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Monitoring and Control of Feral Cats on Kaho`olawe: One Step Towards Eradication

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ABSTRACT: The island of Kaho`olawe provides an extraordinary opportunity for conservation and has been referred to in numerous recovery plans for declining populations of Hawaiian avifauna. The feral cat is widely recognized as one of world's most destructive invasive species and has been implicated in the decline or extinction in a number of native avian species. Of the main 8 Hawaiian Islands, Kaho`olawe presents the most feasible option to eradicate feral cats due to its limited access, remoteness, relatively small size (116 km²), and reserve status. With assistance from a U.S. Fish and Wildlife Service grant, the Kaho`olawe Island Reserve Commission restoration program monitored and controlled feral cats from November 2008 to February 2011. Monitoring techniques included camera traps, tracking stations, spotlight surveys, trapping, and diet and disease analysis. Feral cat density was estimated to be high based on a capture rate and regular monitoring surveys. Cat track observations declined significantly ($P < 0.001$) during the course of the study. Twenty-two of 46 (47.8%) cats tested positive for seroprevalence to the parasitic protozoan *Toxoplasmosis gondii*. A major component of prey items consisted of invertebrates mainly comprising centipedes and intertidal crabs. With cooperation from Island Conservation, information gathered helped create an implementation plan for the eradication of feral cats on Kaho`olawe.

KEY WORDS: eradication, *Felis silvestris catus*, feral cats, Hawaiian Islands, invasive species, Kaho`olawe, seabird restoration

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INTRODUCTION

The Hawaiian archipelago accounts for only 0.2% of the U.S. land area but is home to nearly 75% of recorded extinctions in the U.S. Invasive species are the leading cause of these extinctions. The island of Kaho`olawe is 116 km² and approximately 11 km southwest of Maui (Figure 1). The entire island plus 2 nautical miles offshore is a state reserve with restricted access. The Kaho`olawe Island Reserve Commission (KIRC) manages Kaho`olawe Island Reserve for the State of Hawai`i in trust for an eventual Native Hawaiian Sovereign entity (PBR Hawaii 1995).

Feral cats (*Felis silvestris catus*) have significant impacts on island ecosystems and are a major threat to resident seabird populations (Hilton and Cuthbert 2010, Campbell et al. 2011). The lack of suitable habitat for nesting and foraging and the presence of introduced predators are believed to be the principal factors preventing re-establishment of seabirds, waterbirds, and other native wildlife on the main island of Kaho`olawe. Kaho`olawe is recognized as one of the top-ranked sites for reintroduction and establishment of rare birds; however, these efforts should not be attempted until the island is free of feral cats (Lindsey et al. 1997, SSRI 1998, USFWS 2004a, USFWS 2004b, Mitchell et al. 2005, Morin and Conant 2007). In addition to feral cats, Polynesian rats (*Rattus exulans*) and house mice (*Mus musculus*) are the only other invasive mammals currently on the island.

Kaho`olawe's habitat has been degraded by years of use as a Navy bombing range, and by the impacts of invasive species including feral cats, rats, and grazing ungulates. The Fiscal Year 1994 Department of Defense Appropriation Act established a federal role in the restoration of the island, and Hawaii Revised Statutes, Chapter 6K, identifies habitat restoration and preservation

as some of the primary uses of the island (PBR Hawaii 1995). The restoration of Kaho`olawe places traditional practices and cultural protocols at the forefront of ecological recovery efforts. KIRC sponsored development of the Kaho`olawe Environmental Restoration Plan (1995), which specifically calls for eradication of invasive species. Feral goats have been eradicated from the island, but feral cats and introduced rodents still threaten native seabirds and, along with loss of habitat, are probably responsible for the absence of a variety of birds on Kaho`olawe.

To help restore the Kaho`olawe's natural biota, KIRC is actively restoring ecologically important areas in priority sites and has approved feral cat eradication as the first step towards a completely invasive mammal-free island, the largest in Hawai`i. This study investigates the ecology of feral cats on Kaho`olawe and provides baseline data on feral cat diet, disease, abundance, and distribution to advance the development of an island-wide introduced mammal eradication plan.

METHODS

Abundance and Distribution

Sand Plots

To monitor abundance and distribution of feral cats and trapping efficacy, we installed tracking stations. Sand plots consisted of 1-m² patches of sandy substrate 1-3 cm (0.4-1.2 in) deep that could be raked and checked the following day for cat sign (Forsyth et al. 2005, Mitchell and Balogh 2007). Eight coastal sand plots established at 500-m intervals between Honokanai`a and Kaukaupapa were monitored for 2 consecutive nights on a near-monthly basis from November 2008 through February 2011. We calculated 2 common indices of feral cat abundance as 1) the mean number of tracks per transect per day, and 2) the percentage of station-nights

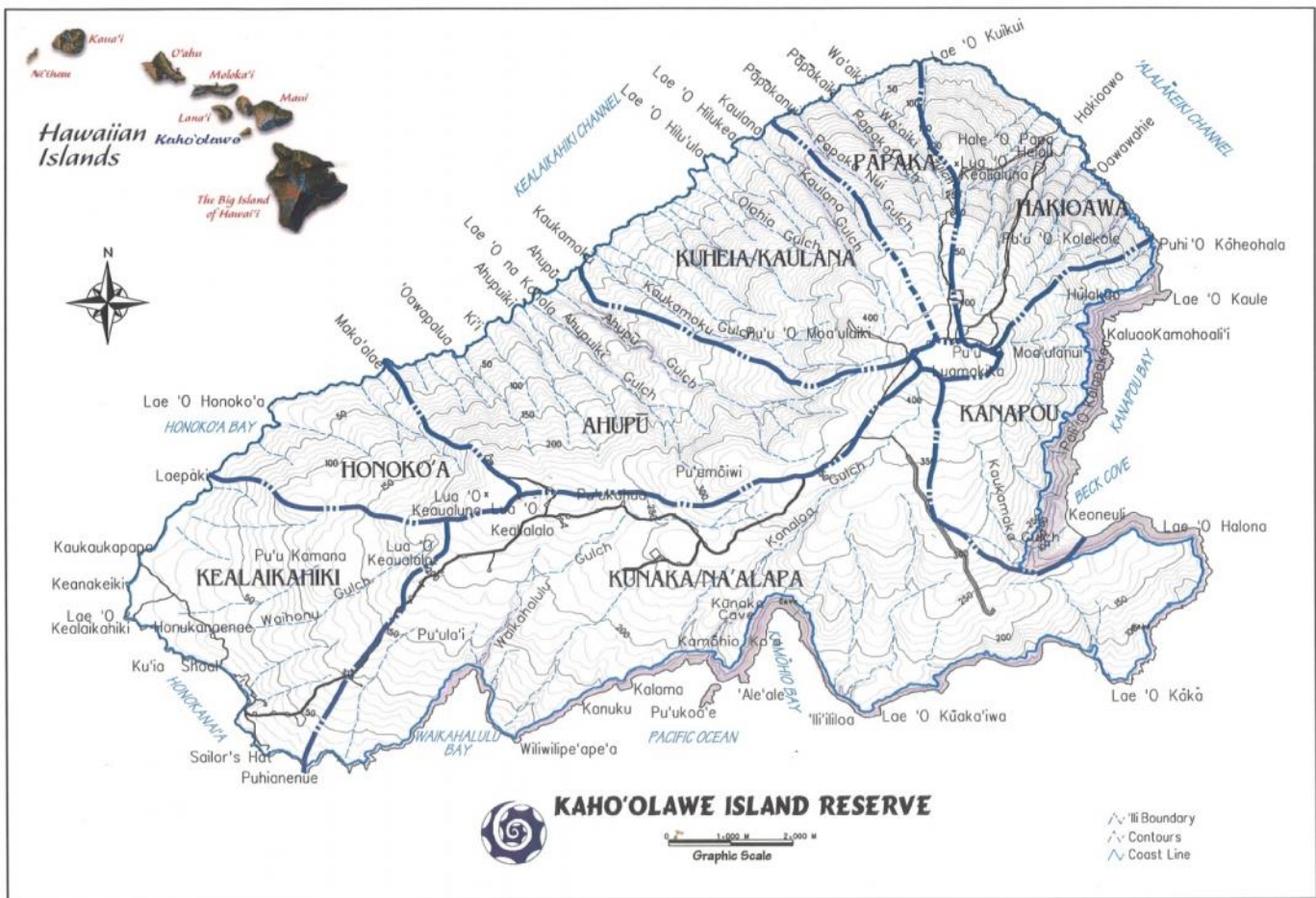


Figure 1. Map of Kaho'olawe with place names, in relation to the Hawaiian Islands.

with tracks (Mitchell and Balogh 2007). Polynomial regression was used to determine change over time during the course of trapping.

Remote Surveillance Cameras

Remote surveillance cameras can aid in evaluating effectiveness of various lures, traps, and also monitoring of daily activity patterns (Hess et al. 2008). Camera placements were determined by feral cat sign (tracks, latrines) and in areas of ecological interest. Five remote surveillance cameras (Reconyx® and Moultrie®) placed at the named locations "Sailor's Hat," "The Cistern," "Pu'u Moiwi," "Lua 'O Kealialalo," and "Kaukukapapa" monitored cats from October 2008 through February 2011. Twenty-four-hour activity periods for feral cats were tabulated over the life of the cameras. Camera "nights" were defined as a 24-hr period beginning at 12:00 AM.

Spotlighting Surveys

Spotlighting surveys were scheduled once every 4 months during the course of the study. One survey equated to 2 consecutive nights, and rainy nights were avoided. The spotlighting route was a 16-km tract on the Kuamo'o road from Honokanai'a to Pu'u 'O Moa'ula nui. Approximately one-half hour after sunset, we drove a Polaris Ranger 4x4 Utility Terrain Vehicle (UTV) at a

slow, constant speed (8 mph) with one observer in the back of the vehicle scanning a 180-degree arc ahead of the vehicle. Eye-shine from feral cats was detected easily with a powerful 2-million-candlepower spotlight with a 12-volt battery supply. All cat detections and their locations (GPS coordinates) were recorded while the vehicle was stationary. After each survey, an index of relative abundance was calculated as the number of cats seen/km (Forsyth et al. 2005, Mitchell and Balogh 2007).

Trapping

Cage or "box" traps were deployed in areas of high cat activity and areas of ecological concern. Tomahawk Model 207 cage traps (Tomahawk Live Traps, Hazelhurst, WI) were covered on the tops and sides with cloth or native vegetation. The back of the trap was left uncovered and the bottom of the trap was covered with sand, dirt, or local grasses. Care was taken to avoid any debris in way of the pressure plate or preventing the door from properly closing shut. Traps were tripped once before setting and were set in accordance to Algar et al. (2001, 2002, 2005), Mitchell and Balogh (2007), and Wood et al. (2002).

A variety of lures were used to entice feral cats into the traps. Lures included Felid-Attracting Phonic (FAPs; Westcare Industries, Nedlands, Western Australia) and feather lures. The feather lures used consisted of 3-4

chicken or owl feathers tied together at the shaft and hung from the back of cage over the pressure plate. Traps were baited with sardines, cat food, Spam[®] (Hormel Foods Corp., Austin, MN), or kitchen scraps. A small amount of bait was put in the front of the trap with the main portion behind the pressure plate.

Trapping was typically conducted 2-3 consecutive nights per month. Cage traps were set in the afternoon, checked in the morning, and then were shut down at the end of the week. Five trap lines were deployed at Lua Makika, the west beaches (Kealaikahiki, Keanakeiki, and Kaukaupapa), base camp (Honokanai`a), the west ridge above Kam hio Bay (K naka), and at Lua `O Kealialalo. Feral cats were dispatched with a single shot to the head from a .22-caliber firearm.

Diet

A standardized necropsy protocol was developed in coordination with the Maui Division of Forestry and Wildlife (DOFAW) and Maui Nui Seabird Recovery Project, where DNA tissue was collected, standard morphometrics were taken, and gastrointestinal (GI) tracts were extracted. Samples were stored in 70% ethanol in a designated freezer for later examination. During analysis, the GI tract was sliced open and contents were run through a fine-mesh sieve. A steady stream of warm running water with detergent was used to break up the GI contents into individual prey items. All prey items were noted and categorized.

Fresh cat scats were collected opportunistically during routine monitoring. GPS coordinates of the collection site were recorded, and scats were bagged and frozen for later analysis. Scats were defrosted and soaked for at least one hr by adding a mild detergent solution to the bags. Once softened, the contents of each bag were examined in the same way as the GI contents. Voucher specimens of all prey types were saved and catalogued. Percent occurrence was calculated by dividing the number of samples with particular diet item by total number of samples multiplied by 100. Bait, lure items, and cloth from the trap were categorized as miscellaneous and not included in the analysis.

Disease

Toxoplasmosis

Toxoplasmosis is caused by the protozoan parasite *Toxoplasma gondii* and is known to be fatal to endangered Hawaiian birds and marine mammals and, in some instances, fatal to humans (Honnold et al. 2005, Ikeda, 2000, Work et al. 2000, 2002). Infections of *T. gondii* are carried from cats to other mammals through ingesting physical and airborne oocysts from cat feces (Ikeda 2000).

A field procedure to collect samples was established for use on Kaho`olawe. Immediately following euthanasia, 2 cardiac blood samples were drawn using vacutainer needles and glass blood collection tubes. Tubes were placed in a test tube rack, which allowed for blood to clot for 30-60 minutes. Samples were then centrifuged for 10 min at 3,300 RPM. A pipette was used to transfer the serum to clean, labeled red-top tubes. Labeled serum tubes were placed immediately into a

refrigerator until shipping. Feral cat serum samples were submitted to Colorado State University's Veterinary Diagnostic Laboratory for testing using Enzyme-Linked ImmunoSorbent Assays (ELISA) to detect antibodies immunoglobulin G (IgG) and immunoglobulin M (IgM) against *T. gondii*.

RESULTS

Abundance and Distribution

Sand Plots

Twenty-two monitoring surveys were carried out from November 2008-February 2011. During the period of November 2009-June 2009 (pre-trapping), fresh cat tracks were recorded at 68±11% (n = 7) of plots. After trapping was initiated in the coastal areas, from August 2009-February 2010, fresh tracks dropped off to 34±12% (n = 6). From March 2010-February 2011, fresh tracks dropped further to 20 ±11% (n = 5, $\bar{x} \pm SD$). A third-order polynomial regression curve ($R^2 = 0.7211$) shows a significant decrease in tracks (Figure 2).

Remote Surveillance Cameras

Detections were highest before trapping commenced in June 2009. Feral cats were detected 26% of the time from October 2008-June 2009 (n = 555) and only 9% of the time during June 2009-September 2009 (n = 202). From October 2009-February 2011, feral cats were detected only 9% of the time (n = 773). All individual camera detection percentages are presented in Figure 3. Feral cats were photographed most often from 8:00 PM-12:00 AM (25%, n = 329 observations). Feral cats were detected the least during the day from 12:00 PM-4:00 PM at 7%. Multiple pictures of the same cat during short time intervals (less than 30 min) were not included for analysis (Figure 4).

Spotlight Surveys

Since April 2009, feral cat observations at Honokanai`a were not detected during the spotlight surveys. This is most likely due to the predator control activities started in late June 2009. Outside of Honokanai`a on the survey route, detections have been relatively consistent over the course of the study. This suggests that although feral cat abundance was down at Honokanai`a, abundance was relatively stable from Lua `O Kealialalo to the east end of the island. Relative abundance was calculated as \bar{x} /km. Results are shown in Table 1.

Table 1. Relative abundance of feral cats (average number of cats observed/km) generated from 6 spotlighting surveys for 2 consecutive nights on Kaho`olawe From January 2009-August 2010.

Survey Dates	Relative Abundance (average cats/km)
January 5-6, 2009	0.25
April 6-7, 2009	0.34
August 25-26, 2009	0.22
December 9-10, 2009	0.16
April 20-21, 2010	0.13
August 17-18, 2010	0.16
February 15-16, 2011	0.19

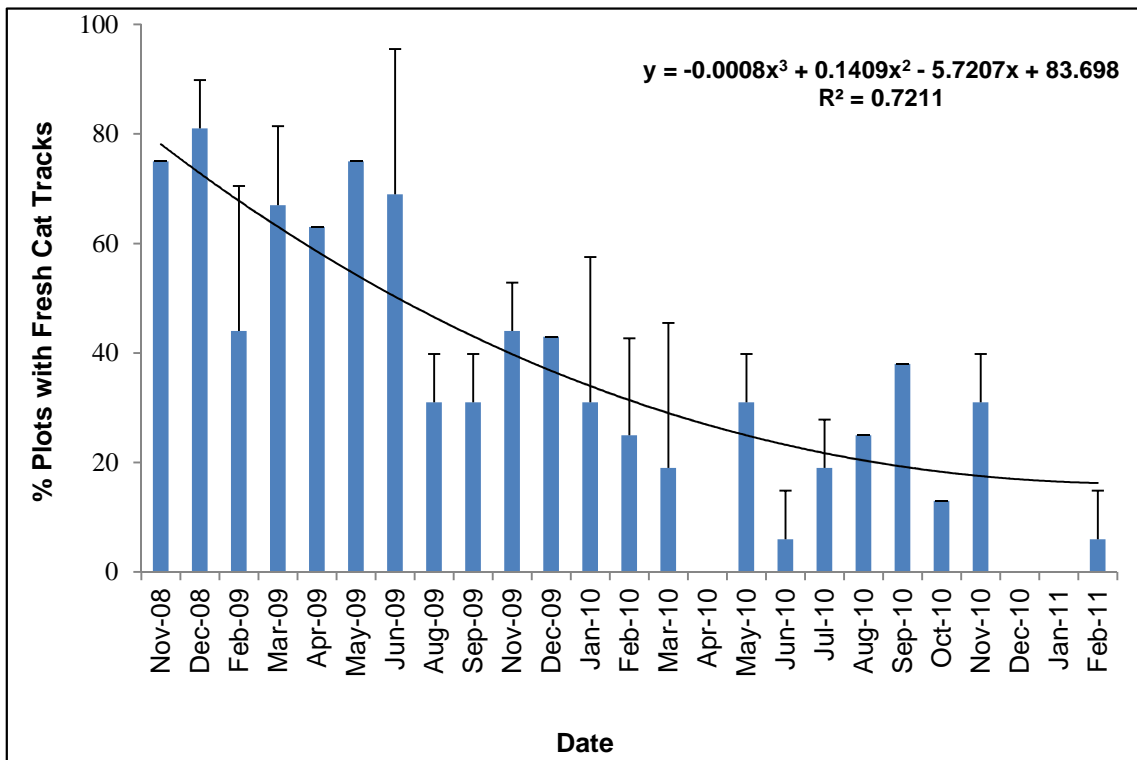


Figure 2. Percentage of coastal sand plots with fresh tracks in each of the 22 monitoring sessions conducted on Kaho'olawe from November 2008 - February 2011. Bars represent mean values from 2 consecutive nights with error bars of 1 standard deviation. Not all sessions had a variance. A third-order polynomial regression line shows a significant decrease ($R^2 = 0.7211$) of tracks.

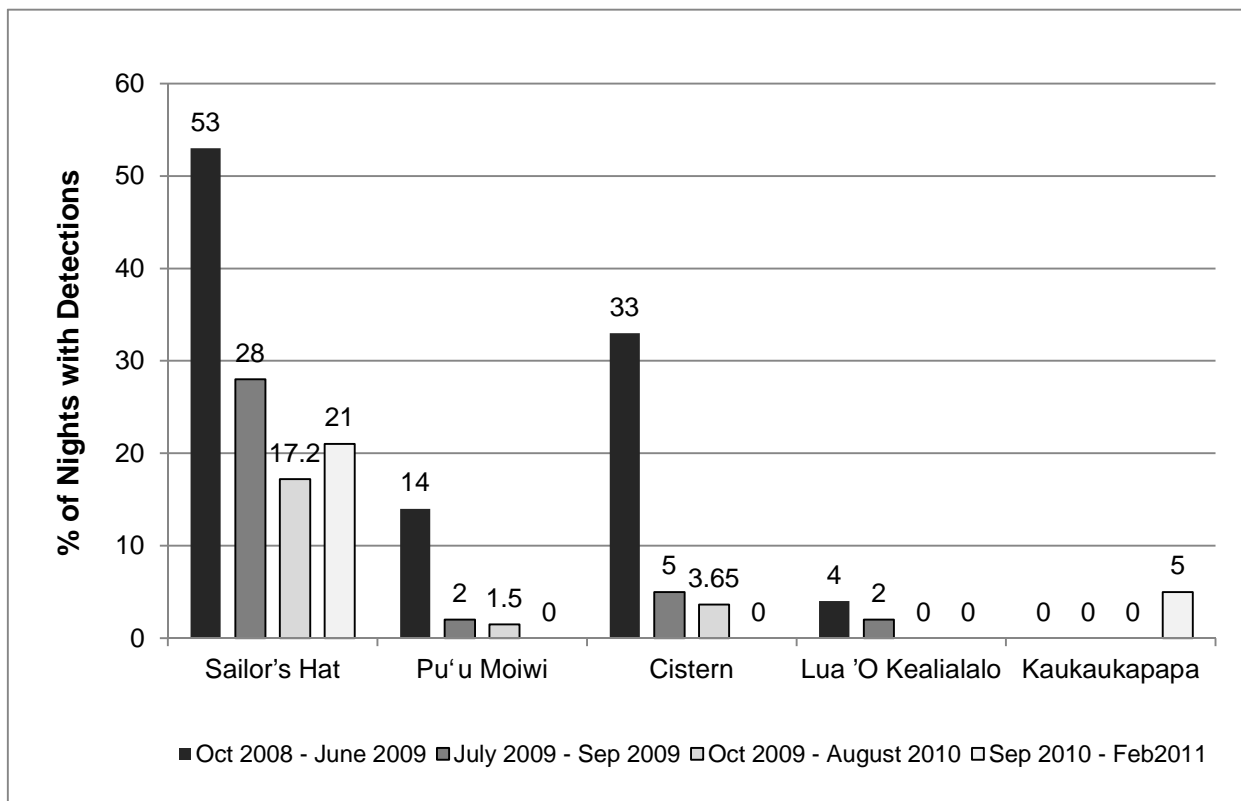


Figure 3. A comparison of the percentage of nights in which feral cat activity was detected by remote surveillance cameras at each of the 5 locations on Kaho'olawe.

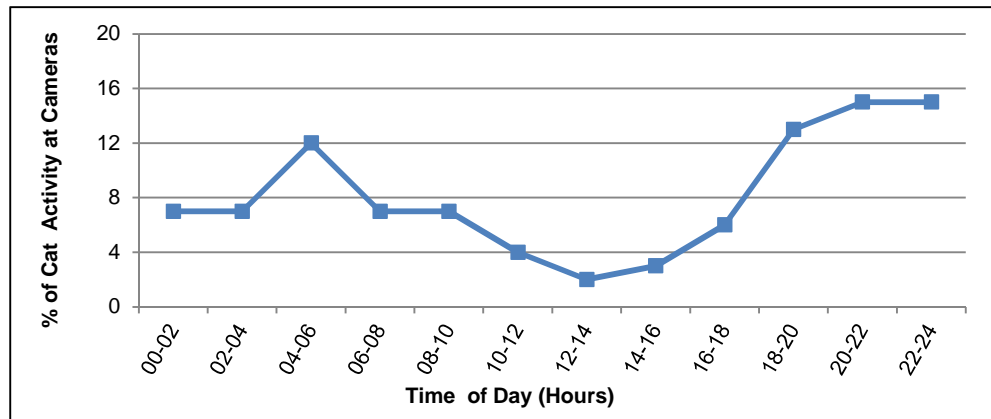


Figure 4. Percentage of feral cats that were photographed in 2-hr increments at 5 remote surveillance cameras on Kaho’olawe from October 2008-February 2011 (n = 329 observations).

Table 2. Morphometrics of adult feral cats (>1 year of age) on Kaho’olawe. Measurements are in millimeters. Male cats (n = 27), female cats (n = 19) ($\bar{x} \pm SE$).

	Mass (kg)	Body length	Tail length	Total length	Skull length	Skull width	Humerus length	Height	Abdominal circumference	Thoracic circumference
Adult Males	3.14±.14	504±7.38	282±5.13	786±12.51	93±2.99	69±1.26	109±2.23	251±4.97	302±10.07	281±6.93
Adult Females	2.00±.04	455±8.99	255±4.20	710±13.19	87±1.63	59±1.42	103±1.98	219±4.63	247±9.97	248±6.07

Table 3. Capture rate per 100 trap-nights for Honokanai’a (base camp), West Beaches (Kealaikahiki, Keanakeiki, Kaukukapapa), and mauka sites (K naka, Lua `O Kealialalo and Lua Makika).

Location	Total Trap Nights	Capture Rate/100 trap nights
Honokanai’a Jun 09– Oct 09	50	54.0
Honokanai’a Nov 09 – Feb 10	51	13.7
Honokanai’a Mar 10 – Feb 11	34	38.2
West Beaches Aug 09 – Feb 11	110	4.5
Mauka sites Jan 10 – Feb 11	92	13.0
All Sites Combined	337	19.0

Trapping

Overall, 64 feral cats were trapped from June 29, 2009 -February 15, 2011. All cats were sexed, aged, weighed, and pelage type was recorded. Most exhibited a tabby pelage category with slight variations, while a smaller percentage fell into the black pelage category (83% and 17%, respectively). Overwhelmingly, most of the cats had a whitish patch on their neck and chest (pers. obs.). Of the 64 cats, 42 underwent dissection, DNA tissue was collected from 37, and detailed measurements were taken of the 46 that were adult cats (Table 2).

At Honokanai’a base camp, initial trap success was high, and overall, 47 cats were trapped. From June through October 2009, referred to as the “knockdown” period, 27 cats were trapped for a capture rate of 54 cats per 100 trap-nights. From November 2009-February 2010, the capture rate decreased to 13.7 per 100 trap-nights (n = 7). From March 2010-February 2011, the capture rate was 38.2 per 100 trap-nights (n = 13). The increase in trap success is attributed to concentrating effort on “hot spots” or “draws” such as the base camp

compost pile. Surveillance camera and sand plot monitoring were also useful in choosing trap placements. For sites at the “west beaches,” the capture rate was tabulated for the length of study for comparison to the mauka sites (Lua `O Kealialalo, K naka, and Lua Makika) (Table 3).

Lures and selective trap placement are believed to increase the overall success rate (Algar et al. 2001, 2002, 2005, Wood et al. 2002, Mitchell and Balogh 2007). Felid Auditory Players (FAPs) were used as an additional lure. FAPs played a repeated recording of a cat “meowing.” Overall, FAPs had a 33.3% success rate; however, this was mainly at the compost pile where feral cats frequented. FAPs had a 13.3% catch rate in areas outside Honokanai’a base camp and was higher than the 8.4% mean capture rate. Best placement of FAPs appeared to be just above trap and out of sight, preferably not touching the trap. It is still uncertain how effective these are, but a remote surveillance camera with a FAP lure photographed a feral cat displaying modest curiosity.

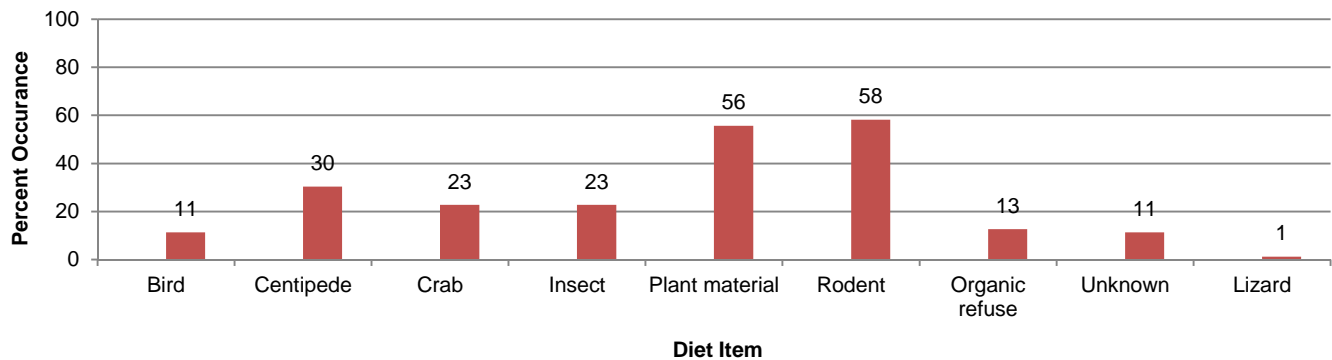


Figure 5. Percent occurrence of dietary components found in both feral cat scat and GI tracts (n = 79). Samples were collected from July 2008-February 2011.

Diet

Forty-two GI tracts and 37 cat scats were analyzed for diet items. Rodents accounted for a major dietary component in each sample size. There was a higher percent occurrence of rodents in the scat versus GI tracts. The 70% to 45% difference might be attributed due to the majority of scat samples (73.5%) being collected during the period with a regular mouse bloom that occurs on Kaho`olawe during years of normal rainfall. The majority of GI tracts collected were from summer 2009-winter 2011 when there was no mouse bloom due to drought (KIRC, unpubl.). The 2 data sets are combined to give a more thorough representation of the major dietary components through 2 years, including one year of normal rainfall and one year of drought. Centipedes, insects, and crabs made up the invertebrate component found. The percentage occurrence of total invertebrates was 61%, compared to 58% for rodents and 11% for birds (n = 79) (Figure 5).

Disease

Toxoplasmosis

Forty-six samples were submitted to Colorado State University's Veterinary Diagnostic Laboratory for testing. Of the samples from 46 cats, 22 (47.8%) tested positive for antibodies to *T. gondii*. Twenty-one cats had positive IgG titers, indicating past or chronic infection. Only one cat had a positive IgM titer, indicating a recent infection with *T. gondii*. There was not a correlation between males and females with infection. The two cats keyed out to be juvenile; both tested negative.

DISCUSSION

Abundance and Distribution

It is evident through monitoring the 8 coastal sand plots, surveillance cameras, spotlight surveys, and trapping that there has been decreased presence and activity of feral cats in Honokanai`a. This has most likely been a direct result of an intensive trapping regime. Among other influences difficult to quantify were a drought on the island in 2010. Remote Automated Weather Station (RAWS) data show precipitation from October 2009-October 2011 to be about one-third of normal, and the drought had a corresponding effect on mammal reproduction. This is evidenced by very low

mouse abundance on Kaho`olawe during the same time (KIRC, unpubl.). Spotlight survey numbers remained fairly consistent, once the resident feral cat population was removed at the base camp. Cat sign was opportunistically recorded, and feral cat presence was recorded island-wide on a regular basis. So even though there was a significantly reduced presence near base camp, feral cat presence remained consistent on an island-wide scale.

The overall density of feral cats appears to be fairly high, evidenced from capture rate of 19 animals per 100 trap-nights. This number might have been inflated due to moving to new areas, finding "hot spots" or "draws," and waiting for immigrating cats to move in before trapping. During the knockdown period from June-October 2009, the high capture rate of 54 animals per 100 trap-nights suggests a feral cat infestation and "source" population at Honokanai`a. If the knockdown period trapping data are removed from analysis, the capture rate is reduced to 11.8 per 100 trap-nights. This is still a high capture rate compared to other studies in Hawai'i (Hess et al. 2008). Continued sign and high capture rate throughout the study suggest a healthy feral cat population on Kaho`olawe.

The cage traps were covered with cloth or native vegetation and served dual purposes: the cover allowed the animals to keep cool and less exposed to morning sunlight and heating, and the cover resulted in less stress to the animal by giving it a chance to hide. All bait types were effective as long as they were fresh, but some problems encountered were tropical fire ants (*Solenopsis geminata*) swarming the bait, mice taking the bait, and heat from the sun drying out the bait. The similar pelages on Kaho`olawe made identification of individual cats difficult. Remote surveillance cameras helped discern unique markings that could be used to identify cats at the camera locations and also confirm individuals at the time of capture.

Diet

Invertebrates and rodents were the major component of feral cat diet on Kaho`olawe. There were a high percentage of centipedes (*Chilopoda*) and crabs (*Graspus graspus tenuicrustatus*, *Ocypode* sp.). Insects mainly consisted of Orthoptera species, with one identified as the grey bird grasshopper (*Schistocerca nitens*). Cock-

roaches (*Blattaria*) were also identified as a prey item. The high percentage of centipedes might be attributed to a lesser abundance of more preferred food resources, or it could be a selected item. It has also been suggested that centipedes will take longer to digest, thus appearing in more samples.

Organic refuse contributed a 13% occurrence in the samples. This might be attributed to sampling the resident feral cat population at the base camp (from GI tracts) at the beginning of the study and/or lower preferred food resources due to drought. Since 2009, the compost pile was moved away from base camp and contained in large drums; however, it still remained a draw for feral cats.

Vegetation consisted mainly of grass, but green kiawe (*Prosopis pallida*) pods and seeds also were found. It is well documented that cats will eat grass to aid in digestion, but the kiawe seed discovery is curious. Kiawe pods are well known as livestock fodder, and this suggests the cats are selecting vegetation as a food resource. The wide range of dietary components shows that Kaho`olawe provides all the necessary food resources to support a healthy feral cat population. During times of drought or when more preferred food resources are scarce, feral cats will switch to other food resources.

Disease

Toxoplasmosis

The high seroprevalence of antibodies to *T. gondii* (47.8%) in the feral cat population sampled can be an indication of a human health risk, and it is among the highest in Hawai`i (Hess et al. 2008). Humans contract the infection through contact with cat feces. This infection can be through physical contact or airborne, and is detailed in Ikeda (2000) "Toxoplasmosis in Hawai`i." The relatively large and stable resident feral cat population at Honokanai a base camp was a health risk to volunteers, staff, and contract workers.

SUMMARY

Continued monitoring shows an island-wide presence of feral cats. Food resources were identified and are available on a year-round basis. Native Hawaiian animals are at risk from toxoplasmosis disease transmission as well as predation (Ikeda 2000, Work et al. 2000, Work et al. 2002, Honnold et al. 2005). Over the course of the study, native birds [Pueo (*Asio flammeus sandwichensis*) and `U`au kani (*Puffinus pacificus*)], were found preyed upon by feral cats. A challenge encountered during the project was the difficulty in reducing a natural wild population in sensitive ecological areas due to remoteness, presence of unexploded ordnance, and labor costs. `Ale`ale and Pu`u Koa`e serve as a breeding ground for Kaho`olawe's seabirds, and in order to allow re-colonization of the main island, feral cats should be eradicated.

Further studies and projects are underway to implement a detailed plan for the eradication of invasive mammal species from Kaho`olawe. The eradication, or complete removal, of one or more invasive alien vertebrates from an island is an exceedingly complex objective that requires detailed planning and thorough engagement of all key stakeholders and the local

community (Cromarty et al. 2002). The Kaho`olawe Island Reserve Commission is now developing plans with Island Conservation to restore the island by removing invasive feral cats and rodents (Parkes 2009, Island Conservation 2012). This action will support natural recolonization of Hawaiian seabirds and aid in the relocation of threatened and endangered species state-wide.

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