would not normally encounter. Unless the comparison of SOS birds and “naturally fledged” birds indicates SOS is not effective in increasing survival, the SOS program should continue, and efforts to further improve its efficacy should be evaluated and implemented.

Stakeholder Buy-In

The recovery of the Newell’s shearwater requires strong partnerships, sufficient and consistent funding, clear measures of success, and regular review and reprioritization of recovery activities as more information becomes available. Recovery of NESH on Kauai will take significant resources in the form of staffing, infrastructure, and funding. To be fully successful, the Service and Hawaii Division of Forestry and Wildlife must have dedicated positions to oversee recovery, secure funding, and develop partnerships with private entities.

Summary

In the course of implementing NESH recovery, the time at which a particular action is implemented is likely to be dependent on funding availability, compliance and permitting steps, and stakeholder support. Below we prioritize the activities we described above based on their perceived impact on the NESH population, and suggest managers use it as a guide for prioritizing management decisions.


Management Priorities for Newell's Shearwater
Colony Management
Actions Away From Colony
Stakeholder Investment
Monitoring
Continue manual predator control at existing managed colonies
Install predator fencing at known suitable sites with social attraction
Start manual predator control at other known colonies
Assess the feasibility of predator here, install fences where suitable, and use social attraction
Continue surveys for new NESH colonies
Install predator fences at sites likely to attract birds from unfenceable sites
Install ungulate fences at colonies not suitable for predator fences and implement predator control or use aerial broadcast of rodenticide in combination with manual cat control
Use aerial rodenticide at landscape
Install predator fences at sites identified as suitable for translocation
Control barn owls
Minimize/underground high strike power line segments
Continue evaluating the power line grid to identify high strike areas
Remove/ turn off high impact lights during the fledgling season
Evaluate lights of differing wavelength to determine which are bird-friendly, and replace existing lights with these, starting with known high-impact areas
Evaluate the efficacy of SOS in increasing survival of downed birds
Continue the SOS program
Ensure staffing, funding, and infrastructure are in place to implement recovery
Build strong partnerships between USFWS, DOFAW, and private sector
Monitor so changes in population can be detected
Evaluate colony management success

Literature Cited

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Appendix 1: Newell's Shearwater Status Review

Taxonomy and Species Description

The Newell's shearwater (NESH) is a member of the genus *Puffinus* and utilizes open tropical seas and offshore waters near its island breeding grounds on forested mountain slopes. NESH is approximately 30 to 35 centimeters long, with a wingspan of 76 to 89 inches, and weighs approximately 395 grams. Its plumage is glossy black above, and white below. It has a black bill that is sharply hooked at the tip. Its claws are well adapted for climbing.

Historic and Current Distribution

NESH were once abundant on all of the main Hawaiian islands, and was even considered to be an important food source to early Polynesians. Approximately 90 percent of the population nests on the island of Kauai. NESH also breed on several of the other main Hawaiian islands where they nest in mountainous terrain. This species is known to nest on Maui, and Hawaii, and may still nest on Oahu.

Based on at-sea observations between 1984 and 1993, Spear et al. (1995) estimated the NESH population at 84,000 individuals (19,300 breeding pairs in the spring and 16,700 breeding pairs in the autumn). From 1993 to 2009, the NESH population on Kauai declined by approximately 75 percent as measured by two independent population indices: ornithological radar and Save Our Shearwaters data (Day et al. 2003; Holmes et al. 2008). Reducing the Spear et al. (1995) Kauai population size by 75 percent and assuming that 10 percent of the population breeds elsewhere, yields an estimated 18,900 individuals on Kauai (Griesemer and Holmes 2011). Assuming a stable age distribution (Ainley et al. 2001), this population size would include approximately 12,040 birds of breeding age. Most recently, in an analysis of at-sea survey data collected from 1998 to 2011, Joyce estimated the population to be 27,011 birds.

Little information is available about the population trends on other islands. On Maui a small population occurs in the west Maui mountains and Kipahulu Valley of Haleakala National Park. They have been detected flying over Lanai City. On Molokai they are thought to nest in Waialea and Waikolu Valleys. On Hawaii Island surveys by Derringer and VanZandt (2011) detected NESH in Pololu and Waipio Valleys in the Kohala Mountains, and colonies previously occurred in the Puna district of Hawaii Island but the nesting area was inundated with lava (Reynolds and Richotte 1997).   Because of the species' nocturnal behavior and low population density on islands other than Kauai, it is likely that other, yet-to-be-detected, breeding sites could occur on each of the islands and possibly Niiahu.

During the autumn, this species is commonly observed at sea in warmer areas with a strong deep thermocline (sea temperature transition layer), more cloud cover, less mixing and where trade winds are less developed (Spear et al. 1995). NESH are well known by the Pacific tuna industry for their association with tuna and large billfish. They are found approximately 1300 kilometers south and east from nest colonies on Kauai in the deep water regions of the Equatorial countercurrent all year round, to the south (up to 25° N), and east (to about 120°W) of the Hawaiian chain (Spear et al. 1995). Their range extends during El Niño events.

LIFE HISTORY

Most of the life history information for this species is based on studies of the Kauai population; life histories of birds on other Hawaiian islands may differ slightly. During their nine-month breeding season from April through early November, NESH live colonially in burrows on forested mountain slopes. These burrows are used year after year and usually by the same pair of birds. A single egg is laid in late May or early June (Ainley et al. 1997b). Both sexes incubate and this period lasts approximately 45 days. Fledging occurs between October and early November. NESH need an open downhill flight path or cliff face to become airborne.

Daily flights of breeding adults to and from the colonies occur only at night and just before dawn. On Kauai, NESH were found to exhibit almost no movement until after complete darkness, whereupon they moved inland in a wave that peaked for 30 to 40 minutes (Day and Cooper 1995). After that peak, the rate of movement decreased steadily until 90 minutes after complete darkness, after which few birds were detected, although there is movement throughout the night. In the morning, NESH begin moving to sea approximately 90 minutes before the first measurable light and movement rates increase rapidly and stops approximately 30 minutes before dawn (A. Raine pers. comm).

Three age classes of NESH are recognized based on demographic factors and assumptions (from Ainley et al. 2001): (1) young-of-year; (2) pre-breeding immature/adult; and (3) breeding adults. The only estimate of breeding activity is from a colony that was under predation and is no longer extant, suggesting the observed rate of 46 percent is lower than would be seen in a stable population (Ainley et al. 2001). First breeding occurs at approximately six years of age (Ainley et al. 1997b). Work conducted by KESRP found varying rates of fledging success at different sites, from 37.5 percent at a site managed for pigs, cats, and rats, but unfenced, to 84 percent at a site surrounded by an ungulate fence with rat and cat control (Raine et al. 2015, Raine and Banfield 2015). No specific data exist on the longevity for this species, but other *Puffinus* shearwaters may reach 30 years of age or more and it is reasonable to assume that this is true of this species as well.

Habitat Description

On Kauai, NESH breed at elevations between 160 and 1,200 meters. NESH usually nest where the terrain is vegetated by an open canopy of trees with an understory of densely matted uluhe ferns (*Dicranopteris linearis*). Some NESH nest in other types of habitat such as on the walls of Waimea Canyon, Kauai, and the Na Pali coast where a forest canopy is absent. Burrows used by NESH are most commonly placed at the base of trees, where the substrate may be easier for the birds to excavate, or within dense beds of uluhe fern. Colonies on other islands occur in habitat types similar to that on Kauai.

Threats

The NESH was listed as a threatened species by the Service in 1975. Predation, fallout due to light attraction, collision with utilities and other structures, and habitat modification have contributed to the population decline.

Predation

Depredation of adults, eggs, and chicks by introduced predatory species, including rat, cat, mongoose, pig, and barn owl likely has the greatest impact on the NESH population (Mitchell et al. 2005; Griesemer and Holmes 2011; Holmes et al. 2011). An individual predator can decimate a seabird nesting colony and create conditions causing colony extirpation, particularly when adults are affected (Igual et al. 2009). Rats prey on shearwater eggs and chicks, and cats and owls kill adults (Telfer 1987; Ainley et al. 1997a, 1997b). KESRP manages each nesting colony for predators, using the most suitable techniques for any particular location, and impacts from predators vary at each location (A. Raine, pers. comm).

The mongoose is thought to have decimated seabird populations on Oahu, Maui, Molokai, and Hawaii, and poses a high level of threat to all native fauna on Kauai if it is introduced there. Two mongoose were trapped near Lihue in the summer of 2012.

Light Attraction

Another major threat is the species' attraction to light. Increasing urbanization and the accompanying artificial lights have resulted in substantial problems for fledgling NESH during their first flight to the ocean from their nesting grounds, and can be an issue for adult birds when bright lights are proximate to breeding areas (A. Raine, pers. comm). When attracted to lights, fledglings become confused and may suffer temporary night blindness. They often fly into utility wires, poles, trees, and buildings and fall to the ground. Since 1979 the Kauai District of Hawaii's Division of Forestry and Wildlife (DOFAW) has supported the Save Our Shearwaters (SOS) program to collect "downed" NESH and other seabirds (i.e., birds that have either collided with structures or fallen out, or have been injured or killed due to exhaustion caused by light attraction). According to SOS files, over 33,000 seabirds have been recovered to date (DOFAW unpublished). The majority of the birds are NESH, which nest in greater numbers on Kauai than Hawaiian petrels. The greatest number of NESH observed being impacted by lights is on Kauai, but small numbers of NESH have been collected on Oahu and Maui.

Telfer et al. (1987) state that the number of fledglings that fallout and are reported to the SOS on Kauai is strongly affected by the number and distribution of lights (i.e., intensity or amount of upward radiation) to attract them. NESH seem to be attracted most to a visible bulb while cumulative glow and glare from many sources of highly attractive lights may draw birds down to lit areas (Hailman 1979; Reed et al. 1985; Reed 1987; Telfer et al. 1987; Podolsky et al. 1998). Recently, Hallman and Holmes (2010) documented changes in numbers and flight behavior of NESH in the presence and absence of a major artificial light source. On nights before and after the use of high intensity lights, 90 and 97 percent of targets were observed flying in a straight line. However, on nights when high intensity lights were used, occurrence of straight line flight paths were reduced to 79 percent, with remaining targets displaying circling and erratic flight behavior associated with light attraction and fallout.

Efforts to reduce the level of light attraction began in the 1980s when Kauai Island Utility Cooperative (and its predecessor Kauai Electric) began replacing unshielded street lights with full-cutoff (shielded) lights across the island as part of its normal maintenance program. All of the over 3,500 streetlights operated by Kauai Island Utility Cooperative are now shielded, as are the lights at the facilities it operates.

COLLISION WITH UTILITIES

Collisions with utility structures are a known threat to seabirds in the Hawaiian Islands. On Kauai, utility structures include power lines (energy transmission and distribution lines) and associated structures, telecommunication wires, cable wires, and other structures, where they are vulnerable to non-native predators. Specifically, power lines traverse the island and are largely above ground, consisting of poles and wires that extend to more than 100 feet tall. The Under Line Monitoring Project of the KESRP used acoustic monitors to document seabird collision with portions of the power line grid. In the 2014 season 1,012 strikes were detected in the areas monitored using this technique. The rate of ensuing injury or mortality is not known, nor is the total number of birds that collide with lines, as the study sampled just a small portion of the island's power lines. It is unfeasible to monitor all lines so both KESRP and the Service have developed models to estimate the number of collisions across the island. The KESRP developed two models (A. Raine, pers. comm.). The sampling based model estimated an average of 3,517 (range 2,960-4,074) collisions per year, whereas the Generalized Linear Model estimated 4,219 (range 1,808-10,850) collisions. The model developed by the Service extrapolated the probable impact of the island's network of power lines and preliminarily estimated that 866 to 3,838 birds could be *killed* every year, using three different rates of mortality for birds that interact with power lines (see Appendix 2 for methodology). Models by both entities will be refined using data from 2015 and subsequent years.

HABITAT MODIFICATION

Nesting habitats have been severely degraded by the presence of invasive plants (Mitchell et al. 2005). Plants such as *Albizia falcataria*, *Psidium* spp., and *Rhodomyrtus tomentosa* displace and out-compete native vegetation. The presence of feral ungulates facilitates the spread and establishment of invasive plants and accelerates soil erosion and degradation. Grazing and trampling caused by pigs and goats alter the vegetation structure and composition, which facilitates the dispersal of non-native predators into new areas following ungulate trails. Pig wallows also provide pools in which mosquitoes can breed thus spreading non-native diseases such as avian malaria. In addition, pigs are known to destroy burrows to eat eggs or chicks, and even incubating adult birds. Feral ungulates have played and continue to play a significant role in modifying breeding habitat, and exterminating seabird colonies in the Pacific and many locations worldwide (Furness and Monaghan 1987; Harrison 1990; LeCorre et al. 2002; Igual et al. 2009).

Many historic shearwater nest sites on Kauai are no longer active due to both the presence of introduced predators and an alteration of vegetation structure and composition. For example, Kaluahonu colony located in southeastern Kauai is now dominated by nearly pure and impenetrable stands of *R. tomentosa*. Intensive surveys conducted by DOFAW in 2003 and 2007 indicated that the breeding activity at this colony, which was active in the early 1990s, has significantly declined in a relatively short timeframe (Holmes and Troy 2008) and surveys carried out by KESRP in this area in 2013 found no birds within the boundaries of the original colony. Colony collapse has also been recorded in several other historical colonies including Kalaheo, Makaleha and Wailua (KESRP, unpublished data). Close proximity to human disturbed areas is another factor that accelerates habitat degradation and loss by increasing both light levels and the relative abundance of invasive plants and predators.

THREATS AT SEA

Marine Debris

Five to 20 million tons of marine debris generated from the 2011 Japan tsunami increases risk of exposure to Newell's shearwater throughout the range, in addition to the existing "garbage patch" that sits between Hawaii and the continental United States.

Fishing Industry

Domestic commercial fisheries have not demonstrated to affect Newell's shearwater. These fisheries include demersal (bottom) and pelagic (open ocean) longline fisheries. Besides the United States of America, other countries operating fisheries with the potential to interact with Newell's shearwater include Japan, Taiwan, China, Korea, Russia, and perhaps others. Information from foreign fisheries is incomplete and some fisheries like the Japanese salmon driftnet fishery operating in Russian territory are documented taking high numbers (186,000 per year) of seabirds with the majority being shearwaters and murres (Artukhin 1999).

Oil Spills and Contaminants
There is potential for oil spills to occur which could affect Newell's shearwater. Petroleum and petroleum products released into the environment are documented as having several deleterious effects on seabirds in general. These effects include disruption in thermoregulation through fouled feathers, toxicity through ingestion (e.g., while preening fouled feathers), contamination of food resources, reduction of prey availability through toxic effects to prey species, and embryo toxic effects. Oil spills in any of the Newell's shearwater range may have serious impacts. The transfer of small amounts (1 microliter) of oil from adults to eggs may be enough to kill an egg. Possible consequences from other contamination are shell thinning (from pesticides), disruption of physical and embryonic development, and reproductive inhibition (from organochlorines and heavy metals). Debris from 2011 Japan tsunami could increases risk of contaminant exposure to Newell's shearwater throughout the range.

Natural Events
Ocean regime shifts, e.g., El Niño Southern Oscillation, are common environmental phenomena arising from large-scale changes in atmospheric pressure affecting wind and oceanographic conditions that ultimately affect ocean productivity. The effects of these changes can be positive or negative depending on species and should be recognized as an important variable in population dynamics. However the extent of these at-sea impacts is not known.

Climate Change
Earth's climate is one of the most pressing contemporary threats to global biodiversity (Clark et al. 2001; IPCC 2007). Climate change is expected to result in regional changes in weather patterns and oceanic productivity that are further predicted to affect seabird populations as well as other plant and animal communities in Hawaii. Changes anticipated in Hawaii may include, but are not limited to, increased thermal stratification of the ocean, increased frequency of El Niño conditions, and changes in ocean productivity (Sarmiento et al. 2004; Devney et al. 2009). Furthermore, more severe weather shifts from increased frequency of hurricanes to possible increases in droughts in some areas could affect breeding habitat.

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APPENDIX 2: MODELLING METHODS AND RESULTS USED TO INFORM THE NEWELL'S SHEARWATER LANDSCAPE STRATEGY