



Predator Control Management Plan

Haleakalā National Park

Natural Resource Report NPS/HALE/NRR—2019/2005





ON THIS PAGE

Endangered Hawaiian goose sentry male at Haleakalā National Park
Courtesy NPS

ON THE COVER

Camera trap photograph of endangered Hawaiian petrel chick at Haleakalā National Park
Courtesy NPS

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Contents

	Page
Figures.....	vi
Tables.....	viii
Appendices.....	viii
Abbreviations.....	ix
Executive Summary	x
Acknowledgments.....	xiii
Chapter 1 Background	1
1.1 Species Descriptions.....	1
1.1.1 Endangered Birds	1
1.1.2 Predator Species	5
1.2 Location.....	12
1.2.1 Frontcountry	13
1.2.2 Backcountry.....	14
1.3 Overview of Trapping Program 1970's - 2016	14
1.4 Trapping Program Transition	16
Chapter 2 Decision Making Process for Predator Control.....	17
2.1 Step 1: Survey for predator activity.....	17
2.2 Step 2: Identify predator hot spots.....	17
2.3 Step 3: Assess characteristics of the hot spot	17
2.4 Step 4: Create and execute a local trapping plan.....	18
2.5 Step 5: Monitor traps and predator activity	19
2.6 Step 6: Evaluate.....	19
Chapter 3 Implementation Methods.....	20
3.1 Predator surveying.....	20
3.1.1 Cats	20
3.1.2 Mongooses.....	21

Contents (continued)

	Page
3.1.3 Rats	22
3.2 Trapping strategy	22
3.2.1 Trap placement	23
3.2.2 Trap numbers and spacing.....	23
3.2.3 Trapping in endangered species habitat	24
3.2.4 Trapping in high visitor use areas	26
3.2.5 Staffing Considerations	26
3.2.6 Trap monitoring systems	27
3.3 Monitoring for predator activity	28
3.4 Trap Types.....	29
3.4.1 Non-Lethal Traps.....	29
3.4.2 Lethal Traps.....	32
3.5 Baits and Lures	37
3.6 Toxicants	40
3.7 Priority trapping areas	40
3.7.1 Frontcountry	41
3.7.2 Backcountry.....	41
3.8 Evaluating trapping	41
3.8.1 Short-term evaluations.....	42
3.8.2 Long-term evaluations.....	42
Chapter 4 Other Applications	43
4.1 Application in other areas of HALE.....	43
4.1.1 Rainforest areas	43
4.1.2 High elevation grassland areas	43
4.1.3 Nu‘u.....	43
4.1.4 ‘Ohe‘o.....	44

Contents (continued)

	Page
4.2 Application in areas outside of HALE	44
4.2.1 Goals of predator control.....	44
4.2.2 Area of predator control	44
4.2.3 Terrain	45
4.2.4 Public access.....	45
4.2.5 Staff experience	45
Literature Cited	46

Figures

	Page
Figure 1. ‘Ua‘u nesting areas at HALE.....	2
Figure 2. Seasonal breeding chronology of ‘ua‘u at HALE.....	3
Figure 3. Nēnē nesting areas at HALE.	4
Figure 4. Seasonal activity and breeding chronology of nēnē at HALE.....	5
Figure 5. Overlapping ‘ua‘u and nēnē habitats and season.....	5
Figure 6. Camera trap image of feral cat entering ‘ua‘u burrow..	6
Figure 7. Monthly cat catches per unit effort in HALE from 2000 - 2014.....	7
Figure 8. Spatial distribution of cats caught associated with traps in HALE from 2000– 2014.....	7
Figure 9. Camera trap image of mongoose entering ‘ua‘u burrow.	8
Figure 10. Monthly mongoose catches per unit effort in HALE from 2000 - 2014.	9
Figure 11. Spatial distribution of mongooses caught associated with traps in HALE from 2000–2014.....	10
Figure 12. Camera trap image of rat in ‘ua‘u burrow. NPS photo.....	11
Figure 13. Monthly rat catches per unit effort in HALE from 2000 - 2014.	11
Figure 14. Spatial distribution of rats caught associated with traps in HALE from 2000– 2014.....	12
Figure 15. The Summit (frontcountry and backcountry) and Kīpahulu Districts of Haleakalā National Park.	13
Figure 16. Frontcountry shrubland near park entrance where nēnē nest..	14
Figure 17. Inside Haleakalā Crater with a view of cliffs where ‘ua‘u nest.....	14
Figure 18. Location of cage traps and names of traplines	15
Figure 19. Examples of mongoose fecal droppings at HALE.	22
Figure 20. Cage trap outfitted with a “goose guard.”	25
Figure 21. Cage trap with VHF telemetry Trap Monitoring System (TMS).	28
Figure 22. Foothold trap, partially buried, shown in a walk through set.	30
Figure 23. Cage trap.....	32

Figures (continued)

	Page
Figure 24. Goodnature™ A24 trap.	33
Figure 25. DOC 250 trap (top view) in box.	34
Figure 26. Body grip trap in box.	35
Figure 27. Snap trap in box.	37

Tables

	Page
Table 1. Trap types by predator species and modifications or restrictions to minimize endangered species capture.....	29
Table 2. Baits, advantages and disadvantages, trap types suitable for each bait and summary of application.....	38
Table 3. Visual, auditory, and olfactory lures used to attract predators within HALE.....	39

Appendices

	Page
APPENDIX A Implementation Schedule	1
APPENDIX B Site Descriptions for Priority Trapping Areas at HALE	1

Abbreviations

DOI:	Department of the Interior
EWM:	Endangered Wildlife Management
GPS	Global Positioning System
HALE:	Haleakalā National Park
NEPA:	National Environmental Policy Act
NFWF:	National Fish and Wildlife Foundation
NPS:	National Park Service
RM:	Resources Management
SOP:	Standard Operating Procedure
TMS:	Trap Monitoring System
USGS:	United States Geological Survey

Executive Summary

This management plan provides guidance and techniques for the control of non-native, mammalian predators at Haleakalā National Park (HALE) to protect endangered ground-nesting ‘ua‘u (*Pterodroma sandwichensis*, Hawaiian petrel) and nēnē (*Branta sandvicensis*, Hawaiian goose). This plan incorporates information on predator trapping at HALE from 1979 to 2018, analysis of trapping data from 2000-2014 provided by the U.S. Geological Survey (USGS), and an evaluation of trapping methods and recommendations from Island Conservation. The goals are to increase endangered bird survival by decreasing predator impacts, and to increase efficiency of trapping effort at HALE. The plan considers minimizing incidental capture of endangered species, increasing efficacy in capturing predator species, staff and funding constraints, visitor encounters with traps, and attention to humane methods for lethal removal. While this plan focuses on predator control to protect ‘ua‘u and nēnē at HALE, concepts within this plan can be used to develop trapping programs in other areas of the park and areas outside the park to protect other endangered species. This document is not intended to fulfill requirements under the National Environmental Policy Act (NEPA) and is not a compliance document.

Chapter 1 includes background information on the park’s trapping program, species descriptions, and location descriptions. Predation by introduced mammals, including feral cats, mongooses and rats, is one of the major limiting factors for ‘ua‘u and nēnē. The park's trapping program mainly consisted of transects of cage traps set in lines (traplines) that border endangered bird nesting habitat in the Summit District of HALE, and have been modified over the years to incorporate different trap types. Trapping focuses on protecting endangered, ground-nesting ‘ua‘u and nēnē by removing rats, mongooses and feral cats.

Chapter 2, the Decision Making Process for Predator Control, is the foundation of the plan and serves as a guide that provides managers with an adaptive management process for executing and evaluating trapping methods. The Decision Making Process is a 6-step guide.

- Step 1: Survey for predator activity

Survey for predator activity by conducting extensive on-the-ground surveys and by camera trap surveillance.

- Step 2: Identify predator hot spots

Combine information from surveying (Step 1) and historical trapping data, which shows locations where predator catches were highest, to identify predator “hot spots.” A predator “hot spot” is an area with a high predator activity (relative to surrounding areas) that is naturally attractive to predators and will continue to attract predators over time.

- Step 3: Assess characteristics of the hot spot

For each hot spot, assess the predator activity, endangered species activity, visitor use, and remoteness.

- Step 4: Create and execute a local trapping plan

Develop plans according to location characteristics identified in Step 3. Set traps in clusters, grids, or lines. A variety of traps, baits and lures may be used. The number of traps and types of traps used are based on target predator species, endangered species activity, visitor use, remoteness of the area, and staff availability. Baits and lures used in conjunction with traps are based on target species, trap type and trap placement.

- Step 5: Monitor traps and predator activity

Monitor traps regularly to reset, rebait and refresh traps sets. All traps, including lethal traps, should be checked as frequently as possible. Minimally, baits and lures need refreshing weekly. Monitor the trapping area for predator activity by conducting on-the-ground surveys and by camera trap surveillance.

- Step 6: Evaluate

Evaluate the trapping plans using data on trap and predator activity monitoring. Conduct short-term evaluations of predator monitoring and trapping data yearly. Long-term evaluation of predator monitoring and examination of trapping data should be conducted every five years.

Chapter 3 outlines the methods and materials that will be used at HALE to adjust the current trapping program and implement trapping plans developed using the Decision Making Process. Specifics on predator monitoring, trapping strategies, target locations, types of traps, baits, and toxicants are covered. Methods other than trapping (predator exclusion fencing, hunting, toxicants and GPS-collared sentinel cats) were considered but were deemed less practical, less effective, or financially infeasible at HALE but may be considered in the future.

Predator monitoring utilizes extensive on-the-ground surveys and camera traps. Observers systematically survey for sightings of predators and predator signs such as fecal droppings, tracks (predator footprints), and depredations. Observers record type of predator, predator sightings, signs, and Global Positioning System (GPS) location. Camera traps monitor for predator activity.

Trapping strategy focuses on trapping all three predators inside or near ‘ua‘u or nēnē habitat and additionally targets cats outside of ‘ua‘u or nēnē habitat at cat hot spots. Local trapping plans must be fluid and adaptive to account for changes in staffing levels, predator levels and seasons, and endangered species seasons. The manager adjusts trapping effort and staff availability to ensure the highest trap efficiency and benefit to ‘ua‘u and nēnē. Trapping strategy considers trap placement, trap numbers and spacing, endangered species habits, visitor use, trap monitoring systems, remoteness and staffing availability.

Trap locations included in this plan focuses on areas to protect endangered ‘ua‘u and nēnē in the frontcountry and backcountry. Habitat information and trapping strategies for specific locations are found in Appendix B.

Trapping methods include the use of non-lethal and lethal traps. All traps can be used in endangered species habitat with modifications or restrictions to minimize capturing endangered species.

Non-lethal traps include cage-type live traps and footholds. Cage traps are the only trap type that targets all predator species (rats, mongooses and cats). Footholds have been the most effective trap for capturing cats. Non-lethal traps are checked as frequently as possible.

Lethal traps are recommended for use in remote areas where frequent trap checks may not be possible. Lethal trap types include DOC 250, body grip, Goodnature™ A24 and snap traps. The DOC 250 is a spring-loaded trap that targets primarily mongooses, but also captures larger rats. Body grip traps are spring-loaded and target feral cats. The Goodnature™ A24 is a repeat-kill trap for rats powered by a CO₂ gas cartridge. Snap traps are spring-loaded traps that target rats.

Baits and lures are used to attract predators into traps. Different types of baits and lures are used in combination with different types of traps, and rotating a variety of baits and lures is helpful in attracting predators.

There are currently no toxicants labeled for use in Hawai‘i for predator control, and there are currently none used as such at HALE. Diphacinone rodenticide was used at HALE from 1995–2013 to supplement trapping efforts to control rodents and mongooses in endangered bird habitat, primarily nēnē nesting habitat at Palikū. Toxicants may be considered in the future to supplement trapping if they become labeled for use and application is feasible.

Chapter 4 describes how this plan can be used to develop local trapping plans within and outside HALE to benefit endangered species, including forest birds. Logistics differ for other areas in the park, especially for remote areas such as Kīpahulu Valley, Ka‘āpahu and the upper elevations of Nu‘u. Differences in predator densities, target endangered species, remoteness, and weather are some factors that affect local trapping strategies in these areas. For locations outside of HALE, the goals of predator control, area of predator control, terrain, and staff experience are factors to consider.

An Implementation Plan outlining yearly goals and Standard Operating Procedures for deploying traps are also included in this plan.

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Chapter 1 Background

Haleakalā National Park (HALE) Resources Management division (RM) manages populations of endangered ‘ua‘u (*Pterodroma sandwichensis*, Hawaiian petrel) and nēnē (*Branta sandvicensis*, Hawaiian goose). These two ground-nesting species nest primarily in the higher elevations of HALE. Predation by non-native mammals including feral cats (*Felis catus*), mongooses (*Herpestes auropunctatus*), and rats (*Rattus* sp.) has been identified as factors limiting population growth and survival of these species (Banko et al. 1999, Baker and Baker 1994, Simons and Natividad Hodges 1998, Natividad Hodges and Nagata 2001). Predation accounted for 54% of known ‘ua‘u mortalities and 35% of all known nēnē mortalities from 1991 to 2011 at HALE (Haleakalā National Park 2012). Recovery plans for both the ‘ua‘u (USFWS 1983) and nēnē (USFWS 2004) include predator control as a key feature for species recovery.

A predator control program to protect ‘ua‘u and nēnē populations has been ongoing at HALE since the 1970s. Predator trapping has been effective in maintaining a relatively low rate of mortality from predators and has contributed to increases of ‘ua‘u and nēnē populations (Haleakalā National Park 2012, Natividad Hodges and Nagata 2001, HALE unpubl. data). HALE RM is constantly evaluating and assessing the trapping program. Despite trapping efforts, introduced predators continue to impact endangered bird populations.

This plan is a guide to assist managers in developing and implementing predator control trapping strategies at HALE. The goals of this plan are to increase endangered bird survival by decreasing predator impacts and to increase efficiency of trapping effort.

Adaptive management strategies that consider changes in populations, distribution, and behavior of both endangered birds and introduced predators are outlined. Methods incorporate techniques that are effective for removing rats, mongooses, and feral cats while minimizing non-target capture of endangered ground nesting birds. Methods also consider fluctuations in staff and funding, public perception, and visitor experience. While this plan focuses on predator control to benefit ‘ua‘u and nēnē at HALE, concepts are applicable to other endangered species such as forest birds and in locations outside of HALE. This document is most effective for management at HALE when cross-referenced with Haleakalā National Park Predator Control Method Review (Jolley and Hanson 2016). This document is not intended to fulfill requirements under the National Environmental Policy Act (NEPA) and is not a compliance document.

1.1 Species Descriptions

1.1.1 Endangered Birds

1.1.1.1 ‘Ua‘u (Hawaiian Petrel)

The ‘ua‘u (Hawaiian Petrel, *Pterodroma sandwichensis*) was federally listed as endangered in 1967 (USFWS and Telfer 1983). Birds once nested from sea-level to high elevations in a variety of habitats (Munro 1944, Olson and James 1982, Simons 1985) but have suffered large population declines over time (Simons and Natividad Hodges 1998). Some factors that have contributed to population declines include predation by introduced mammalian predators (Munro 1955, Berger

1972, Atkinson 1977, Simons 1983, USFWS and Telfer 1983, Natividad Hodges and Nagata 2001), habitat destruction (Berger 1972), and human consumption of adults and chicks (Bryan 1914, Munro 1955). Since the late 1970's, HALE RM maintained an aggressive program to improve habitat quality by removing feral ungulates and introduced predators which allowed for an increase in the 'ua'u population (Natividad Hodges and Nagata 2001). There are currently over 2,500 known 'ua'u nests (HALE unpubl. data). The population is estimated at 3,000–4,000 breeding pairs out of an estimate of 8,000–9,000 individual birds (Haleakalā National Park 2012, HALE unpubl. data). This estimate represents a 10-fold increase from the estimated population of 300–400 breeding pairs in 1966 (Larson 1967).

At HALE, 'ua'u are nocturnally active and vocal near breeding colonies. The Hawaiian name 'ua'u (pronounced oo-WAH-oo) is similar to their distinctive vocalizations that are heard as the birds fly around the colony. 'Ua'u are pelagic feeders, subsisting primarily on squid, fish, and crustaceans caught near the sea surface (Simons 1985, Simons and Natividad Hodges 1998). 'Ua'u forage widely across the central, northern and eastern Pacific Ocean, even during the breeding season (Warham 1990, Simons and Natividad Hodges 1998, Adams 2007).

At HALE, 'ua'u nests are mainly found in sparsely vegetated subalpine areas on Mount Haleakalā, from approximately 2,350 m to 3,050 m (approx. 7,700 ft. to 10,000 ft.) elevation (HALE unpubl. data, Figure 1). Adults nest in burrows on steep slopes with sparse vegetation (Brandt et al. 1995) excavated in cinders or natural cavities in lava rock. The highest density of nests, approximately five burrows per hectare (2.47 acres), is located along the steep walls of Haleakalā Crater in alpine habitat, from approximately 2,440 m to 2,740 m (approx. 8,000 ft. to 9,000 ft, HALE unpubl. data) elevation. Nests are also found on cinder cones, in shrublands above approximately 2,130 m (approximately 7,000 ft.) elevation and scattered throughout other areas of the Crater (Figure 1).

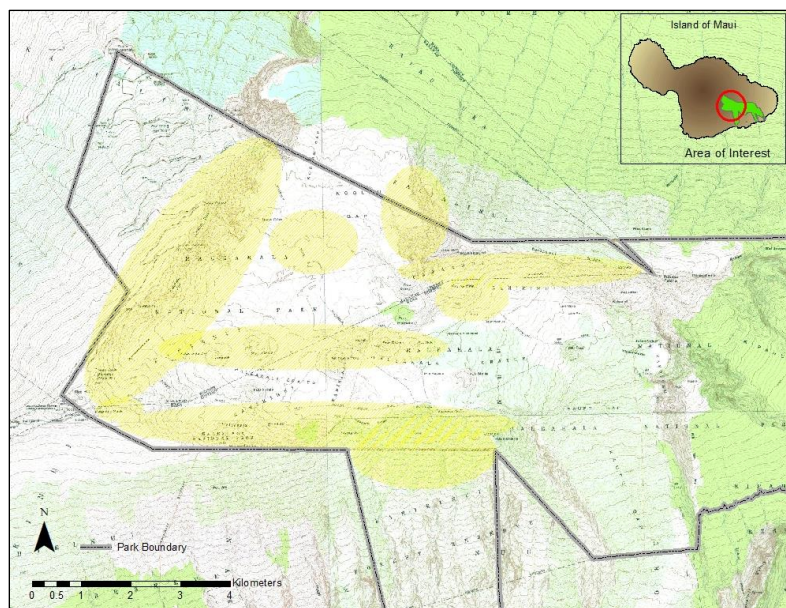


Figure 1. 'Ua'u nesting areas (yellow) at HALE (NPS 2018).

‘Ua‘u are long-lived, monogamous seabirds, with adults reaching approximately 35 years of age (Simons 1984). ‘Ua‘u are at their nesting sites at HALE from February through November each year (Simons 1985, Simons and Natividad Hodges 1998, NPS 2012). ‘Ua‘u live out at sea and are absent from HALE from mid-November through mid-February (Figure 2).

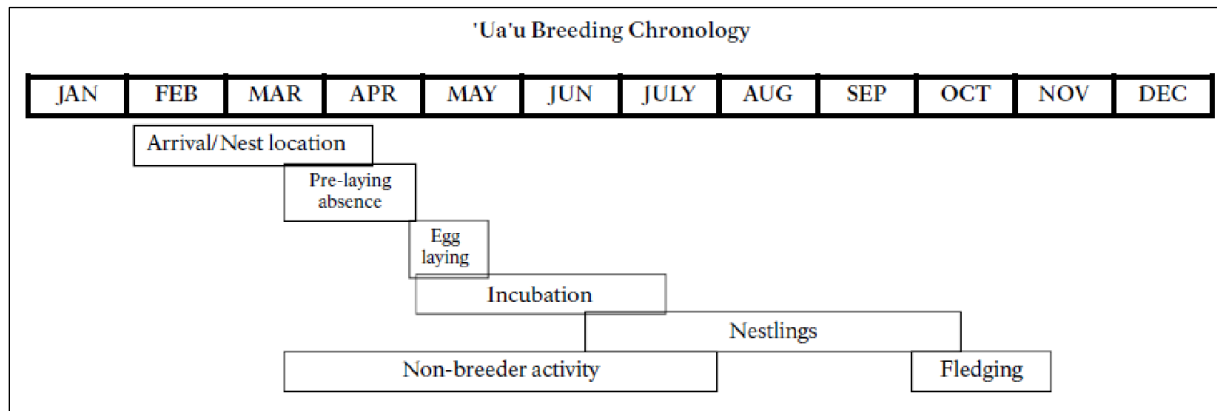


Figure 2. Seasonal breeding chronology of ‘ua‘u at HALE.

Birds arrive mid-February to attend burrows, find mates, and new breeding pairs prepare new burrows. Breeding adults lay eggs from April to mid-May. Each nesting pair produces only one egg per year. If this egg fails, the birds will not re-nest. Hatching occurs in July and August after an average incubation period of 55 days (Simons 1985). At the time of hatching, failed and non-breeding adults typically depart the colony, although some adults remain with chicks until fledging (HALE unpubl. data).

After hatching, chicks remain in burrows alone while parents forage for chick provisioning. Foraging expeditions range from five to 10 days (HALE unpubl. data) with a single foraging trip totaling more than 10,000 km (6,214 mi., Adams and Flora 2009). Fledging begins in late September and ends in mid-November (HALE unpubl. data). By the end of November, all birds are absent from the colony, and remain at sea until the next breeding season in mid-February. Not all birds return each year. The average percentage of burrows showing signs of ‘ua‘u activity from 1993 to 2014 is $59.2\% \pm 0.2\%$, with lower percentages of burrows showing signs of activity in El Niño years (HALE unpubl. data).

1.1.1.2 Nēnē (Hawaiian Goose)

Nēnē (Hawaiian Goose, *Branta sandvicensis*) are the largest extant native terrestrial bird in the Hawaiian Islands and the official state bird of Hawai‘i. Before the 20th century, numbers were estimated statewide to be as high as 25,000 (Paxinos et al. 2002). Hunting, habitat loss, and introduced predators contributed to severe declines of nēnē, particularly in coastal lowlands where habitat alterations were most pronounced (USFWS 2004). The species experienced a dramatic population decline by the 1940s, when there were only 50 individuals estimated (Baldwin 1945). Recovery efforts were started in the 1960s within HALE and approximately 500 captive-bred nēnē were released into the backcountry from 1962–1977 (USFWS 2004). The park also managed a small

scale propagation program from 1972–1983, with open-top pens located near Park Headquarters and Hosmer Grove (Tamayose 2006).

The statewide population estimate for nēnē in 2017 was 3,146 individual birds, with 566 on Maui (Nēnē Recovery Action Group 2018). Predators, vehicle collision, and habitat modification remain the biggest threat to the species (Rave et al. 2005, Work et al. 2015). The toxoplasmosis parasite (*Toxoplasma gondii*), which is carried and transmitted by feral cats, also contributes to nēnē mortality (Work et al. 2002, Work et al. 2015).

Banko (1988) identified predation by introduced mammals as a primary limiting factor for nēnē within HALE. Broad scale predator and ungulate control began in the 1970s, and nēnē populations stabilized. Based on mark-resight data, the population at HALE has fluctuated between 200 and 300 individuals since 1988, with an estimate of 280 individuals in 2018 (HALE unpubl. data). The majority of nests are located near the original release site at Palikū in the backcountry and at the park baseyard in the frontcountry (Figure 3).

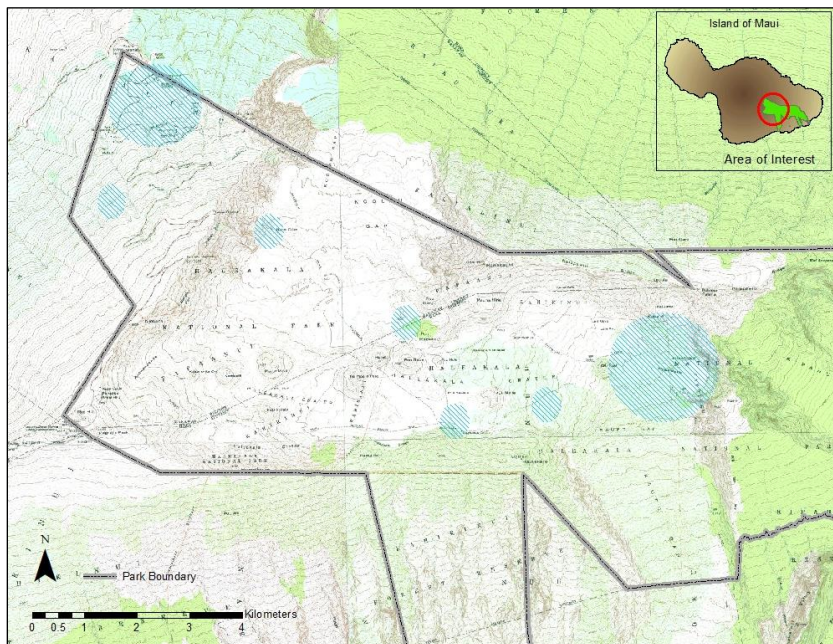


Figure 3. Nēnē nesting areas (blue) at HALE.

Nēnē are long-lived, monogamous geese that lay three to five eggs (Banko et al. 1999). Nēnē are at HALE year-round and use different areas of the park throughout the year. Nesting season at HALE starts in late October and ends in late April (Figure 4). If early season nests fail, nēnē may re-nest. From May through July, nēnē molt, losing their flight feathers. Flocking occurs after molt, from July through September. During flocking nēnē commonly congregate in grassland areas of HALE including on lawns near offices, cabins and campgrounds, as well as large grasslands in remote wilderness areas.

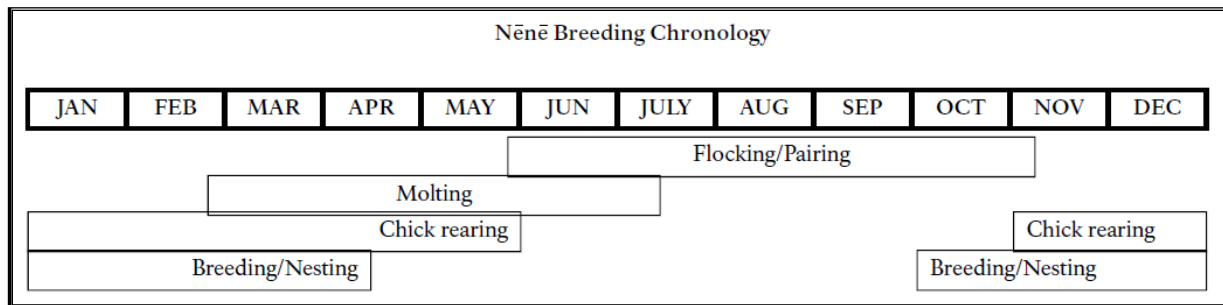


Figure 4. Seasonal activity and breeding chronology of nēnē at HALE.

The nesting habitats and seasons of ‘ua‘u and nēnē overlap (Figure 5). Efforts to manage predators that prey upon these species incorporate these overlaps.

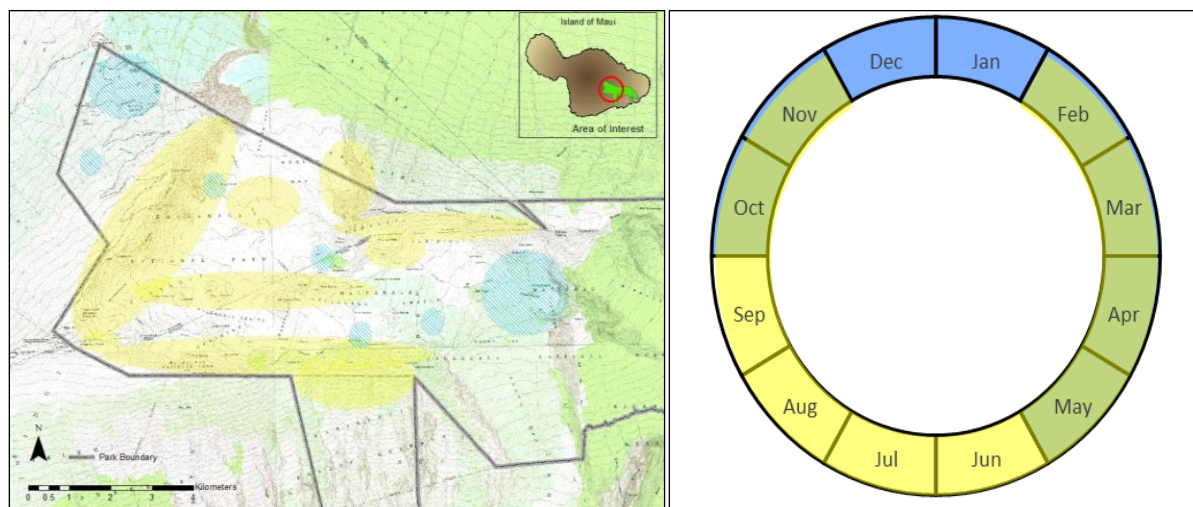


Figure 5. Overlapping ‘ua‘u (yellow) and nēnē (blue) habitats (left) and season (right, in green).

1.1.2 Predator Species

1.1.2.1 Feral Cats

Cats (*Felis catus*) introduced to islands have frequently become the dominant, apex predator (Hess 2016). The consequences have been devastating for native wildlife including the decline, extirpation, and extinction of numerous bird species (Dickman 1996, Nogales et al. 2004). Cats can also carry diseases to the detriment of wildlife. Toxoplasmosis has been known to kill endangered Hawaiian monk seals (*Monachus schauinslandi*), nēnē, and critically endangered ‘alala (*Corvus hawaiiensis*; Work et al. 2000, 2002, 2015, Honnold et al. 2005). Cat depredation of endangered birds in Hawai‘i has been documented in many habitats (Natividad Hodges 1994, Hess et al. 2007, Lindsey et al. 2009, Judge et al. 2012). At HALE, camera traps captured photos of cats entering ‘ua‘u nests (Figure 6) and preying upon ‘ua‘u (HALE unpubl. data).



Figure 6. Camera trap image of feral cat entering 'ua'u burrow. NPS photo.

Home ranges of cats are dependent on several factors including territorial behavior, social interaction, food resources, and landscape characteristics. Goltz et al. (2008) estimated home ranges of feral cats on Mauna Kea, Hawai'i Island in sub-alpine woodland (similar habitat to the summit district of HALE) at 772 ha (1,908 acres) for females and 2,050 ha (5,066 acres) for males. Daily mean movements of cats ranged from approximately 100 m (328 ft.) to 6,000 m (3.7 mi.) per day. Cats range farther at night when they are actively roaming and hunting (Haspel and Calhoun 1989).

HALE trapping data based on catch per unit effort from 2000 to 2014 suggests seasonal trends in cat captures with rates being lowest from March through May and highest in October through January (Figure 7; Kelsey et al. 2019). Cat captures were dispersed throughout all areas at HALE with traps, and were caught more in shrub-covered areas than in barren and developed areas. Sample sizes were too small to detect a correlation with elevation (Figure 8; Kelsey et al. 2019). This suggests that cats travel through all areas of HALE, and home ranges and daily movement may be similar to those found at Mauna Kea. Cats are captured at very low rates at HALE (0.9 ± 0.4 cats per month, HALE unpubl. data). However, Simons (1985) found that a few vagrant cats were responsible for a relatively large number of depredated 'ua'u at HALE. Therefore, capturing these few cats are necessary for survival of endangered ground-nesting birds.

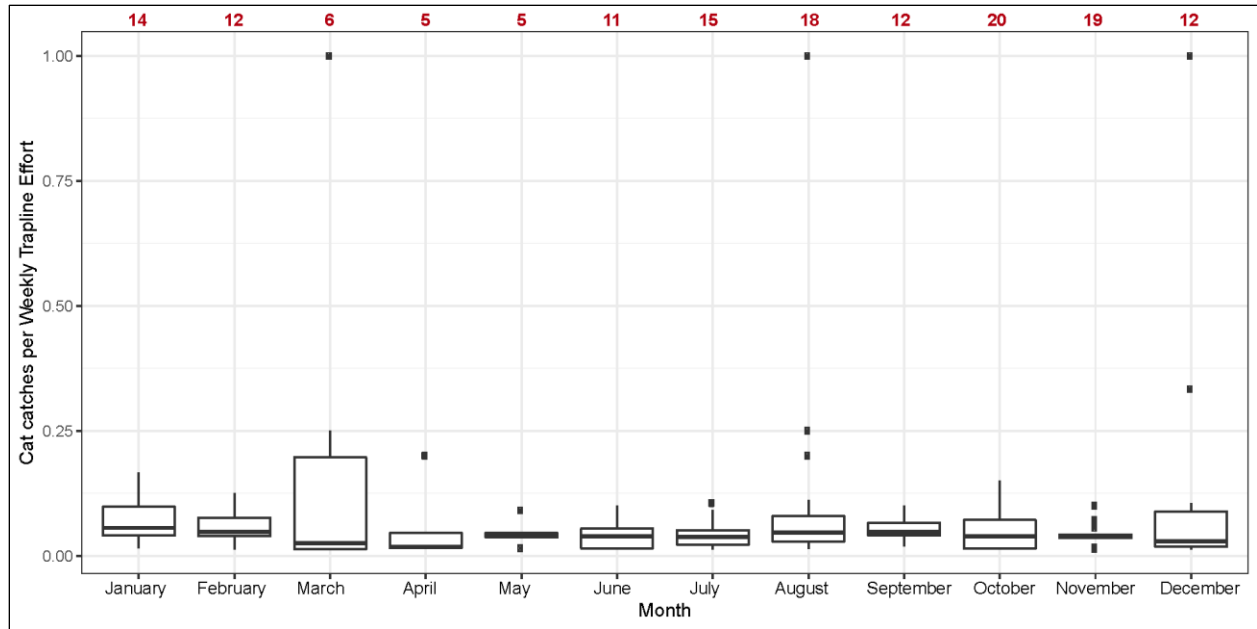


Figure 7. Monthly cat catches per unit effort in HALE from 2000 - 2014. The thick black line is the median, the lower and upper hinges correspond to the first and third quartiles, upper whisker corresponds with the inter-quartile range, and the dots represent outliers. The red numbers are the sample size of total catches in each month over the 15-year study period (Kelsey et al. 2019).

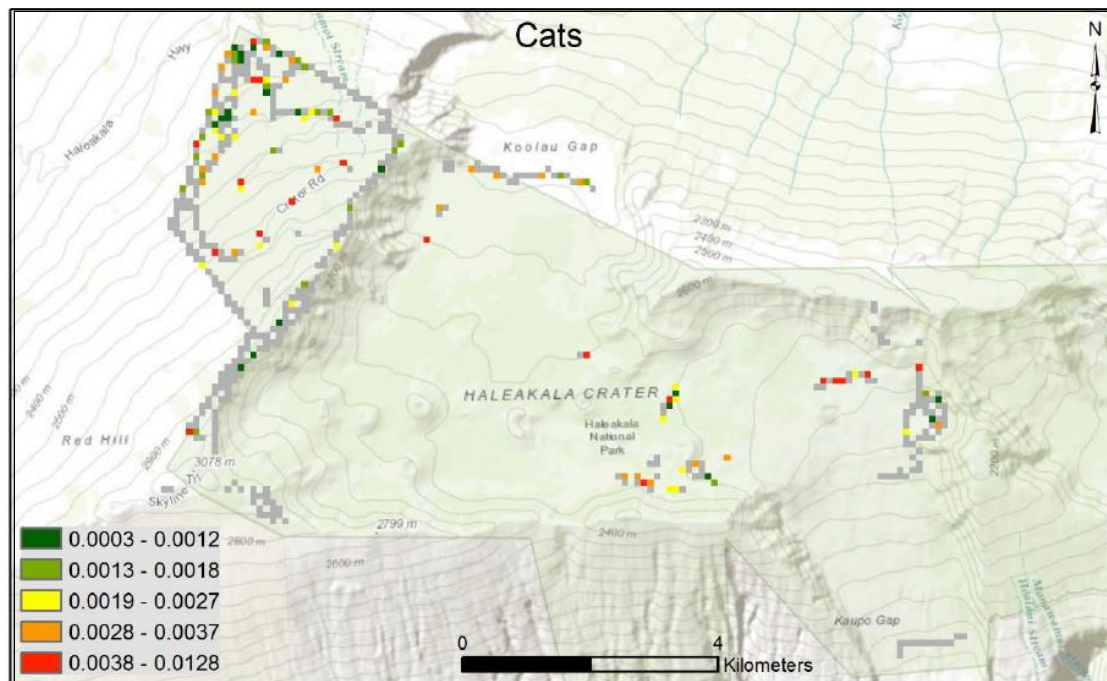


Figure 8. Spatial distribution of cats caught associated with traps in HALE from 2000–2014. Colors and values indicate cats caught per trapping effort (Kelsey et al. 2019).

1.1.2.2 Mongooses

The small Indian mongoose (*Herpestes auropunctatus*), native to southeast Asia, was introduced to the Hawaiian Islands from Jamaica in 1883 to reduce rat populations in sugar cane fields (Hays and Conant 2007). Mongooses may have been effective at reducing damage to sugarcane by Norway rats, but only for a short period prior to the arrival of Black rats (Atkinson 1977). Mongooses are now regarded as pests and predators of ground-nesting birds such as endangered nēnē, breeding seabirds, and several waterbird species (Stone and Loope 1987, Banko 1992). Banko (1992) found that mongooses accounted for 62% of unsuccessful nēnē clutches on Hawai‘i and Maui between 1978 and 1981. The species has also been implicated in several extirpations of endangered Hawaiian waterbirds and shorebirds (Hays and Conant 2007). While currently recognized as *Herpestes javanicus* (ITIS 2019, Wozencraft 2005), DNA barcoding indicates that nonnative mongoose populations in Hawai‘i are *Herpestes auropunctatus* (Bennett et al. 2010).

Mongooses are primarily active during the day (Nellis and Everard 1983) and range from sea level to 3,015 m (9,950 ft.) at HALE (HALE unpubl. data). Sizes of home ranges are highly variable: small ranges of only 1.4 ha (3.5 acres) occur at lower elevations while ranges up to 30 ha (74 acres) have been observed in high elevation sub-alpine habitat (Nellis and Everard 1983, Hays and Conant 2003, Pitt et al. 2015). On Haleakalā, mongooses are captured on camera traps throughout the park (Figure 9) and at 3,084 m (10,000 ft.) at the adjacent Haleakalā Observatories (Chen 2017).



Figure 9. Camera trap image of mongoose entering ‘ua‘u burrow. NPS photo.

As with cats, trapping data at HALE based on catch per unit effort suggest seasonal trends in mongoose captures with capture rates being lowest in April and May and highest from October through December (Figure 10; Kelsey et al. 2019). Kelsey et al. (2019) found that mongoose catches

were correlated with colder temperatures, further supporting that mongoose catches are higher in the winter months. Mongooses were most commonly caught in tree-covered areas at lower elevations (Figure 11; Kelsey et al. 2019). Mongooses are captured at low rates (average 2.9 ± 1.0 mongooses per month) however, as with cats, Simons (1985) found that a few mongooses were responsible for a relatively large number of depredated 'ua'u at HALE. Capturing these few mongooses are necessary for survival of endangered ground-nesting birds.

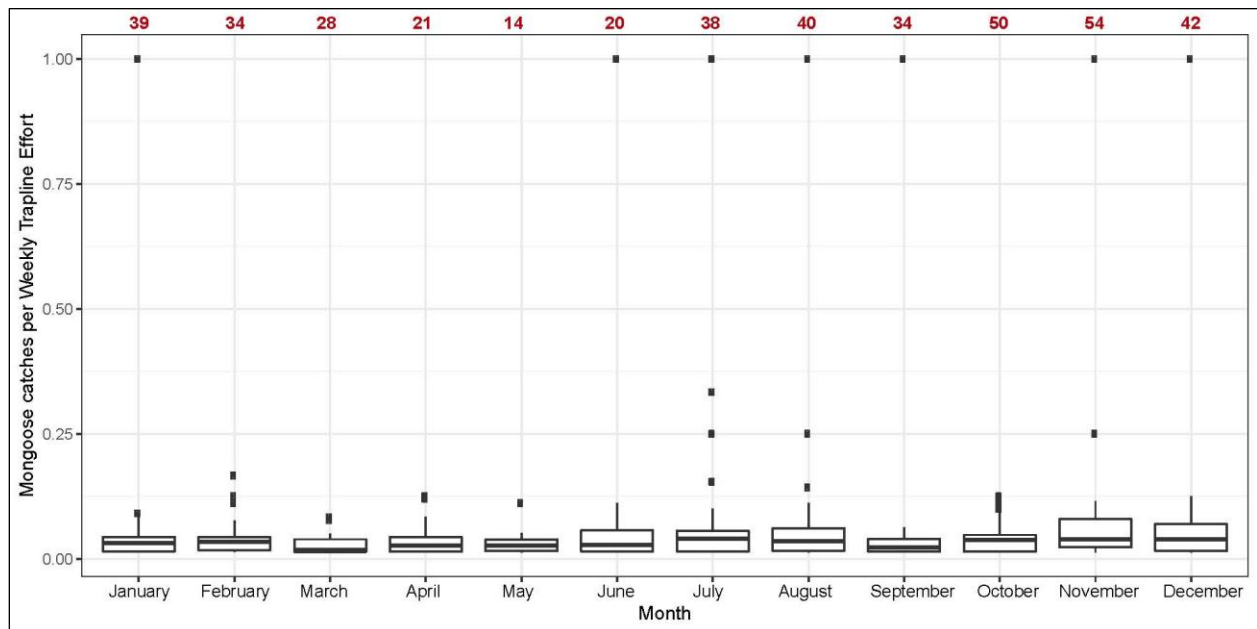


Figure 10. Monthly mongoose catches per unit effort in HALE from 2000 - 2014. The thick black line is the median, the lower and upper hinges correspond to the first and third quartiles, upper whisker corresponds with the inter-quartile range, and the dots represent outliers. The red numbers are the sample size of total catches in each month over the 15-year study period (Kelsey et al. 2019).

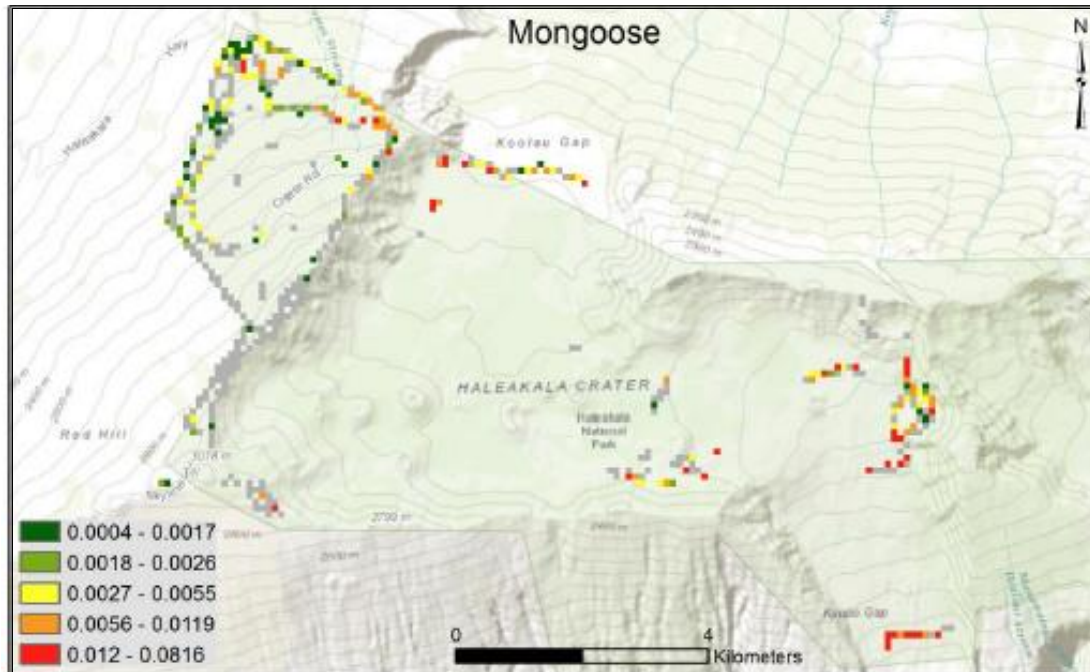


Figure 11. Spatial distribution of mongooses caught associated with traps in HALE from 2000–2014. Colors and values indicate mongooses caught per trapping effort (Kelsey et al. 2019).

1.1.2.3 Rats

Rats (*Rattus* spp.) are abundant on most of the world’s inhabited islands, causing widespread ecological damage and human health problems (Hess 2016). Rats prey on birds at all life history stages (Caut et al. 2008), and compete for food resources by preying on invertebrates and seeds, often interrupting reproduction in plants (Lindsey et al. 2009). Rats have caused severe declines of burrowing seabirds on island ecosystems (Atkinson 1985, Diamond 1985, Dobson 1988). Larson (1967) considered the black rat (*Rattus rattus*) as the primary threat to ‘ua‘u at HALE and noted rat activity and dead nestlings in several burrows. Rats also carry several diseases that are communicable to humans, domestic mammals, and native wildlife. These include murine typhus, leptospirosis, giardia, and bubonic plague (Tomich et al. 1984). Rats are commonly caught on camera traps at ‘ua‘u burrows (Figure 12) and prey primarily upon eggs of birds rather than birds at HALE (HALE unpubl. data).

Trapping data at HALE based on catch per unit effort show that rat catches are highest June through September, and lowest in December and January (Figure 13). Kelsey et al. (2019) also found that rat catches were positively correlated with warmer temperatures, further supporting that rat catches are higher in the summer months. Rats were more likely than the other predator species to be caught at high elevations (Figure 14; Kelsey et al. 2019). Capture rates of rats were relatively high (average 53.0 ± 10.3 rats per month) compared to cats and mongooses at HALE.



Figure 12. Camera trap image of rat in 'ua'u burrow. NPS photo.

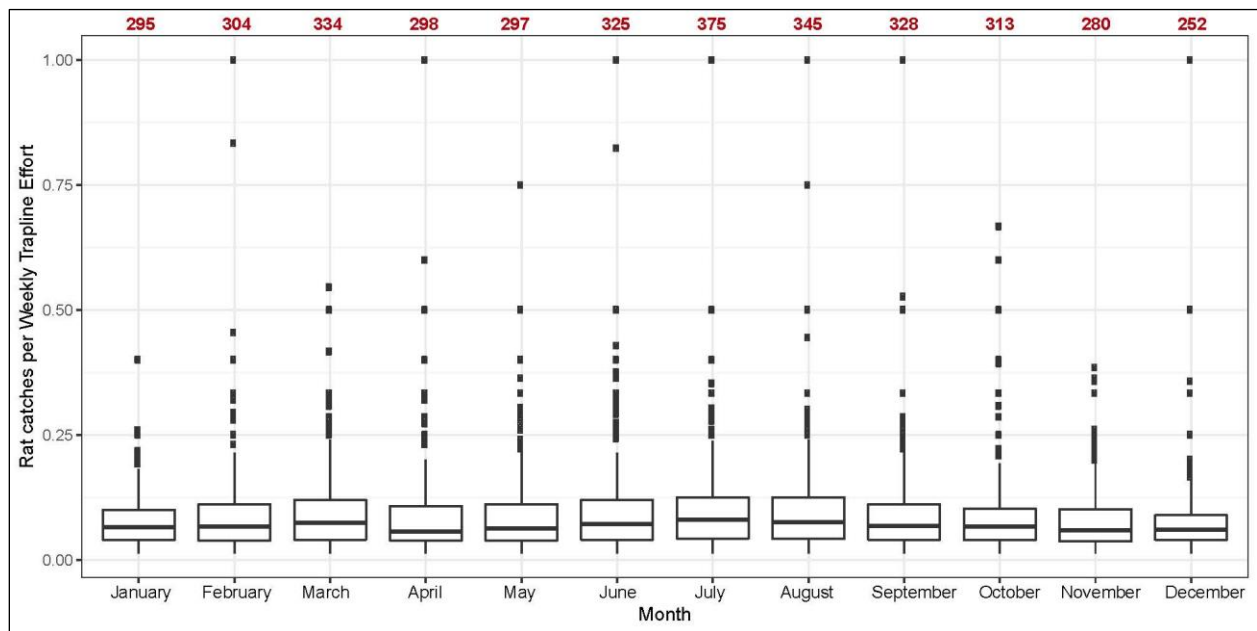


Figure 13. Monthly rat catches per unit effort in HALE from 2000 - 2014. The thick black line is the median, the lower and upper hinges correspond to the first and third quartiles, upper whisker corresponds with the inter-quartile range, and the dots represent outliers. The red numbers are the sample size of total catches in each month over the 15-year study period (Kelsey et al 2019).

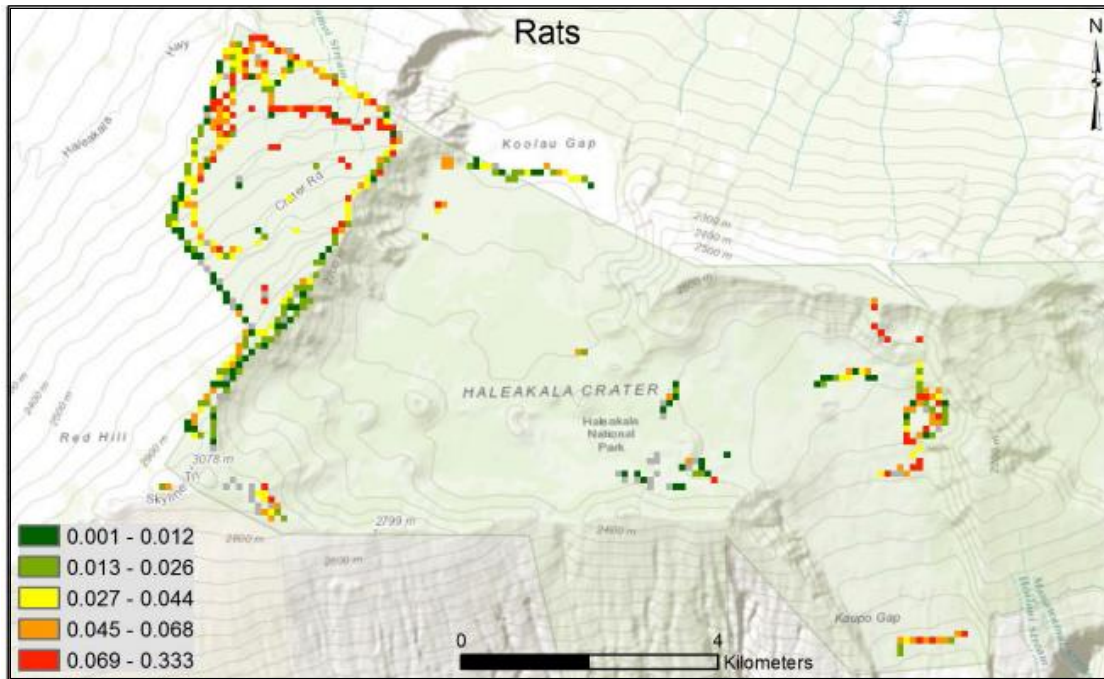


Figure 14. Spatial distribution of rats caught associated with traps in HALE from 2000–2014. Colors and values indicate rats caught per trapping effort (Kelsey et al. 2019).

1.2 Location

Haleakalā National Park is located on the eastern portion of Maui. The National Park Service manages approximately 13,445 ha (33,222 acres) of federal lands on the island of Maui. There are two districts in the Park, the Summit District and the Kīpahulu District (Figure 15). The Summit District includes two visitor centers, Park Headquarters, the RM baseyard, Highway 378 that leads to Haleakalā Summit at 3,055 m (10,023 ft.), and the large wilderness of Haleakalā Crater.

The upper elevations of the Kīpahulu District is a restricted entry biological reserve where NPS resource management focuses on habitat protection, restoration, and invasive species management (DOI/NPS 1995). The Kīpahulu District includes a small coastal area, ‘Ohe‘o, where RM conducts a small trapping program for pest control purposes.

The Nu‘u parcel was acquired in 2008 by NPS (Hawai‘i Bureau of Conveyances 2019). Breeding populations of ‘ua‘u and nēnē, the focal endangered species for this plan, occur at the Summit and Nu‘u. There are two geographic categories for the Summit, which are frontcountry and backcountry (Figure 15). An ungulate control fence, completed in 1988, encloses the entire Summit. Ungulates were removed to near zero by 1990, and ungulates that occasionally breach the fence are removed (Natividad Hodges and Nagata 2001). Fencing and feral animal control is in progress at Nu‘u to protect habitat for native species, including ‘ua‘u and nēnē.

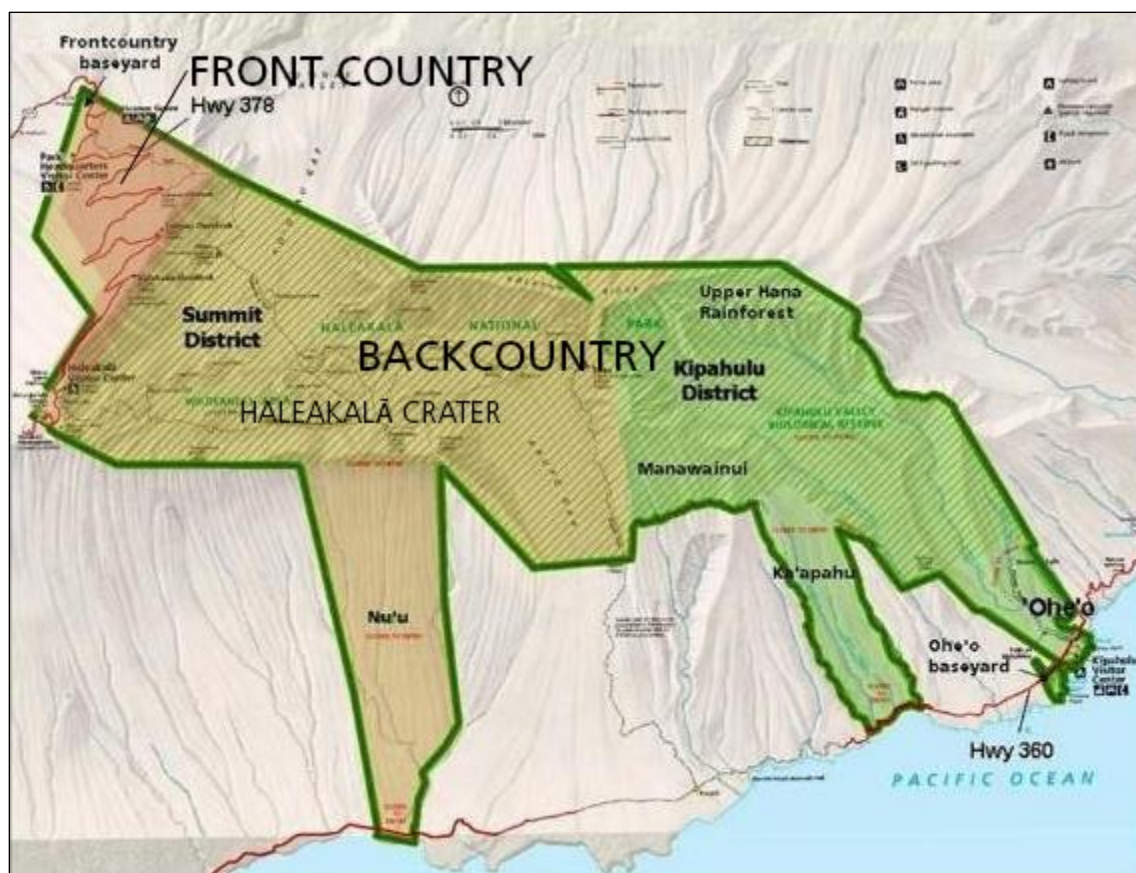


Figure 15. The Summit (frontcountry and backcountry) and Kīpahulu Districts of Haleakalā National Park.

1.2.1 Frontcountry

The frontcountry includes areas readily accessible by vehicle in the western portion of the Summit District, outside of Haleakalā Crater. The area starts from the park entrance at approximately 2,060 m (6,775 ft.) elevation to the summit of Haleakalā Crater at 3,055 m (10,023 ft.) and encompasses about 1,200 ha (2,965 acres). Ecosystem gradients consist of native shrubland at the lower elevations (Figure 16) to sparsely vegetated cinder deserts near the summit (Figure 17). The shrubland and portions of the cinder desert provides foraging resources and shelter for numerous wildlife species, including nēnē. The cinder desert and portions of the shrubland provide breeding habitat for ‘ua‘u. More than 1,200,000 visitors annually visit the frontcountry, accessing HALE via Highway 378 (NPS IRMA 2019).



Figure 16. Frontcountry shrubland near park entrance where nēnē nest. NPS photo.

1.2.2 Backcountry

The backcountry consists of areas accessible by extensive hiking east of frontcountry areas. The backcountry covers approximately 5,000 ha (12,355 acres) of Haleakalā Crater (Crater) and Kaupō Gap. Elevation ranges from 1,340 m (4,400 ft.) in Kaupō Gap to 2,740 m (9,000 ft.) elevation at the Crater. As with the Summit, the Crater is characterized by the same ecosystem gradients with the majority of the area being cinder deserts with sparse vegetation (Figure 17). The Crater has a network of trails used by visitors and park staff. Work in the backcountry often requires overnight stays in remote NPS cabins. The area is bordered by steep cliffs that is the primary nesting area for ‘ua‘u.



Figure 17. Inside Haleakalā Crater with a view of cliffs where ‘ua‘u nest. NPS photo.

1.3 Overview of Trapping Program 1970’s - 2016

The predator control program at HALE was initiated in the 1970’s to reduce the effect of predation on nēnē and ‘ua‘u by mongooses, cats and rats. Cage and foothold traps were used to capture predators in frontcountry and backcountry locations. Traps were active year-round to protect both ‘ua‘u and nēnē during their alternating nesting seasons, with temporary closures occurring when staff availability was limited.

Cage traps targeted all predator species and were in fixed locations along transects referred to as “traplines.” Approximately 350 cage traps in both frontcountry and backcountry locations (Figure 18) were checked and baited at least once a week. Cage traps have been in use at HALE since the late 1970s. In the frontcountry, cage traps were set along park borders, in clusters in a few discrete

locations, and in a line bordering the ‘ua‘u colony near the crater rim. Backcountry traps were placed in a few discrete locations, with the highest concentration of traps at Palikū, the primary nesting area for nēnē.

Foothold traps have been in use at HALE since 2007, though on a much smaller scale than cage traps. Foothold traps were placed strategically to capture cats. About ten footholds were in use at any given time. Traps were carefully set and removed in selected locations depending on predator activity levels, endangered and non-target wildlife levels and behavior, season, and visitor use levels. Foothold traps were occasionally set in existing ‘ua‘u burrows during the months when ‘ua‘u were completely absent from the area. Foothold traps were set in burrows where ‘ua‘u depredations occurred, or where cats had been documented. Care was taken to avoid disturbance to the burrow when setting traps in or near a burrow entrance. Foothold traps were also set in crevices that looked like a burrow entrance, but were not active burrows.

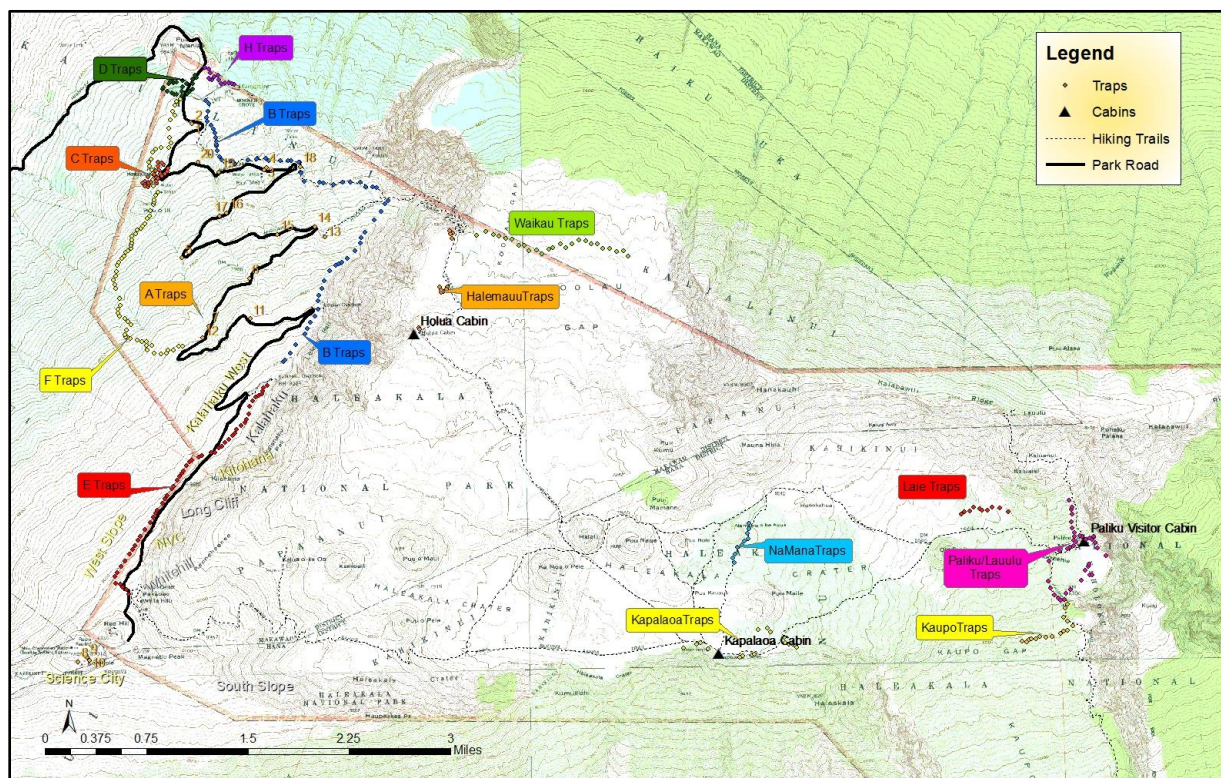


Figure 17. Location of cage traps and names of traplines (in colored text box).

The trapping program was labor-intensive with the high number of traps that needed constant monitoring. The estimated time to monitor and rebait all traps once was approximately 50 person hours, including backcountry hiking times. Much of the work was conducted by the equivalent of two people: one biological science technician and three interns that are staggered throughout the year in 4-month time periods. Additionally, predator capture rates were low, with predators caught 4% of the time (Kelsey et al. 2019). Although capture rates were low and monitoring of traps labor

intensive, this trapping program has proven successful in increasing the breeding success of ‘ua‘u (Natividad Hodges and Nagata 2001) and decreasing predation rate on nēnē (HALE unpubl. data.).

1.4 Trapping Program Transition

The trapping program at HALE has been successful in providing for the net benefit of endangered ‘ua‘u and nēnē, but is labor intensive. To improve the efficiency of the predator trapping program, the trapping strategy is evolving from an extensive, constantly armed presence to a more targeted, adaptive approach based on predator monitoring. The remaining chapters of this plan describe a Decision Making Process for Predator Control and implementation methods that began at HALE in 2017.

During this transition, HALE will continue to utilize and modify this plan. Some frontcountry traplines have been dismantled and traps placed according to guidelines in this plan. New traps, baits, lures and monitoring systems are being tested and modified. Modifications learned during this transition period are reflected in this plan.

Chapter 2 Decision Making Process for Predator Control

This chapter describes the 6-step Decision Making Process for Predator Control, with further details on Implementation Methods covered in Chapter 3. The steps are:

1. Survey for predator activity
2. Identify predator hot spots
3. Assess characteristics of the hot spot
4. Create and execute a local trapping plan
5. Monitor traps and predator activity
6. Evaluate

2.1 Step 1: Survey for predator activity

Survey for predator activity by conducting extensive on-the-ground surveys and by camera trap surveillance. This provides baseline data on predator species presence, prevalence, and predation on endangered birds in an area. On-the-ground surveys will be done for mongooses and cats. Rats are ubiquitous and are assumed present in any habitat, including endangered bird habitat. Therefore, targeted surveys for rats will not be done.

2.2 Step 2: Identify predator hot spots

A predator “hot spot” is an area with a high level of predator activity (relative to surrounding areas) that is naturally attractive to predators and that will continue to attract predators over time. Hot spot areas may contain natural landscape features, vegetation, or food resources that are attractive to predators. Predator activity level is determined in relation to surrounding areas. The size of a hot spot may vary by location.

Identify hot spots by analyzing predator survey data and historical trapping data. Survey data show areas where predator signs and sightings are abundant. Historical trapping data show areas where past predator catches were abundant. These data paired with an on-the-ground understanding of the location are used to determine hot spots. Once identified, hot spots are locations where intense trapping effort can produce maximum results.

2.3 Step 3: Assess characteristics of the hot spot

Assess the characteristics of each hot spot by gathering all information on predator activity, endangered species presence, human use of the area, and remoteness of the area. Information may come from field surveys, maps, and reports, and by communicating with staff familiar with the area.

2.3.1 Predator signs and activity

Determine the presence and type of predators present by using information from predator surveys (Step 1) and data from previous trapping. Some hot spots are attractive for a variety of reasons, with multiple species of predators attracted to the same area. However, there may be areas with higher

activity of one predator species. For example, an area may show a higher prevalence of mongooses than cats.

2.3.2 Endangered species activity

Conduct a thorough on-the-ground survey of the hot spot area to determine ‘ua‘u and nēnē activity. Observers should look for birds, nests, and bird signs indicating activity (fecal droppings, feathers, footprints etc.). Deploy camera traps if on-the-ground survey results are uncertain.

2.3.3 Visitor use

Determine visitor use levels or potential for use. Locate proximity to visitor trails, including unmarked or unmaintained trails, campgrounds, and cabins. Utilize existing GIS and other maps, and conduct on-the-ground surveys to document unmapped social trails used by visitors.

2.3.4 Remoteness

Determine the difficulty of accessing the area to set and monitor traps. Consider hiking and transportation time to the location from the frontcountry or backcountry cabins and the difficulty of the terrain, which may affect staff safety.

2.4 Step 4: Create and execute a local trapping plan

Traps may be set in clusters, grids, or along a line within a predator hot spot. The number and types of traps set depend on the target predator, endangered species activity, visitor use, and remoteness identified in Step 3, as well as staff availability. In general, the level of predator activity will determine the trapping effort in a hotspot, but trapping effort may be limited by endangered species activity, visitor use, and remoteness.

2.4.1 Predator signs and activity

Predator species and activity levels are the primary drivers that determine trap numbers and types in a trapping plan. The number and density of traps increases with predator activity levels in the area. The target predator species dictates the type of trap to deploy. Multiple species may be targeted by using a variety of traps in the same area.

2.4.2 Endangered species activity

Trapping must minimize unintentional capture of ‘ua‘u and nēnē. This may require constant monitoring and modifications to traps to prevent endangered bird capture in endangered bird habitat. Consult with biologists on staff to determine necessary modifications.

2.4.3 Visitor use

Public perception and visitor experience at HALE are very important. A visitor may perceive encountering a trap or trapped animal negatively. Traps are set in a way that minimizes the chances of incidental visitor encounters, and sometimes causing less than ideal trap placement.

2.4.4 Remoteness

Remoteness of an area can limit the number of traps set in a location. Short-term, intensive trapping may occur when staff is camping in remote locations. Lethal traps are recommended for use in areas where traps cannot be checked frequently. When set correctly, lethal traps ensure instant mortality of captured animals. As such, lethal traps must be set to avoid capture of non-target species.

2.4.5 Staff availability

Adjust numbers of traps, trap types and locations according to staff availability. When staffing is limited, concentrate on areas with the highest net benefit to endangered species.

2.5 Step 5: Monitor traps and predator activity

Once traps are set, monitor traps regularly and record data from each check. All traps, including lethal traps, require some level of monitoring to reset, rebait, and refresh the set, and should be checked as frequently as possible. Most bait will need to be refreshed every week regardless of trap type.

Regularly monitor for predator activity before, during, and after trapping in an area. Monitor for predator activity by conducting on-the-ground surveys for predator signs and by implementing camera trap surveillance.

2.6 Step 6: Evaluate

Evaluate the trapping plans using data on trap and predator activity monitoring. Conduct short-term evaluations of predator monitoring and trapping data yearly. Conduct long-term evaluation of predator monitoring and trapping data every five years. Regular evaluations allow managers to adapt the trapping program to best fit current situations. It also allows managers to learn from management actions and their impacts.

Chapter 3 Implementation Methods

This chapter focuses on predator control methods implemented at HALE beginning in December 2017 for protecting ‘ua‘u and nēnē populations (Appendix A Implementation Schedule). Methods in this chapter are specific to HALE and can be adjusted to suit other managed areas (Chapter 4). Implementation of trapping follows the Decision Making Process for Predator Control, utilizing the traps, staff, and funding available. This section presents specifics on predator surveys, trapping strategy, monitoring for predator activity, evaluating trapping, types of traps and baits, and priority trapping areas. Additional information on how to set and monitoring traps can be found in the standard operations procedures (SOPs) for HALE (Kaholoaa et al. 2019b), and Appendix B provides details on each targeted location at HALE.

Methods other than trapping (predator exclusion fencing, hunting, toxicants and GPS-collared sentinel cats) were considered but were deemed to be less practical, less effective, or financially infeasible (Jolley and Hanson 2016) and are dismissed from consideration at this time but may be considered in the future.

3.1 Predator surveying

Determine predator activity by conducting extensive on-the-ground surveys and by camera trap surveillance. Because of the large land area of the park, prioritize areas for predator surveys according to (1) identified ‘ua‘u and nēnē habitat, (2) predator home ranges and behaviors, and (3) areas that are reasonably accessible for trapping.

HALE has increasingly been using camera traps to monitor areas for predator activity (Kaholoaa et al. 2019a). Camera traps are especially helpful in areas with poor tracking substrate such as shrubby, vegetated areas and in remote areas where ground surveys are only occasionally possible. Another advantage is that camera traps are able to capture all predator activity, cat, rat and mongoose, at a location. At HALE, camera traps placed at ‘ua‘u burrows have provided good indicators of predator presence, as predators are naturally attracted to burrow entrances. Camera traps can also be placed on possible predator travelways or cat dens.

On-the-ground surveys are best done by trained personnel. Survey for predators by searching for predator signs such as fecal droppings, tracks, and depredated carcasses. Record each predator sign using GPS. GPS locations of predator signs show trends across the landscape and will help to identify hot spots and target trapping areas. After data collection, observers should destroy or remove predator signs in the field to avoid duplicate recording; for example, break up and bury cat fecal droppings.

The following outlines on-the-ground survey methods for each predator species, incorporating predator home range data.

3.1.1 Cats

Due to the large home range of cats (700 ha, 1,730 acres), a cat captured anywhere in the park will likely benefit ‘ua‘u and nēnē. Therefore, surveying for cat activity should focus on areas attractive to

cats, such as gulches, trails, and caves, without regard to distance to ‘ua‘u or nēnē habitat. Cats often walk across soft, sandy surfaces and can be detected by their tracks (Jolley and Hanson 2016). Fecal droppings are also readily visible. Feral cat fecal droppings are cylindrical with rounded sections, points on both ends and usually filled with animal fur.

Cats may utilize particular areas as travelways, toilets, and/or dens. Finding these areas of cat activity should be a priority. Cats prefer the “path of least resistance” including edges and high and low points. Cats also follow the natural flow of the landscape, and are drawn to prominent features such as large boulders or trees (Jolley and Hanson 2016). Cat dens are typically caves or crevices identified by prey carcasses, bones, and cat fecal droppings nearby. Search for areas with multiple cat fecal piles in close proximity to each other. These indicate cat “toilets” that cats visit repeatedly, and are good locations to trap.

3.1.2 Mongooses

Mongoose home ranges (30 ha, 74 acres) are smaller than cat home ranges. Surveying for mongooses should concentrate within ‘ua‘u and nēnē habitats. Survey for mongooses by searching for fecal droppings (Figure 19).

Mongoose fecal droppings are similar in size and shape to nēnē fecal droppings, but can be differentiated by the following (Jolley and Hanson 2016). Mongoose feces:

- Contain animal matter, such as fur, bones and feathers, while nēnē feces contain only plant matter.
- More consistently cylindrical shaped than nēnē feces.
- Have more flattened ends than nēnē feces.
- Are more durable than nēnē fecal droppings because of composition; will bleach grey with time and remain present through rain events, while nēnē fecal droppings break down.



Figure 18. Examples of mongoose fecal droppings at HALE.

3.1.3 Rats

Rats are ubiquitous and are found in every habitat. Therefore, on-the ground surveys for the presence of rats across landscapes are not necessary. Predator survey for rats can be done using camera traps or by utilizing the snap trap grid in place at Palikū. If further rat population monitoring is needed in the future, camera traps, snap traps, or tracking tunnels can be deployed to determine rodent activity levels. Since rats have small home ranges (3 ha, 7 acres), monitoring should focus within endangered bird habitat.

3.2 Trapping strategy

Trapping strategy focuses on trapping all three predators in or near ‘ua‘u or nēnē habitat and additionally targets cats outside of ‘ua‘u or nēnē habitat at cat hot spots. Concentrating trapping at predator hot spots ensures that trapping effort focuses in ideal locations. Local plans must be fluid and adaptive to account for changes in staffing levels, predator levels and seasons, and endangered species seasons. The manager adjusts trapping effort and staff availability to ensure the highest trap efficiency and benefit to ‘ua‘u and nēnē. For example, if staff is limited, focus efforts in ‘ua‘u habitat during the ‘ua‘u breeding season and in nēnē habitat during nēnē nesting season. Cats are targeted at hot spots throughout the year regardless of endangered bird habitat or season. Both long-term and short-term strategies for predator control are incorporated.

Long-term trapping focuses on using the Decision Making Process to identify and trap within target hot spot locations. Hot spots will continue to attract predators; therefore, trapping in those locations year-round could eliminate resident predators and any subsequent incoming predators.

Short-term intensive trapping provides a quick, targeted response to predator sightings or endangered bird depredations when needed. Short-term trapping can be conducted both in the front- and backcountry, and is designed to catch predators in that particular area before they travel to another area. Traps are set then removed once the predator is no longer in the area, typically after 1-2 months.

A backcountry trapping strategy that may be beneficial at HALE is to rotate intense trapping efforts between different backcountry locations to maximize trapping coverage. Intense trapping in backcountry hot spots should be conducted for at least one month, allowing cats to cycle through their home range (Jolley and Hanson 2016). This should “trap out” the cats that utilize the area before rotating to another area. The exact timeline for rotating locations is dependent on staffing, cat captures, predator monitoring data, and seasonality of endangered birds. For example, short-term trapping may target an area near an ‘ua‘u burrow cluster for two months during ‘ua‘u season, then rotate to nēnē habitat for the beginning of nēnē nesting season. This will allow some level of control in multiple areas with limited staff.

A combination of all lethal trap types may be used in locations where weekly monitoring is unfeasible. These lethal trap clusters would be best suited to remote areas where monitoring traps may be more difficult, or during times when there is limited staff to monitor traps regularly. These traps will still need some level of monitoring to bait and reset traps, and should be checked at least monthly.

Trapping strategy includes use of a combination of traps in areas. Chapter 3.4 provides details for traps types and associated target predators.

3.2.1 Trap placement

Individual site selection for trap placement within the predator hot spot is crucial to successful predator control, especially when targeting cats. Trappers with the most experience and knowledge determine specific trap placement (see Chapter 3.2.5). Once the traps are set in an ideal location, less experienced trappers can be trained to monitor and reset traps.

To determine ideal trap locations within a hot spot, look for landscape features (trails, gulches, prominent rock formations, etc.) that may be predator travelways, attractants, or cover from the elements. Trapping is more successful in vegetated areas (Kelsey et al. 2019). Ideal trap locations for cats are cat dens and cat toilets (see Chapter 3.1.1). Trap locations should also consider the direction of prevailing wind, which carries the scent of the bait or lure. Large open cinder landscapes, such as those in the crater, do not contain prominent landscape features nor provide cover for predators and are less ideal.

Trap placement for Goodnature™ A24 traps should focus on areas where rats feed and live, rather than travelways. Place traps in somewhat protected areas where the rat feels safe to stop and eat, not out in the open. Goodnature™ rodent detector chew cards may be used to determine ideal trap placement.

Trap placement may need to be adjusted to less ideal locations due to endangered species activity, endangered species season, and visitor activity. Areas with endangered bird activity requires further modifications to trap sets (see Chapter 3.2.3) to avoid accidental capture of these birds.

3.2.2 Trap numbers and spacing

The number of traps set depends on the level of predator activity, landscape layout, priority of the resource to be protected, and the ease in which traps can be checked (including staffing

considerations). For example, traps bordering an endangered bird nesting area in the frontcountry may have more traps than an area away from endangered bird habitat targeting only cats. Trap spacing will be determined mainly by the level of predator activity and the landscape. Traps may be set in a cluster, line, grid or singly (such as in a culvert targeting cats). Distances between individual traps may vary depending on ideal trap placement locations (see above). The attractiveness of the exact trap location is more important than a specified spacing interval. A single well-placed trap is more effective than multiple poorly placed traps.

Clustering a variety of traps at a hot spot location is recommended, especially when using Goodnature™ traps. Goodnature™ traps are self-setting and capable of multiple rodent kills. Cats and mongooses may be attracted to these sites to scavenge dead rodents. Thus, Goodnature™ traps may be used as an attractant when paired with mongoose and cat traps. Clusters of traps improve efficiency by allowing multiple traps to be serviced in one stop. This also allows for different baits and lures to be used in individual traps in the same area, which may increase the area appeal to a predator.

There are some areas where setting traps along a line is beneficial, such as along a fence or trail. Traps set in lines can also provide predator defense at borders of endangered bird nesting habitat, or be used to encircle a developed area that may be an attractant to predators.

Setting traps in grids can provide intensive trapping in a defined area, but is time consuming, can cause extensive habitat damage when traps are checked frequently, and in most cases at HALE, are not practical. Trapping grids can be implemented where maximum predator control is desired, such as a small, defined nesting area of endangered bird habitat. Goodnature™ traps are ideal for grids since they do not require frequent monitoring but can be initially costly.

3.2.3 Trapping in endangered species habitat

US Fish & Wildlife Service Native and Endangered Species Recovery permit (TE014497-16) issued to HALE allows for incidental “take” (injury or death) of two nēnē and one ‘ua‘u per calendar year while conducting activities relating to enhancing the survival of listed species, including trapping. Exceeding these numbers will cause immediate suspension of the activity that caused the incidental take. If trapping causes injury or mortality of nēnē or ‘ua‘u at any level, traps in that vicinity are immediately closed, and methods re-assessed.

Trapping in endangered bird habitat requires constant monitoring and, when warranted, implementing modifications to traps (Chapter 3.4) to prevent non-target capture. Close proximity to ‘ua‘u burrows, for example within 10 m, and the presence of nēnē goslings are two factors that would necessitate trap modifications to prevent accidental capture of endangered birds and their young.

All traps can be modified to prevent endangered species capture (See Chapter 3.4 Table 1). Modifications restrict entry into traps, significantly lowering the ability of a trap to catch a predator (Jolley and Hanson 2016). One example is the use of a goose guard on cage traps in areas where goslings are present. The goose guard is made of hardware cloth cut to block the lower half of the entrance to the trap (Figure 20). The blocked entrance prevents goslings from entering the trap, but it

deters predators from entering the trap as well. However, predators still are caught in traps with goose guards (HALE unpublished data).



Figure 19. Cage trap outfitted with a “goose guard.”

A trap monitoring system (TMS, see Chapter 3.2.6 Figure 21) allows for traps to be set less conservatively when traps can be monitored daily. For example, while using TMS on cage traps in nēnē nesting habitat during nesting season, goose guards were removed from a few select traps when the trap could be monitored physically or by TMS daily, then closed when staff were not able to monitor them on the weekend.

New innovations in trapping strategies that increase predator catch while preventing endangered bird catch may be developed and tested to improve the program in the future. Camera trap surveillance is useful to record wildlife-trap interactions of both predators and endangered species when testing a new trap or trapping method. Set and bait a trap without arming it and set a camera trap to record wildlife-trap interactions. Testing should be done for a sufficient amount of time to determine efficacy in catching predators while not harming endangered birds. Review camera trap data and determine if an endangered bird may be harmed by an armed trap. If camera data indicate that endangered birds will likely not be harmed, arm the trap and continue to monitor with the camera trap initially. Camera trap data can also determine predator interactions with the trap, and if modifications to the trap or set are needed.

Negative impacts of human disturbance, including disturbance by field biologists on nesting birds is well documented (Safina and Burger 1983, Burger 1981, Manuwal 1978). Responsible management for species benefits must consider the effects of the management action, including field workers on the environment and effects of controlling predators on other non-native invasive species. Habitat damage by field workers can be minimized by incorporating the seven principles of Leave No Trace (Leave No Trace Center for Outdoor Ethics ©2012), especially travelling and camping on durable surfaces.

3.2.4 Trapping in high visitor use areas

Setting traps to minimize the chance of incidental visitor encounters sometimes causes less-than-ideal trap placement. Set traps hidden from direct view from visitor use areas such as campgrounds, trails, cabins, visitor centers, and overlooks. Site selection, trap placement, placement of visual or auditory attractants and marking flags must minimize the chance of a visitor discovering a trap or a trapped animal.

Although hiking trails are excellent areas to trap, especially for cats, traps may be discovered by visitors if set directly on a trail. Set traps off the trail and hidden from view. Lures may be used to attract predators to traps off the trail, being careful not to attract visitors to the trapping site. Limit or closely monitor footholds and body grip traps, even if they are out of view. Trapping on backcountry trails, especially unofficial trails, may be considered if the plans include setting traps during times of little to no visitor hiking (such as late afternoon to early morning). Explanatory, interpretive signs may help in visitor use areas to educate visitors or to ask them to keep out due to sensitive restoration work occurring in the area (Jolley and Hanson 2016).

All staff working in the predator control program should be trained in speaking with visitors when questioned about their activities, with focus on the protection of vulnerable endangered species. Any conversation that becomes uncomfortable or contentious should be referred to a supervisor.

3.2.5 Staffing Considerations

HALE Endangered Wildlife Management (EWM) staff currently consists of biologists, technicians and interns. Biologists are permanent, year-round employees, with advanced science degrees and decades of experience. Technicians are temporary, year-round employees with undergraduate degrees and are hired for one to four years. Technicians may have some predator control experience when hired, and receive both on-the-job and formal training (through workshops and Fur Takers of America Trapper's College). Interns are short-term (8 to 16 weeks), students, and have little to no trapping experience.

Biologists maintain knowledge and experience on the biology of predators and endangered birds, predator control and trapping, visitor use and overall park management. Biologists guide the overall predator control strategy of the program using the Decision Making Guide. This includes creating and implementing trapping plans, determining hot spots and trap placement within those hot spots, and directing the testing of new traps or methods. Throughout the trapping implementation, biologists prioritize trapping strategy, trap numbers, and target areas according to priorities and resources available. These individuals must have experience and knowledge in predator trapping techniques, trap placement, predator behavior, endangered species behavior, landscape features, and visitor use.

Technicians accumulate knowledge during their appointment, but they may not be able to stay beyond their term of employment. The program loses that accumulated knowledge once the employee leaves. Technicians assist in implementing trapping plans, monitor traps, conduct landscape level predator sign monitoring, and train and direct interns in monitoring traps, camera traps, and conducting predator surveys.

The EWM program typically has 3-4 interns per year who are on staff for about 4 months each. Interns are primarily field workers that are trained to monitor traps. Interns can assist with on-the-ground survey for predator signs, but this skill typically takes months to develop.

3.2.6 Trap monitoring systems

Trap monitoring systems (TMS) are electronic devices that relay the status of the trap from a remote location. Devices could be either a small transmitter attached to a trap that transmits an electronic signal that relays information on whether a trap is open or triggered, or a remote camera monitoring system that relays a picture of the trap. Information can typically be received on a computer, cell phone, or by radio signal receiver depending on the unit. A number of products that utilize a variety of methods exist and at a range of prices.

TMS increases the efficiency of a trap because it allows immediate response to triggered traps. If staff are available, traps can be reset that same day. This allows for faster turnaround in baiting and resetting triggered traps, increasing the trap nights that the trap is available.

Live traps can be set less conservatively near endangered bird habitat with daily TMS monitoring. For example, cage traps with TMS may be set in nēnē habitat without any modifications that would restrict entry into the trap, as long as staff are available to monitor and physically check the trap on the same day.

TMS would be most effective when staff are readily available and able to check traps that have been triggered within a day or two. Therefore, TMS would have the greatest applicability in frontcountry locations, where traps can be reached and checked within a day. TMS applicability for backcountry traps is limited by the difficulty in getting to triggered traps. Traps could be monitored while staff are camped in the backcountry near the traps, or when traps are accessible from the frontcountry and can be checked that same day.

There are challenges in fully implementing a TMS at HALE. The system must be able to transmit a reliable signal. In many situations at HALE, terrain obstructs electronic signals to VHF receivers, cell phone towers or satellites. Terrain also affects selecting and installing a location for a system that requires a hub relay.

Even with TMS, traps must still be physically monitored weekly to rebait traps, same as the current rate of physical checks, until more durable baits can be found or bait theft reduced. Most TMS do not indicate bait status. Full implementation of TMS must account for the staff time required to conduct daily remote checks, respond to triggered traps, and conduct regular physical checks to rebait traps.

Costs for a complete system can be challenging if not prohibitive. In 2016, the cost of equipment and service for one year of a Celium system was just over \$10,000 (Jolley and Hanson 2016) and did not include labor to install a hub and retrofit of traps. Costs for camera traps that allow for access by cell phone or internet currently start at approximately \$250 per camera and may include monthly costs for cell or internet service. Because of costs, Jolley and Hanson (2016) recommended investing in trials of different trap types over trials of TMS.

Since initial costs to implement full TMS is high, HALE currently uses less expensive methods such as VHF telemetry systems (Figure 21) and camera traps with capabilities to access images via cell phone or internet on a small-scale. Jolley and Hanson (2016) suggests researching and trialing more extensive TMS (eg. Celium Platform by Encounter Solutions, NZ) as a medium term goal for HALE. While promising, TMS may be suitable for a long-term goal, with the intermediate goal of pilot testing smaller, more affordable systems.



Figure 20. Cage trap with VHF telemetry Trap Monitoring System (TMS).

At HALE, any TMS that transmits via radio frequency needs to go through a frequency allocation procedure through the NPS Radio Program Management Division prior to purchase.

3.3 Monitoring for predator activity

Monitoring for predator activity within the trapping area is achieved by on-the-ground surveys for predator signs and by implementing camera trap surveillance. Monitoring provides an overall indication of predator activity, which can be used to determine the efficacy of the trapping in the area. Both methods can be done concurrently with monitoring traps.

Conducting on-the-ground surveys for cat and mongoose signs should occur at least twice a year in trapping areas. Follow the same procedures described for predator surveying to find and GPS predator signs (see Chapter 3.1). HALE has historically relied on on-the-ground surveys for predator activity, but has been increasingly incorporating camera traps for monitoring since 2014. On-the-ground predator monitoring is subject to the ability of the observer to accurately locate predator signs.

Camera traps are effective at tracking multiple species of predators over long periods of time. Initial testing at ‘ua‘u burrows detected all three predators (rats, mongooses, and cats) at burrow entrances while simultaneously collecting data on the ‘ua‘u activity. Camera traps can be deployed along trails or gulches to identify key predator travel routes, or along boundaries to determine if external

properties are serving as a source for invasive predators (Jolley and Hanson 2016). Disadvantages of camera traps include the relatively high cost of cameras, chances of mechanical failure, and staff time to view and sort through images. As more camera trap monitoring is incorporated into the project, more staff time must be allotted for reviewing images.

Other methods that are not currently used but may be deployed in the future are tracking tunnels and snap traps grids, both of which would target rats and mongooses. Tracking tunnels are used extensively in New Zealand for rodent and mustelid detections (Gillies and Williams, 2013). However, a single rat may track multiple tracks in a single tunnel or track through multiple tracking tunnels, which could indicate an increased relative abundance (Blackwell et. al., 2002). A snap trap grid provides the added function of rodent removal, but once triggered, a snap trap is out of service so may give an incomplete measure of abundance.

3.4 Trap Types

Trapping methods include the use of non-lethal and lethal traps (Kaholoaa et al. 2019b). With the exception of cage traps, each trap type targets specific predators. All traps can be placed in endangered species habitat with modifications or restrictions to minimize capturing endangered species (Table 1). Using a combination of traps in an area increases the likelihood of capturing multiple individuals and species. While many traps types exist, the types of traps used at HALE have proven to be efficient for the target predators and minimizes capture of endangered species (Goodale et al. 2014).

Table 1. Trap types by predator species and modifications or restrictions to minimize endangered species capture.

Species	Trap type	Modifications or restrictions
Rats	Snap traps	Place in box
	GoodnatureTM A24	None
	Cage traps (7" x 7")	Block entrance
Mongooses	Cage traps (7" x 7" or 10" x 10")	Block entrance
	DOC250	Place in box
Cats	Foothold traps	Restrictive trap placement (such as in crevices or cubbies with no nearby endangered bird sign)
	Body grip traps	Place in box
	Cage traps (10" x 10" or 10" x 12")	Block entrance

3.4.1 Non-Lethal Traps

Two types of non-lethal traps are effective for predator control at HALE: foothold traps and cage traps. Footholds target feral cats, while cage traps target all predator species.

3.4.1.1 Foothold Traps

Target predators: Feral cats

Advantages:

- Most effective for catching cats, especially trap-shy individuals
- Relatively easy to transport
- Trap set design is fluid and can be adapted to the location, cat behavior, and endangered bird activity

Disadvantages:

- Requires high level of regular monitoring
- Higher skill level and training needed set/reset trap

The foothold trap (Figure 22) has been the most effective trap for targeting cats at HALE (Goodale et al. 2014). The most feral of cats will not enter a cage or box type trap, whereas the foothold trap is buried in the ground and is not obviously visible. It blends into the landscape and can therefore take advantage of a cat's natural behavior.



Figure 21. Foothold trap, partially buried, shown in a walk through set.

Foothold traps are best set by the most experienced trappers with knowledge of both predator behavior and endangered bird behavior. Foothold traps can be set and removed in select locations depending on predator activity levels, endangered species activity levels, time of year, and human use level. Trapper experience is crucial when setting in areas where endangered birds are present, where a more restrictive trap set location such as a cubby or cave is the primary modification to

prevent endangered bird capture. Once set, less experienced trappers are able to monitor and reset traps.

Trapping strategy for foothold traps focuses on trapping long-term in hot spot locations where regular monitoring is relatively easy, and for short-term durations in specific target areas where recent cat activity has been documented and a quick targeted response is warranted.

Short-term intense trapping can also be done in remote backcountry locations when traps are set at the beginning of the trip then closed or removed before leaving the backcountry. Depending on accessibility, spike camping in a target remote area may be an option. For backcountry hot spots, intense cat trapping effort in an area for several weeks to several months, then rotating to another area for trapping is recommended (Jolley and Hanson 2016).

Foothold traps may be clustered with other traps, but in general it is a good stand-alone trap.

3.4.1.2 Cage Traps

Target predators: Cats, Mongooses, Rats

- Advantages:
- Captures multiple species
- Endangered birds accidentally captured have a higher chance of survival
- Requires less skill to set/recheck

Disadvantages:

- Requires high level of regular monitoring
- Not effective for trap-shy animals
- Bulky to transport
- Modification for preventing endangered bird capture decreases efficacy

Predator control at HALE has historically relied on cage traps (Figure 23). Cage traps are easy to set, and are ideal to use when field staff have little to no trapping experience. Cage traps have the ability to capture all three predators: rats, mongooses, and cats. Although cage traps are less efficient at catching feral cats when compared to other methods, cats are still captured in cage traps at HALE. They can be used in endangered bird habitat with modifications. Frequent monitoring is necessary to release any endangered birds or to dispatch any predators captured in these live traps. Cage traps can be clustered or set along a line in predator hot spots. Traps with a 7" x 7" entrance are better suited for capturing rats and mongooses, while traps with a 10" x 10" or 10" x 12" opening are better suited for capturing cats, although both sizes of traps have caught all three predators at HALE. The trap efficacy for each target species will depend on trap size, for example, a larger size trap is more effective at catching a cat than the smaller size, so the trap size used should reflect which predator(s) are being targeted.



Figure 22. Cage trap.

3.4.2 Lethal Traps

3.4.2.1 Goodnature™ A24 Traps

Target: Rats

Advantages:

- Self-resetting multiple kill trap
- Can be self-baiting with automatic lure pump
- Very minimal monitoring required with automatic lure pump
- Low skill level to check/reset
- Relatively easy to transport
- No handling of carcasses- less chance of zoonotic exposure to trapper

Disadvantages:

- At risk for mechanical failure
- May create a “feeding station” for other predators such as cats, mongooses, and native short-eared owls (*Asio flammeus sandwichensis*, Pueo)
- May cause unsanitary conditions in areas with high rat densities and captures

The Goodnature™ trap (Figure 24) is the only self-resetting trap available for predator control in Hawai‘i as of 2019. Each trap triggers up to 24 times on one CO₂ cartridge. This is much more efficient than snap traps, which need to be reset after one trigger. When outfitted with an automatic lure pump, the Goodnature™ trap is also self-baiting. Unlike other traps, the Goodnature™ traps do not require the trapper to handle any carcasses to reset the trap, reducing the risk of zoonotic exposure to the trapper.



Figure 23. Goodnature™ A24 trap.

Trapping strategy at HALE incorporates Goodnature™ traps in endangered bird habitat to control rodents, especially in remote locations. Goodnature™ traps have been set without harm to ‘ua‘u or nēnē. Goodnature™ traps can also be set with other types of traps in a cluster in any habitat, providing rodent control to prevent bait theft from the other traps. Because the Goodnature™ trap is a self-setting repeat kill trap, carcasses of rats can accumulate below the trap, which attract larger scavenging predators such as cats, mongooses and owls, including pueo. It could possibly be used as an attractant for cats and mongooses in trap clusters.

The Goodnature™ with automatic lure pump has been tested at HALE with mixed success. The automatic lure pump ran out of bait in about 3 months in many cases, perhaps due to the high elevation. Goodnature™ traps continue to be tested and incorporated at HALE.

Goodnature™ traps can be clustered with other lethal traps (DOC 250's, body grips) to target multiple species without the need for frequent monitoring. These lethal trap clusters would be best suited to remote areas where monitoring traps may be more difficult, or during times when there is limited staff to monitor traps regularly.

3.4.2.2 DOC 250 Traps

Target: Mongooses, Rats

Advantages:

- Effective for mongooses
- May also catch rats
- Kill trap does not require constant monitoring
- Can be set in remote locations
- Requires less skill to set/recheck

Disadvantages:

- Must be placed in box- heavy and bulky, hard to transport
- May cause bodily harm to trapper
- Medium level of monitoring needed for baiting/resetting

The DOC 250 is a lethal trap effective for removing mongooses (Peters et al. 2011). During testing at HALE rats were also extensively caught. Traps are housed in boxes with two layers of hardware cloth with mongoose sized off-set holes which excludes non-target species (Figure 25). Peters et al. (2011) found that mongooses were more willing to enter a DOC 250 trap through two baffles than to enter a cage trap.



Figure 24. DOC 250 trap (top view) in box.

The DOC 250 in the box is designed to exclude birds and can be used to target mongooses in endangered species habitat, especially in nēnē nesting habitat at Palikū. Ideally, traps should be monitored every week to clear carcasses and ensure bait freshness. Since timely dispatching of live animals is not a concern, time between checks could be long. If traps are to be left out longer than a week, more durable baits should be used.

The DOC 250 can be paired with other lethal traps (body grip traps, Goodnature™ traps) to target multiple species without the need for frequent monitoring. These lethal trap clusters would be best suited to remote areas where monitoring traps may be more difficult, or during times when there is limited staff to monitor traps regularly. DOC 250's can also be considered in areas where trapping serves as a perimeter to the park, such as the frontcountry (Jolley and Hanson 2016).

During testing, when DOC 250 traps were paired with Goodnature™ traps, rats were still often caught in the DOC 250 instead of the Goodnature™ trap.

3.4.2.3 Body grip trap (Belisle™ #220 Super X trap)

Target: Cats

Advantages:

- Kill trap does not require constant monitoring

Disadvantages:

- When placed in box, heavy and bulky, hard to transport, may deter cats
- May cause bodily harm to trapper
- Medium level of monitoring needed for baiting/resetting



Figure 25. Body grip trap in box.

Trapping strategy is to use body grip traps to target cats, especially in remote areas where regular monitoring of traps is difficult. Determining where to set body grip traps is best done by the most experienced trappers with knowledge of both predator behavior and endangered bird behavior. Body grip traps have been used sparingly at HALE and strategies are still under development.

There are three ways that body grip traps can be set: (1) in a box structure, (2) on a ramp leading up from the ground, or (3) in the open. The set that is most protective for endangered species is the chimney box: an “L” shaped (1 trap) or upside-down “T” shaped (2 trap) box with the entry point on top. During initial testing, camera trap data showed a cat investigating the chimney box but not entering the chimney. Chimney boxes are bulky and difficult to transport. Body grip traps may be set in a less restrictive rectangular box with an open side entry point in areas where there is low or no endangered bird activity.

Any trap set in a box requires a cat be willing to alter its natural behavior to enter and investigate what is in the box; therefore, trap-shy cats may not get caught. As an alternative, traps may be set near the top of a ramp leading up from the ground, which may deter non-target capture and is in a more open environment that may be more attractive to cats (Jolley and Hanson 2016).

A strategy being tested by HALE is to set the body grip trap within the entrance to ‘ua‘u burrows during the winter when the ‘ua‘u are not present, since cats explore the entrances to burrows. The selected burrow will be one that telescopes inward to the nest chamber, funneling the cat into a

narrowing tunnel. This set provides a natural barrier around the trap to prevent non-target interference yet allowing the cat to behave naturally.

The Hono a Pali Mitigation Project on Kaua‘i had success using body grips in “blind sets,” which is a walkthrough set that funnels the predator to walk through the trap (Pias et al. 2017). However, there is a higher risk of non-target bycatch using this method, so this method must be tested at HALE before incorporating it into a trapping plan.

Body grip traps can be paired with other lethal traps (DOC 250’s, Goodnature™ traps) to target multiple species without the need for frequent monitoring. These lethal trap clusters would be best suited to remote areas where monitoring traps may be more difficult, or during times when there is limited staff to monitor traps regularly.

3.4.2.5 Snap Traps

Target: Rats

Advantages:

- Kill trap does not require constant monitoring
- Safe to use in endangered bird habitat when set in boxes
- Low skill level to check/reset
- Low trap costs

Disadvantages:

- Single kill trap requires medium level of monitoring for baiting/resetting (much more than Goodnature™ traps)

Snap traps are effective at removing rats if monitored regularly. When placed in a box, snap traps are safe to use in endangered bird habitat (Figure 27). Currently, snap traps are used in Protecta™ bait boxes in a 50m grid at Palikū to control rats in nēnē nesting habitat during nesting season (October – April).



Figure 26. Snap trap in box.

Although over \$100 dollars cheaper per trap than Goodnature™ traps, snap traps are single kill and require a much higher level of monitoring to be effective. Ideally, snap traps should be checked weekly to remove carcasses and insure bait freshness, though constant monitoring is not necessary since it is a lethal trap. Weekly checks can cause considerable habitat damage by observers walking through the grid. Care must be taken to minimize habitat damage.

3.5 Baits and Lures

Baits and lures are used to attract predators into traps, and can be critical especially when traps are set outside of ideal locations. In general, baits attract predators based on hunger, whereas lures entice predators to a trap. Lures may appeal to a predator's curiosity, territorial or sexual impulses, and can attract predator based on olfactory, visual, or auditory senses. In field application, baits and lures are used for the same purpose: to attract predators into traps. There are several possible baits (Table 2) and lures (Table 3) for use at HALE and with many applications.

Bait and lure attractiveness may vary by species and individuals over time, for example by season or age of the predator. Rotating baits and lures in an area is helpful in attracting predators that may be attracted to one bait or lure and not another. When multiple traps are set in a cluster, use a variety of baits and lures to maximize the attractiveness of the cluster to individual predators passing nearby. For example, visual lures above the cluster may be paired with cat and dog food in a cage trap and bobcat urine and a commercial lure at a foothold set. Likewise, a large cage trap targeting cats may be set with a feather hanging toward the back of the trap as a visual lure, cat and dog food bait in the trap to appeal to a cat's hunger, and bobcat urine around the trap to appeal to a cat's territorial nature.

There are two major considerations that will decrease bait or lure efficacy: freshness and bait loss. Freshness of the bait or lure is important to maintain attractiveness. All baits and lures degrade and become ineffective over time, some faster than others. Monitor traps regularly to maintain the freshness of the bait or lure. If a trap (for example, a lethal trap) is to be left out without monitoring for an extended time, the most durable baits or lures should be used.

Bait loss has been a significant problem for trapping at HALE. During regular monitoring of cage traps from 2000 - 2014, 62% of traps were found without bait during subsequent checks (Kelsey et al. 2019). When bait loss occurs, the trap is less effective in attracting and catching predators. At HALE, bait loss is likely due to bait theft by mice or juvenile rats too light to trigger traps. Strategies to prevent bait loss could include covering the bait can with hardware cloth, hanging baits from a small plastic bag with a hole cut in the bottom, wrapping baits in cheesecloth, or suspending the bait from the top of the trap.

Table 2. Baits, advantages and disadvantages, trap types suitable for each bait and summary of application.

Bait	Advantages	Disadvantages	Trap	Summary
Canned Cat/Dog Food	•Attractive when fresh •Medium freshness longevity •Attractive to all predators	•Rots and molds when wet •Bait theft by rodents, insects	Cage, DOC 250, Body grip, Snap Trap	Excellent bait when rebaited regularly to maintain freshness.
Dry Dog Food and Used Cooking Oil	•Inexpensive •Effective when fresh •Medium freshness longevity •Easy to use	•Degrades in water • Bait theft by rodents	Cage, DOC 250, Body grip	Inexpensive and effective; use in rotation or combination with more enticing baits and lures.
Dog Treats (strips/jerky)	•Visually attractive •High visual longevity •Not easily stolen •Easy to use	•May lose attractive smell quickly	Cage, DOC 250, Body grip	Is not easily stolen and is a good visual lure, but loses its olfactory attractiveness quickly.
Squid	•Long lasting •Visually attractive •Not easily stolen • Attractive smell that persists •Effective when wet	•Requires extra preparation •Smell diminishes when desiccated (smell returns when rehydrated)	Cage, DOC 250, Body grip, Foothold	One of the most durable baits that attracts all predators, but especially mongooses and cats.
Canned Sardines	•Attractive smell •Medium freshness longevity	•Prone to rotting	Cage, DOC 250, Body grip, Foothold	Effective bait especially for mongooses and cats. Increase freshness longevity by hanging in a small bag with a hole cut in the bottom corner.
Commercial Bait	•Long lasting •Not stolen by mice •Attractive smell •Effective when wet	•Expensive •Smell diminishes when desiccated (smell returns when rehydrated)	Cage, DOC 250, Body grip, Foothold	Durable but very expensive. Can be used in all types of traps targeting cats and mongooses. May not be attractive to rats.

Table 3 (continued). Baits, advantages and disadvantages, trap types suitable for each bait and summary of application.

Bait	Advantages	Disadvantages	Trap	Summary
Egg (actual or imitation)	• Long lasting • Not stolen by mice • Effective even when wet	• Fragile	Cage, DOC 250, Body grip, Foothold	Good for targeting mongooses.
Dried meats	• Long lasting • Visually attractive • Attractive smell • Effective when wet	• Time consuming to prepare • Expensive if purchased	Cage, DOC 250, Body grip, Foothold	Good for targeting cats.
Peanut Butter	• Easy to use • Inexpensive	• Used only for rats • Sometimes eaten by slugs	Goodnature™ A24, Snap Trap	Inexpensive and effective.
Goodnature™ Chocolate Formula	• Easy to use • High longevity	• Used only for rats	Goodnature™ A24, Snap Trap	Can be purchased for refilling Goodnature™ A24 lure bottle or preloaded in Automatic Lure Pump.

Table 3. Visual, auditory, and olfactory lures used to attract predators within HALE.

Lure	Advantage	Disadvantage	Traps used in	Applications
Feathers (visual)	• Inexpensive • Easy to set • Very effective for cats • Can be harvested from introduced birds	• Medium longevity, needs replacement after several bouts of inclement weather	Cage, Foothold, Body grip	Hang from live traps or areas near kill traps to visually attract cats. Can use wings harvested from introduced birds and desiccated.
Shiny objects (visual)	• Any shiny object such as Christmas ornaments, old CD's, etc. may be used • Inexpensive • High longevity	• May attract people (unusual, looks like trash) • Must be removed after use	Cage, Foothold, Body grip	Shiny objects piques a cat's interest. Hang to visually attract cats into an area. Not for use near human use areas.
Predator caller (auditory)	• High longevity • Effective for trap wary cats	• Cycles through batteries quickly • Needs to be out of earshot of human use areas	Cage, Foothold, Body grip	Versatile and effective in most trap types. Effective in caves in conjunction with footholds.
Pongo (olfactory)	• High longevity • Attractive from long distances • Highly effective for cats	• Difficult to get fresh cat urine and feces.	Cage, Foothold, Body grip	Mixture of cat urine and feces. Versatile and effective. Use in any cat traps.

Table 3 (continued). Visual, auditory, and olfactory lures used to attract predators within HALE.

Lure	Advantage	Disadvantage	Traps used in	Applications
Commercial lures (olfactory)	•High longevity •Highly effective for cats •Professionally designed to elicit certain responses, such as territory, curiosity, or sex	•Must be stored and transported carefully- strong smell	Cage, Foothold, Body grip, DOC 250	Effective especially at targeting cats. Many varieties on the market, in general, select bobcat lures.
Bobcat urine (olfactory)	•Highly effective for cats •Piques cats territorial instinct •Very little needed per set	•Can be difficult to handle and keep fresh	Cage, Foothold, Body grip	Use in conjunction with other baits and lures. Use in any cat traps.

3.6 Toxicants

Currently there are no toxicants or pesticides labeled for conservation use in Hawai‘i, and none are currently being used for predator control at HALE. Diphacinone rodenticide was used at HALE from 1995–2013 to supplement trapping efforts to control rodents and mongooses in endangered bird habitat, primarily nēnē nesting habitat at Palikū. Diphacinone became a restricted use pesticide under a Special Local Need label in 2004 when used for conservation purposes.

In December 2013, the new Special Local Need (SLN) label for Ramik® Mini-Bars became more prohibitive and rodenticide baiting at HALE was suspended. The label required an expansive treatment area and rigorous treatment schedule which made diphacinone application prohibitive, especially in the backcountry. The SLN label expired on December 16, 2018, and has not been renewed as of this writing, though it is expected to be renewed. Toxicants, including rodenticides, may be considered in the future if labeled appropriately and approved by the HALE Integrated Pest Management Coordinator. However, consideration should be given to the amount of toxicants that would need to be applied over time to maintain predator control, and if the same level of predator control can be achieved by other means such as expanded Goodnature™ trap use.

3.7 Priority trapping areas

This section provides general descriptions of initial priority trapping areas at HALE and considerations for implementing trapping in each area. These are priority areas because the areas (1) encompass or contain predator hot spots, (2) are important nesting areas for ‘ua‘u and nēnē, and (3) are accessible by hiking, ground transportation or both. Although these are initial priority trapping areas, surveying for predator activity (Step 1) and follow-up evaluation (Step 6) may show the need to adjust these target areas. Specific trapping locations therefore may fluctuate throughout the year, depending on the priority, and does not preclude trapping in areas not described in this section.

Trapping locations are divided into frontcountry and backcountry locations. Appendix B provides details on each targeted location, including a general description of the area, accessibility to trapping locations, ‘ua‘u and nēnē activity, target predators, and trapping strategies.

3.7.1 Frontcountry

Priority areas for frontcountry trapping are (1) slopes along the crater rim where ‘ua‘u nest, and (2) shrubland areas where nēnē nest. Nesting seasons of ‘ua‘u and nēnē alternate with slight overlap (Figure 5).

Based on nesting seasons, predator control focuses on trapping for rats and mongooses along the crater rim during ‘ua‘u nesting season (approximately February to November), and in shrubland areas during the nēnē nesting season (approximately October through April). Cat control occurs in all frontcountry areas year-round, and focuses on cat hot spots. Specific descriptions of each area are located in Appendix B.

3.7.2 Backcountry

The priorities for backcountry predator control are to protect the highest concentration of nēnē nesting activity in the park at Palikū and to protect ‘ua‘u that are nesting within and on the slopes of Haleakalā. All backcountry locations are remote, requiring hours to hike to the nearest trapping locations. The backcountry is also accessible by horseback on trails or by helicopter. The backcountry is not accessible by ground transportation vehicles.

Work cabins are available for overnight stays at Palikū and Hōlua. Palikū Patrol Cabin is the primary work cabin. It is well equipped for repeated stays of 3 – 5 days, and is the regularly used by EWM and park staff. The Hōlua work cabin is a small shelter with minimal equipment for repeated stays and is only occasionally used by EWM staff. Visitor cabins at Hōlua and Kapalaoa are sporadically available and require at least six months advance notice to reserve. Because the crater is vast as well as remote, predator control will largely be tailored according to accessibility from work cabins, and it is especially critical to identify predator hot spots in which to concentrate efforts. Specific descriptions of each area are located in Appendix B.

3.8 Evaluating trapping

Adaptive management is a systematic approach for improving resource management by learning from management outcomes (Williams et al. 2009). Controlling predators for the benefit of endangered species is a continuously on-going project at HALE. Trapping plans must be evaluated and modified to fit current situations.

Predator control activities could have unintended effects on the dynamics of non-native as well as native species. Focusing control on one predator species in an area could cause shifts in prey base for other predator species (Casula et al. 2006). For example, feral cats often prey on rats as indicated by the presence of rat fur in the majority of cat feces examined. Focusing control of only rats in one area could shift predation pressure by cats to endangered birds.

Use trap and predator monitoring data to evaluate the efficacy of current trapping plans and update methods and plans. Look for trends in predator captures, levels of predator activity, and predation on

endangered birds. Continuously research and incorporate any new trap methods or technologies. Explore and test alternative methods to meet predator control objectives. Use these results to modify plans to increase efficiency and efficacy.

3.8.1 Short-term evaluations

Conduct short-term evaluations of predator control activities yearly. Due to the relatively low predator densities at HALE, evaluations at intervals shorter than a year may not include annual cycles and may be misleading. Determine if adjustments to the trapping strategy, trapping locations, or trap numbers are necessary.

3.8.2 Long-term evaluations

Conduct an evaluation of predator surveying and trapping data every 5 years. Determine if changes to the plan are necessary. Some examples of changes warranted by long-term evaluation include:

- Increasing the number of traps in areas with high predator catches or high levels of predator activity;
- Reducing the number of or removing traps in areas with low predator catches, or no signs of activity;
- Trapping in areas where new hot spots are discovered;
- Increasing trapping effort in an area if endangered bird depredations begin or continue, or if predator activity is not decreasing;
- Adjusting the trapping plan to consider the actual staff time required to monitor traps, especially if actual monitoring time takes longer than originally estimated (i.e. traps are not being monitored as frequently as necessary due to time and staff constraints).
- Incorporating new methods or trap types.

Chapter 4 Other Applications

4.1 Application in other areas of HALE

The Decision Making Process can be used to develop local trapping plans for other endangered species, including forest birds. Logistics differ for other areas in the park, especially for remote areas such as Kīpahulu Valley, Ka‘āpahu and the upper elevations of Nu‘u. Differences in predator densities and weather are some factors that need consideration when developing a local trapping plan in these areas.

4.1.1 Rainforest areas

The montane wet forest (rainforest) areas of Kīpahulu Valley, Ka‘āpahu, Manawainui, and Upper Hana Rainforest provides habitat for the endangered ‘ākohekohe (crested honeycreeper, *Palmeria dolei*) and kīkēkoa (Maui parrotbill, *Pseudonestor xanthophrys*) and the threatened ‘i‘iwi (*Drepanis coccinea*) and ‘a‘o (Newell’s shearwater, *Puffinus auricularis newelli*). Endemic ‘apapane (*Himatione sanguinea*), Maui ‘amakihi (*Chlorodrepanis virens wilsoni*), and Maui ‘alauahio (Maui creeper, *Paroreomyza montana newtoni*) are also present. Maui nukupu‘u (*Hemignathus lucidus affinis*) and Maui ‘ākepa (*Loxops coccineus ochraceus*) once occurred but have not been recently sighted and may be extinct.

Cats, mongooses, and rats all occur in rainforest areas (HALE unpublished data). Predator control should focus on areas where endangered birds are present, and focus on all three predators using clusters of different types of traps. A combination of long-term lethal traps and bursts of short-term intensive trapping while camping would be ideal, especially considering that transportation to these areas require costly helicopter travel. Due to the amount of precipitation, streams, and intermittent pools of the rainforest areas, toxicant baits placed directly on the ground is not recommended.

4.1.2 High elevation grassland areas

The high elevation grasslands at Kalapawili and Kuiki provide grazing habitat for nēnē, and flocks of nēnē are often seen here, especially during the summer. ‘Ua‘u nest on the ridge inside the crater rim from Kalapawili. Cats, mongooses and rats occur in these areas (HALE unpublished data). Kalapawili can be accessed from Palikū via Lau‘ulu Trail in about 2 hours and Kuiki can be accessed via an unmaintained trail in about 1.5 hours. Long-term lethal traps are suggested for these remote areas and should focus on cats and mongooses.

4.1.3 Nu‘u

Nu‘u extends from the crater rim at 7,700 ft (2,350 m) elevation to sea level on the southern slope of HALE. The entire area has been impacted by years of ungulate grazing and erosion, and much of the native vegetation has been lost. Upper elevations of Nu‘u contain native sub-alpine shrubland. Native birds including the endangered nēnē, ‘ua‘u, and ‘akē‘akē (Band-rumped storm petrel, *Oceanodroma castro*) were detected at upper elevations and may nest in the area. Native forest birds, including ‘apapane (*Himatione sanguinea*), ‘i‘iwi (*Drepanis coccinea*) and Maui ‘amakihi (*Chlorodrepanis virens wilsoni*) are also present in the upper elevations of Nu‘u.

Although surveys for predators have not been conducted, it is likely that all three predators occur. Predator control should focus on areas where endangered birds are present, and on controlling all predators using clusters of different types of traps. If only limited monitoring of traps is possible, a combination of long-term lethal trapping and bursts of short-term intensive trapping while camping for a week is ideal.

4.1.4 ‘Ohe‘o

The ‘Ohe‘o area at the southeastern coast of the park is mostly developed and contains the Kīpahulu Visitor Center, a campground, trails, and a baseyard. Much of the vegetation at ‘Ohe‘o is non-native, and the area is a popular visitor destination. There are high levels of cats, mongooses, and rats in the area, which are mostly attracted to and scavenging in the developed areas.

Cats, mongooses and rats are pests rather than predators of endemic birds, and there are no endangered birds present in the area. There are high levels of cats, mongooses and rats as well as high visitor use of the area. All traps should be placed out of direct sight of visitors. Trapping strategy is to use Goodnature™ traps, DOC 250s, and cage traps set away from human use areas. Goodnature™ traps and cage traps should be used where there is a possibility of human interaction. Trapping must be closely and regularly monitored to minimize visitor interactions with captured animals or traps and to ensure timely and humane dispatch of trapped animals. The number of traps set should not exceed the amount of traps that can be regularly monitored by staff.

4.2 Application in areas outside of HALE

The Decision Making Process is a step-by-step guide that may be applied to predator control trapping programs outside of HALE to decrease predators in native species habitat. The methods in Chapter 3 will need to be tailored to each location. By using the Decision Making Process as a foundation together with methods and materials mentioned in this plan, managers can adjust trapping strategies to suit their program needs.

In addition to the factors listed in the Decision Making Process, application of this plan outside of HALE will need to consider the goals of predator control for that area, the size of the predator control area, terrain, public access, and staff experience.

4.2.1 Goals of predator control

Organizational goals, procedures, and guidance in other locations may differ from HALE, and managers can adjust trapping strategies to best adapt to the goals of their location. For example, areas managed to mitigate incidental take of endangered birds may be required to have a much higher level of predator control. In addition, predation pressure may affect endangered species more critically in certain areas and require a higher level of control, especially for very rare species. In some situations, methods other than trapping will need to be considered, such as predator exclusion fences, hunting, and the use of toxicants.

4.2.2 Area of predator control

The management area that predator control will occur will affect the overall trapping strategy. The area managed for predator control at HALE is relatively large, encompassing about 5,500 ha (13,590 acres). If the management area of the target location is smaller with all other factors being equal, a

higher level of predator control could be possible. A small target location may allow for a more complete trapping coverage using grids targeting different predators. In addition, a smaller area will allow for faster responses to predator detections.

4.2.3 Terrain

In addition to remoteness, the terrain affects the implementation of a predator control plan. In areas where terrain is steep or heavily vegetated making it difficult to pass, the manager must consider the safety of staff and the possible negative effects of trampling of vegetation to conduct predator control. Only limited control may be possible in those situations, or other methods such as toxicants may need to be considered. In general, terrain that is more difficult to access by people, such as areas with steep cliffs, is also difficult for predators to access.

4.2.4 Public access

The National Park Service strives to balance natural resource management with visitor enjoyment. Trails, cabins, and visitor centers are located within endangered bird habitat. At HALE, measures are taken to avoid visitor exposure to traps. Applying this plan to areas that are not open to the public eliminates visitor use as a factor. For example, traps may be placed on trails that are only used by resource staff.

4.2.5 Staff experience

Staff experience in predator control is important for understanding the Decision Making Process, implementing a predator control plan, and determining trapping strategy for their location. An experienced trapper is the best person to design and implement a trapping plan. Staff experience in predator detection, monitoring, trapping, and behavior improves the overall predator control program.

Staff experience in native species biology is also important. Knowing the behavior of the species to be protected is important to avoid incidental capture. Knowledge of native species biology and breeding seasons can assist the manager in timing predator control efforts, especially when staff or funding resources are limited.

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APPENDIX A Implementation Schedule

Year 0:

- Build boxes for DOC 250 and body grip traps
- Build and test rodent exclusion methods for baits
- Implement testing of lethal traps
- Observe interactions of endangered birds with DOC 250 and body grip boxes
- Survey for predator sign

Years 1-3

- Identify hot spots
- Develop and implement trapping plan, incorporating a variety of traps
- Monitor traps
- Monitor for predators in the trapping area
- Conduct yearly predator surveys over broader landscape
- Adjustments as needed
- Research trap monitoring systems

Year 3+:

- Monitor traps
- Monitor for predators in the trapping area
- Conduct yearly predator surveys over broader landscape
- Review trapping data
- Adjustments as needed
- Research trap monitoring systems

Year 5+

- Evaluate trapping program
- Consider implementation of trap monitoring systems
- Determine if changes need to be made to the plan

APPENDIX B Site Descriptions for Priority Trapping Areas at HALE

Accessibility to specific trapping locations is defined by the amount of time to reach the location by hiking, ground transportation or both from the frontcountry baseyard.

- High: < 1 hour
- Moderate: >1 hour and < 4 hours
- Low: > 4 hours

‘Ua‘u and nēnē activity are defined by the presence and breeding status of the species.

- High: Birds present and actively nesting in an area.
- Moderate: Birds present or occasionally present. Area may have occasional active nests, only a few active nests per year, or active nesting activity has not occurred in recent years.
- Low: Birds may be occasionally present or not present. No known nests in the area.

Frontcountry

Crater Rim and South Slope

(Figure B1)

Accessibility: High - Moderate
 ‘Ua‘u activity: High (February to November only)
 Nēnē activity: Low
 Target predators: Cats, mongooses, rats

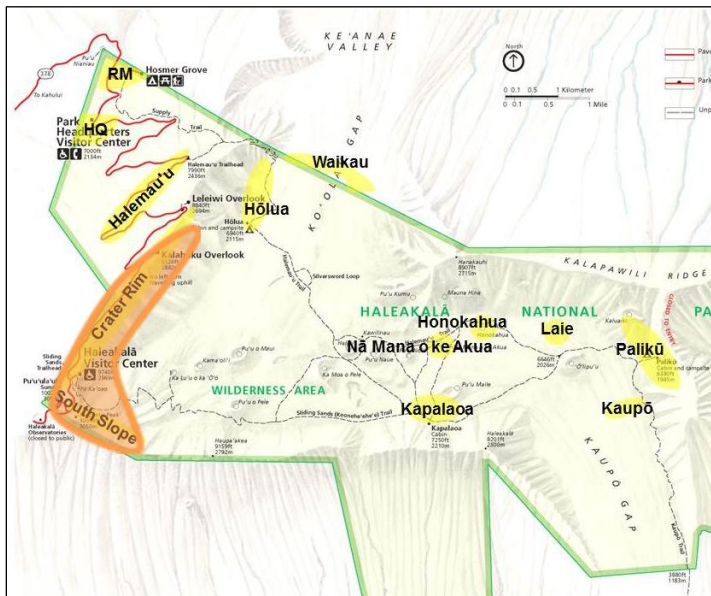


Figure B1. Map showing the crater rim and south slope areas of the frontcountry.

These areas are primary nesting habitats of the ‘ua‘u, especially on the inner slopes (crater side) of the rim. Areas accessible for predator control span from the South Slope to Halemau‘u Trail. There are occasional depredations of ‘ua‘u by cats and mongooses, and although not common, when a predator does enter the area, numerous ‘ua‘u may be depredated in a short time frame. Vegetation is sparse, and the habitat is in the alpine (aeolian) zone. Cats and mongooses are likely vagrant and not residents, but may be attracted into the area due to the abundance of ‘ua‘u burrows. Camera trap data (HALE unpublished data) show that rats frequently enter burrows but quickly exit, and do not appear to be depredating ‘ua‘u adults or fledglings. Camera trap data also show that cats occasionally visit burrows. Trapping strategy in this area implements clusters or short lines of traps targeting cats, mongooses and rats, especially in the lower elevation range of the rim.

Developed Areas

(Figure B2)

Accessibility:	High
‘Ua‘u activity:	None
Nēnē activity:	Moderate - High
Target predators:	Cats, mongooses, rats

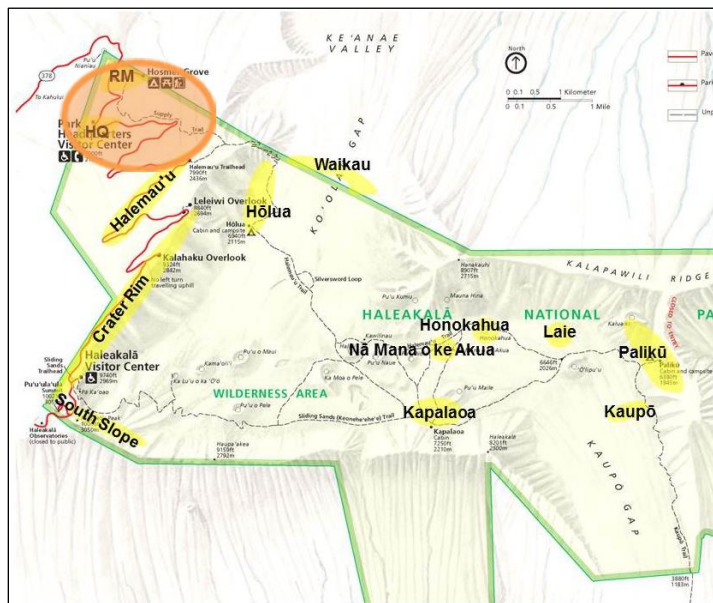


Figure B2. Map showing the developed areas of the frontcountry.

The developed areas at the Park Headquarters, Resources Management (RM) baseyard and Hosmer Grove attract rats and mongooses (Figure B2). The highest concentration of nēnē nests in the frontcountry are near these areas. Predator control in these areas is an on-going priority. Trapping strategy focuses on having traps or clusters of traps encircling the entire developed area and targeting all three predators. Traps are modified when nēnē goslings are in the area. Pu‘u Ō‘ili and adjacent gulch serves as a natural attractant for cats. Recent ground surveys indicate high cat activity in the area. Historical trapping data show medium to high level of cat catches, and a medium level of mongoose catches in the area.

Halemau'u

(Figure B3)

Accessibility:	High
‘Ua‘u activity:	Low - Moderate (February through November only).
Nēnē activity:	Moderate - High
Target predators:	Cats

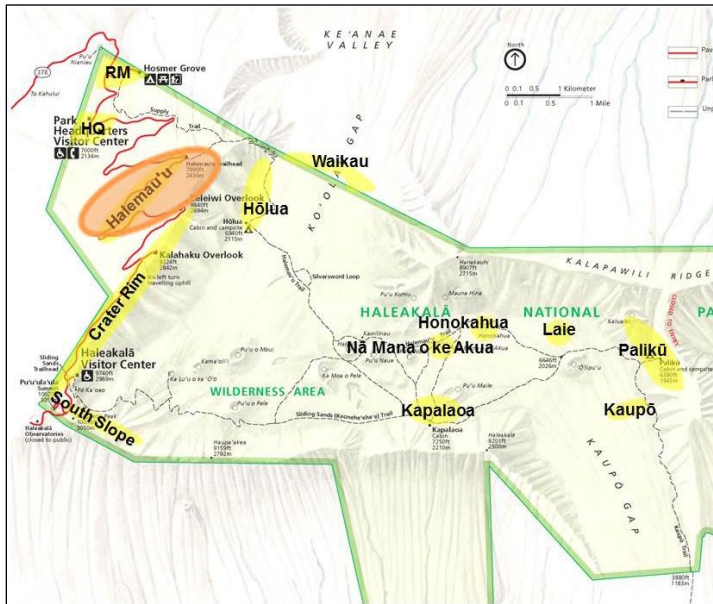


Figure B3. Map showing the Halemau'u area of the frontcountry.

This location spans the area adjacent to the park road between Halemau'u parking lot and the 8,500-ft. turn along the park road, and is in between the 'ua'u colony at higher elevation and the nēnē population at lower elevation. The habitat is a transition between alpine (aeolian) and subalpine shrubland. Just below the 8,500-ft turn, there is a prominent grove of eucalyptus trees and a series of small shallow caves are attractive to predators. There are also numerous gulches starting from higher elevations and running downhill that have caught a high number of cats over the years (Kelsey et. al. 2019). These gulches are attractive to cats, and could be serving as cat highways leading up to the 'ua'u burrows at higher elevations. Nēnē nests are occasionally found below the 8,500-ft. area between the eucalyptus grove and Park Headquarters, but in very low densities (Figure 3). This area is a prime location to target cats because of the numerous attractive landscape features and the near absence of endangered birds. Trapping strategy focuses on placing individual traps or clusters of traps in areas attractive to cats or where cat sign is prevalent, utilizing foothold and cage traps. Mongooses are targeted secondarily, and have been caught historically in medium densities at the 8,500-ft area and downhill (Kelsey et al. 2019). Trapping strategy for mongooses would be included with clusters of cage traps that are set for capturing cats.

Backcountry

Palikū

(Figure B4)

Accessibility:	Low from frontcountry, High from Palikū Cabin
‘Ua‘u activity:	Low - Moderate (February through November only)
Nēnē activity:	Moderate - High
Target predators:	Cats, mongooses, rats

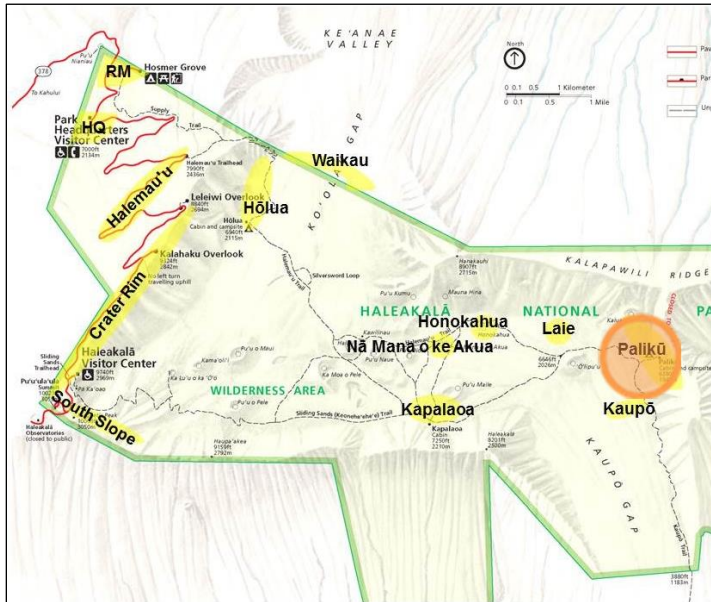


Figure B4. Map showing the Palikū area of the backcountry.

Palikū was the original release site of nēnē on Maui in 1962, and is still the area with the greatest concentration of nēnē activity including nesting in the park. The habitat at Palikū is transitional between subalpine shrubland and the edge of montane rainforest, and it is one of the wettest areas of the crater. There is a Visitor Cabin, Patrol Cabin, campground, horse stables and pasture located at Palikū. There are a few known ‘ua‘u nests on Lau‘ulu Trail above Palikū leading up to the Kalapawili ridge that have suffered cat depredations over the years. Mongooses and rats are also prevalent. Predator control strategy at Palikū targets cats, mongooses and rats, focusing traps in hot spot areas. Predator control at Palikū is a high priority during the nēnē nesting season (October – April), though modifications to traps must be made to prevent accidental capture of nēnē goslings.

Hōlua

(Figure B5)

Accessibility:	Low - Moderate from frontcountry or Palikū, High from Hōlua Cabin
‘Ua‘u activity:	High (February through November only)
Nēnē activity:	Moderate
Target predators:	Cats, mongooses, rats

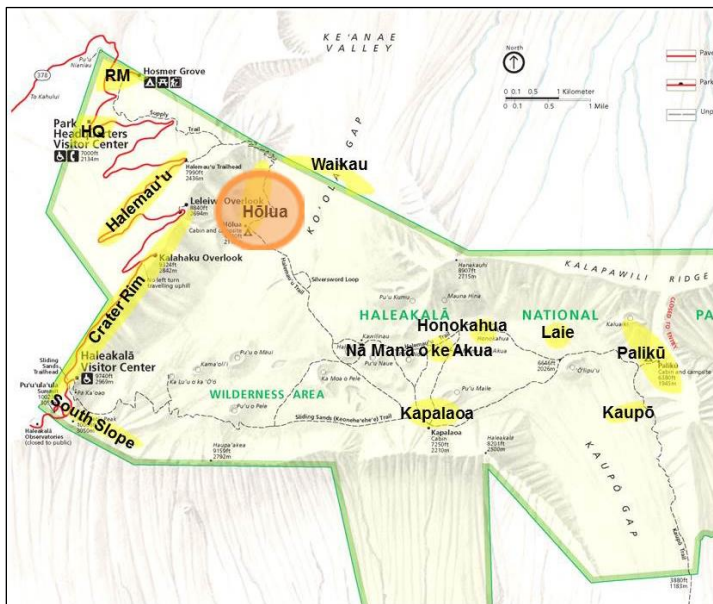


Figure B5. Map showing the Hōlua area of the backcountry.

The Hōlua area is at the crater floor below the Leleiwi pali (cliff) in subalpine shrubland. There is a visitor cabin, small staff cabin, campground, and horse pasture at Hōlua. ‘Ua‘u burrows are plentiful in the ridges above the cabin and there are clusters of burrows in the flats leading toward the central crater from the cabin. Nēnē are often observed browsing on the grass lawn in front of the visitor cabin, and nēnē nests in the area are occasionally found but in low numbers. Mongooses and cat signs are prevalent between the Hōlua Cabin and the base of the Halemau‘u switchbacks (Kelsey et al. 2019). Therefore, predator control strategy should focus on capturing these species. Rats will be targeted primarily right at the cabin area. Because of the moderate – low accessibility from the frontcountry or Palikū, only a few trap clusters should be set in key predator hot spots. Trapping efforts in the area can increase if overnight stays at Hōlua become a regular part of the backcountry trip, or if conducting targeted short-term trapping out of Hōlua.

Kapalaoa

(Figure B6)

Accessibility:	Moderate from frontcountry or Palikū
‘Ua‘u activity:	High (February through November only)
Nēnē activity:	Moderate
Target predators:	Cats, mongooses, rats

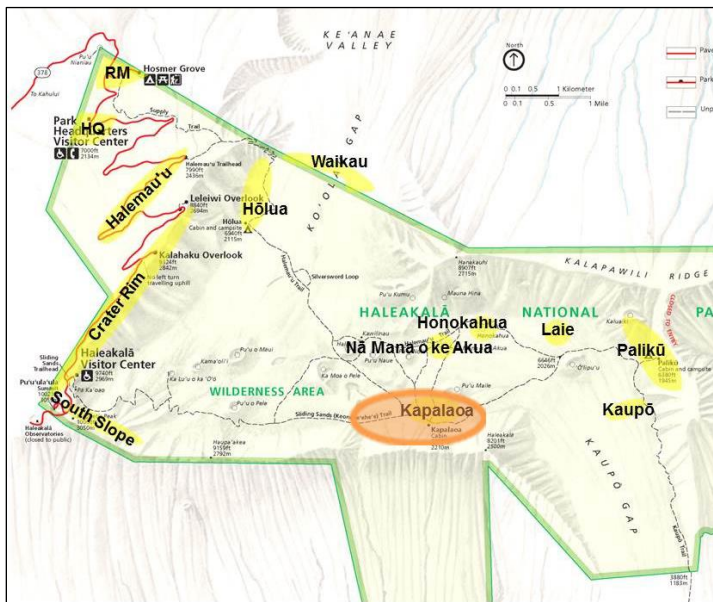


Figure B6. Map showing the Kapalaoa area of the backcountry.

Kapalaoa is located in an open cinder landscape consisting of subalpine shrubland and sparse grassland. There is a visitor cabin there. ‘Ua‘u burrows are plentiful in the ridges above the cabin and there are clusters of burrows in the flats leading toward the central crater from the cabin. Nēnē are often seen browsing on the grass lawn in front of the visitor cabin, and nēnē nests are occasionally found in the area but in low numbers. Following the base of the ridge east of the cabin there is a gulch that is a mongoose and cat hot spot. There is also cat activity at the base of Pu‘u Maile near a cluster of ‘ua‘u burrows. Predator control strategy should focus on controlling cats and mongooses in hot spots, and targeting rats at the cabin area.

Na Mana o ke Akua

(Figure B7)

Accessibility:	Moderate–low from frontcountry and Palikū, High from Kapalaoa Cabin
‘Ua‘u activity:	High (February through November only)
Nēnē activity:	Moderate
Target predators:	Cats, mongooses, rats

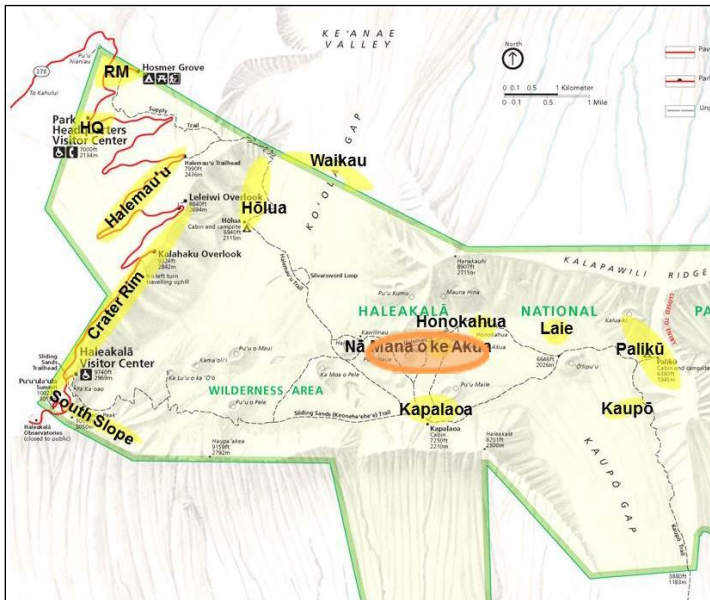


Figure B7. Map showing the Na Mana o ke Akua area of the backcountry.

Na Mana o ke Akua is a cat hot spot located in the central crater. This area consists of a mostly cinder and aʻa landscape with some shrubs, grasses and small mamane. There are many crevices in the lava that cats may traverse and den in, and the ʻuaʻu burrows in the area provide an attraction for predators. Trapping in lava crevices has been successful in catching cats, and predator control should continue to be a priority here, targeting predator hot spots.

Honokahua

(Figure B8)

Accessibility:	Low from frontcountry, High – Moderate from Kapalaoa and Palikū Cabins
ʻUaʻu activity:	Moderate (February through November only)
Nēnē activity:	Moderate
Target predators:	Cats, mongooses

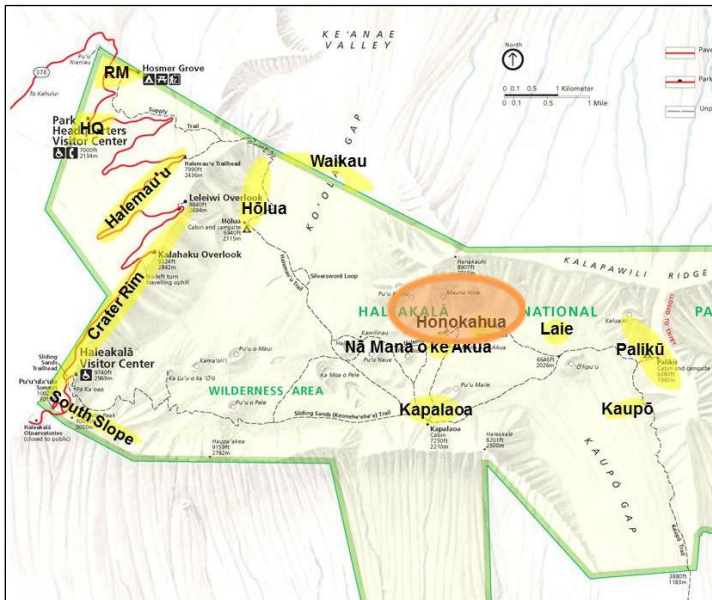


Figure B8. Map showing the Honokahua area of the backcountry.

Honokahua refers to the area from Honokahua cinder cone toward the base of Mauna Hina facing Palikū, consisting primarily of subalpine shrubland on cindery slopes. It is a known cat hot spot, and mongooses are occasionally present (HALE unpublished data). There are ‘ua‘u burrows in the area that have suffered depredations over the years. Honokahua can be accessed by the Halemau‘u Trail either on the way in or out of Palikū. Predator control strategy focuses on cats and mongooses, though precautions must be taken due to the presence of ‘ua‘u burrows and occasional nēnē in the area.

Lā‘ie

(Figure B9)

Accessibility:	Low from frontcountry, High from Palikū Cabin
‘Ua‘u activity:	Low (February through November only)
Nēnē activity:	High
Target predators:	Cats, mongooses, rats

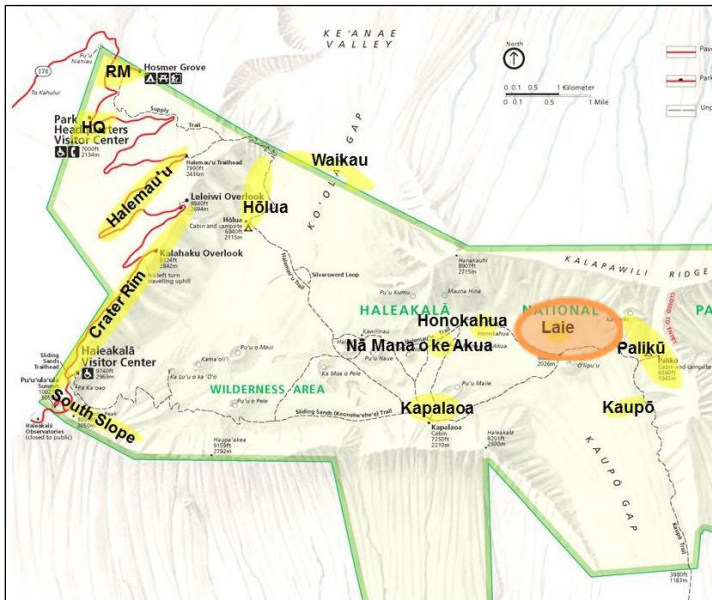


Figure B9. Map showing the Lā'ie area of the backcountry.

Lā'ie is located at the base of Kalapawili ridge, and the habitat varies from open lava flows to subalpine shrubland and grassland. Nēnē often flock and nest in this area. There are many crevices found in the lava flows that may serve as dens for cats, and this area is known as a cat and mongoose hot spot. There are currently 10 cage traps in the area, and trapping should continue to be a priority here during the nēnē nesting season (October – April), though modifications to traps must be made to prevent accidental capture of nēnē goslings while they are present.

Kaupō

(Figure B10)

Accessibility:	Low from frontcountry, high from Palikū Cabin
Endangered species:	Moderate nēnē nesting and activity, no 'ua'u activity
Target predators:	Mongoose, cats

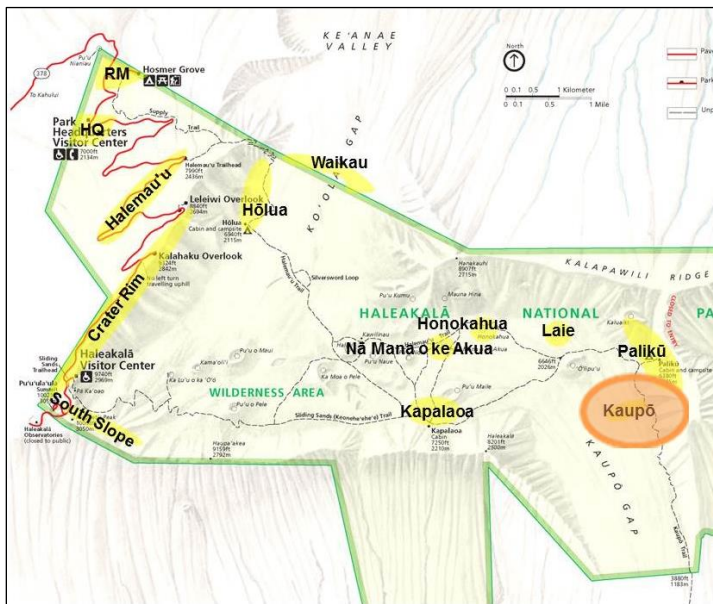


Figure B10. Map showing the Kaupō area of the backcountry.

Kaupō is adjacent to Palikū, and is at the edge of the nēnē population range. There are less nēnē that utilize the area than Palikū. The habitat at Kaupō consists of ‘a‘ā vegetated by shrubland that spans the Kaupō Gap. Presently, traps cross only a small portion of the gap from the Kaupō trail at about 1825m (5987 ft.). Although this area is a mongoose hot spot, trapping in Kaupō is secondary to Palikū, or may be opened if trapping at Palikū is limited due to nēnē goslings in the area. There is also a lower Kaupō trapline at about 1250m elevation that has been closed since 2005 due to accessibility issues. The lower line is a low priority due to its distance from ‘ua‘u and nēnē populations and its remote nature.

Waikau

(Figure B11)

Accessibility:	Moderate from frontcountry, Moderate – Low from Hōlūa Cabin
‘Ua‘u activity:	Moderate (February through November only)
Nēnē activity:	Moderate
Target predators:	Mongoose, cats

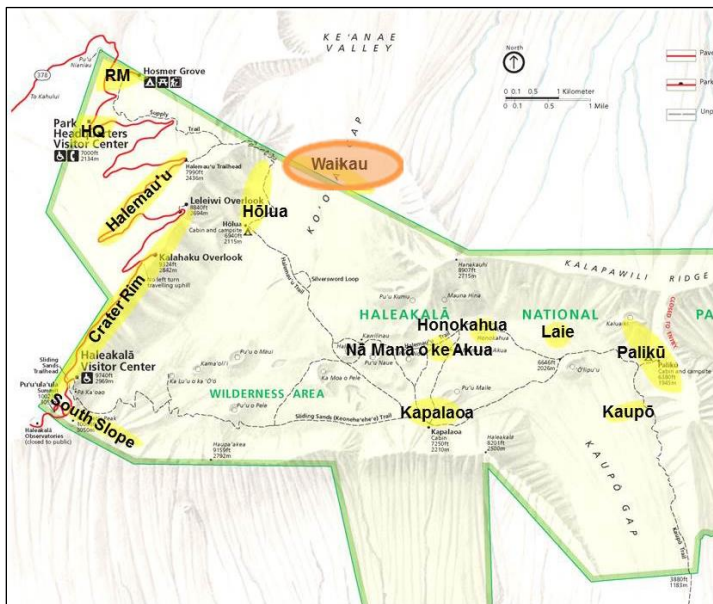


Figure B11. Map showing the Waikau area of the backcountry.

Waikau refers to the area at the base of Hanakauhi Peak and across Ko‘olau Gap from the base of the Halemau‘u switchbacks. The habitat at Waikau is subalpine shrubland, with an unmaintained trail to Waikau that passes through open lava fields and shrubland. Currently there are traps placed through Ko‘olau Gap from the base of the Halemau‘u switchbacks to Waikau. This trapline is closed because of low staffing levels and moderate accessibility, but mongooses were often captured when traps were open (Kelsey et. al. 2017). Because trapping has not been regular, target predator surveying is needed to determine current predator activity and hot spots. Predator control should target mongooses and cats, and Waikau would be a good candidate for short-term targeted predator control based out of Hōlua or spike camping at Waikau.

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