



Figure 5. View of lower Waikolu Valley and `Ōkala Islet from Waikolu Overlook, Moloka`i, 2005.



Figure 6. Aerial view of Kūka`iwa`a Peninsula, Kalaupapa National Historical Park, Moloka`i, 2005.

Small Mammal Inventory

The inventory was conducted in several phases in spring 2005 with each transect taking four days to complete. All 75 stations were set at 50 m intervals within each transect and were monitored for three consecutive nights each. The survey periods were: Pu`u Ali`i NAR, 21–24 March; lower Waikolu Valley, 28–31 March; lower Waihānau Valley, 11–14 April; Kauhakō Crater, 19–22 April; Kūka`iwa`a, 25–28 April; and upper Waihānau and upper Waikolu, 3–6 May.

We experimented with several methods of gathering presence/absence information for small mammals. Both removal and census methods were utilized at each survey station. One large and two small snap traps, a Tomahawk® live cage trap, a tracking tunnel, and a glue board were set at each station. Traps were set and checked approximately every 24 hours to remove captured individuals and to replace bait, if needed. Tracking tunnels and cage traps were baited with hot dogs, while snap traps and glue boards were baited with peanut butter. Logistics and cost prevented prebaiting at each site to allow for animals to investigate the introduction of foreign objects and food sources into their territories. Traps were anchored to avoid being moved by animals. Tomahawk® cage traps were strategically covered with vegetation, keeping the opening of the trap clear. This camouflaged the traps and created a tunnel effect, which likely made the traps more enticing to cats and mongooses. Animals captured in the Tomahawk® traps were photographed, marked with aerosol paint, and released unharmed since the purpose of the survey was to determine presence/absence and not to conduct predator control. If a rodent captured in a snap trap was still living when the trap was checked, it was euthanized with carbon dioxide gas. Captured individuals were identified to species and classified by sex *in situ*. Field staff were trained to sex animals utilizing available specimens. The field data collected included: date, time, observer, area, transect, station number, GPS waypoint, weather (cloud cover, estimated to the nearest 10%; wind, according to the Beaufort scale; and rain, based on a 0–4 scale), trap type, trap status (no catch, catch, tripped with bait, tripped without bait, bait replaced, bait stolen, trap missing, trap not checked, trap not set), species, age, and gender.

Trap shyness has been observed in Haleakalā National Park when attempting to trap feral cats (Bailey 2007). To increase detection of the feline population of KALA, tracking tunnels were utilized in the hope that they would prove to be more effective in recording presence. The effectiveness of the baited tunnels and tracking ink was tested over two nights in Waihānau Valley prior to the field study (14–16 March 2005). The water-resistant tracking tunnels are one meter in length, and 20 x 20 cm in height and width (Figure 7). A 20 x 20 cm area of tracking ink was placed in the center-bottom of the tunnel. The hot dog bait was placed on a small piece of leaf which in turn was placed in the center of the tracking ink. The animals' prints were captured upon exit on tracking paper (Figure 8). The proportion of stations with animal prints was determined for each species at each transect.



Figure 7. Small mammal tracking tunnel, Pu`u Ali`i Natural Area Reserve, Moloka`i, 2005.



Figure 8. Mongoose and feral cat tracks, lower Waihānau transect, Kalaupapa National Historical Park, 16 March 2005.

Two sizes of sticky or glue traps were purchased for use: the large Catchmaster® 45 x 28 cm traps, and the smaller Trapper® 11.5 x 23 cm traps. The glue boards were only used at stations where they could be safely sheltered from forest birds (Figure 9). The larger Catchmaster® glue traps were only used at Pu`u Ali`i NAR, as no other site provided adequate cover for the large boards. Extreme weather conditions (e.g. heat, sun, rain) compromise the effectiveness of the glue, often allowing a captured animal to free itself from the board, leaving only signs of its presence.



Figure 9. Small glue trap placement, Pu`u Ali`i Natural Area Reserve, Moloka`i, 22 March 2005.

Trapping results for rats and mice are reported by trap night. A trap night is one trap set per night. Mouse capture rates were calculated using the number of trap nights for both

rat and mouse snap traps because mice were sometimes caught in rat traps. Rat capture rates were calculated using only large rat traps and the large glue boards, which assumes it is not possible to capture a rat in the smaller mouse snap trap. We corrected our number of trap nights to account for sprung traps, which reflects sampling effort more accurately. We used the formula developed by Beauvais and Buskirk (1999) to assess trap nights:

$$\text{Corrected trap night} = (\text{traps} \times \text{nights}) - (\text{sprung traps} \times 0.5)$$

The corrected trap rate is reported as the number of individuals/100 CTN (corrected trap nights).

Sprung Tomahawk® traps (for cats and mongooses) were accounted for by calculating a sprung trap as half a trap night (Seymour et al. 2005).

RESULTS

This survey detected the presence of four mammalian species: black rat, house mouse, mongoose, and cat. The brief pilot study of the baited tracking tunnels showed that they were effective in determining the presence of some target species. We found that cats and mongooses did enter the tunnels and that the ink pads and tracking paper provided sufficient prints to identify species. The survey did not detect the presence of Norway and Polynesian rats. Although feral dogs (*Canis familiaris*) were not detected via any trapping or tracking method used in this survey, dogs were heard, and tracks noted all along the Pu`u Ali`i NAR transect.

Black rats were captured or recorded along all transects except upper Waikolu Valley. A total of 19 black rats were captured; 14 in large snap traps, four in small (mouse) snap traps, and one on a glue board (Table 2). Only in one instance did a glue trap capture a rat. All other 22 rat detections in glue traps showed signs of presence only (Table 6, Figure 10). Tracking tunnels showed the presence of rats on four occasions. The trap rate for rats/100 CTN was 3.48.

Table 2. Summary of black rat captures (large snap traps) and tracks at Kalaupapa National Historical Park, March–May 2005.

Area	Rat CTN ¹	# Rat Captures	Rat Capture Rate ²	Percent of Stations with Tracking Tunnel Rat Sign
Pu`u Ali`i NAR	67.5	3	4.4	0%
Upper Waikolu	62.5	0	0	0%
Upper Waihānau	62.5	2	3.2	0%
Lower Waihānau	63.5	1	1.5	0%
Lower Waikolu	64.5	3	4.72	9%
Kauhakō Crater	61.5	2	3.25	9%
Kūka`iwa`a	48	4	8.3	0%
Total	430	15	3.48	3%

¹Corrected trap nights; ²Number of rats per 100 corrected trap nights

House mice were found in Pu`u Ali`i NAR, upper Waikolu, upper Waihānau, and Kauhakō Crater. Ten mice were captured using both snap trap sizes (four mice) and the glue boards (six mice; Table 3). The glue traps also indicated four instances of mice sign (Table 6). There was no sign of mice in the tracking tunnels. The trap rate for house mice was 1.2.

Table 3. Summary of house mouse captures and tracks at Kalaupapa National Historical Park, March–May 2005.

Area	Mouse CTN ¹	# Mouse Captures	Mouse Capture Rate ²	Percent of Stations with Tracking Tunnel Mouse Sign
Pu`u Ali`i NAR	129.5	2	1.54	0%
Upper Waikolu	125	3	2.4	0%
Upper Waihānau	120.5	2	1.66	0%
Lower Waihānau	127	0	0	0%
Lower Waikolu	116	0	0	0%
Kauhakō Crater	118.5	3	2.53	0%
Kūka`iwa`a	93.5	0	0	0%
Total	830	10	1.2	0%

¹Corrected trap nights; ²Number of mice per 100 corrected trap nights

Mongoose were found at six of the seven transects and absent from lower Waikolu Valley. Forty-two mongooses were caught using the Tomahawk® traps (Table 4). Tracking tunnel results showed the presence of mongooses on 60 occasions. Two instances of mongoose sign (hair only) were documented by the glue traps (Table 6).

Table 4. Summary of mongoose captures and tracks at Kalaupapa National Historical Park, March–May 2005.

Area	Mongoose CTN ¹	# Mongoose Captures	Percent of Stations with Tracking Tunnel Mongoose Sign
Pu`u Ali`i NAR	33	2	9%
Upper Waikolu	32	8	45%
Upper Waihānau	26	1	9%
Lower Waihānau	33	3	82%
Lower Waikolu	32.5	0	0%
Kauhakō Crater	33	16	82%
Kūka`iwa`a	26	12	88%
Total	215.5	42	45%

¹Corrected trap nights

Feral cats were found in lower Waihānau Valley, lower Waikolu Valley and Pu`u Ali`i NAR. Two cats were trapped using the Tomahawk® traps (Table 5). Tracking tunnel results showed the presence of cats on three occasions. There was no cat sign recorded on the glue boards.

Table 5. Summary of cat captures and tracks at Kalaupapa National Historical Park, March–May 2005.

Area	Cat CTN¹	# Cat Captures	Percent of Stations with Tracking Tunnel Cat Sign
Pu`u Ali`i NAR	33	1	0%
Upper Waikolu	32	0	0%
Upper Waihānau	26	0	0%
Lower Waihānau	33	0	27%
Lower Waikolu	32.5	1	0%
Kauhakō Crater	33	0	0%
Kūka`iwa`a	26	0	0%
Total	215.5	2	4%

¹Corrected trap nights

Glue boards recorded the presence of mice, rats, and mongooses. We observed 23 instances of rat sign or capture occurring at all transects except lower Waikolu Valley. Mouse sign or capture was documented at Pu`u Ali`i, upper Waikolu Valley, upper Waihānau Valley, and Kauhakō Crater, including one instance when two individuals were caught on the same board. We noted only two instances of mongoose sign on glue boards at upper Waikolu Valley and lower Waihānau Valley. No birds were captured or left sign, but there was one instance of a gecko being caught in a glue board. The glue boards neither captured nor recorded signs of any animals in lower Waikolu Valley.

Table 6. Summary of animal sign and captures¹ on glue boards in Kalaupapa National Historical Park, March–May 2005.

Type of Capture	Rat	Mouse	Mongoose	Avifauna
Sign Only	22	4	2	0
Animal Captured	1	6	0	0

¹227 total glue boards deployed



Figure 10. *Rattus* spp. hair and scat on small glue board, Kalaupapa National Historical Park, 2005. Weather data collected for the census sessions are summarized in Table 7.

Table 7. Summary of weather conditions during census periods, March–May 2005.

Area	Average Cloud Cover (%)	Average Rainfall ¹	Average Wind Speed ²
Pu`u Ali`i NAR	68	0	2
Upper Waikolu	5	0	1
Upper Waihānau	16	0	1
Lower Waihānau	55	0	1
Lower Waikolu	94	1	1
Kauhakō Crater	14	0	3
Kūka`iwa`a	36	0	2

¹Rain Code: 0 = no rain, 1 = drizzle

²Wind Code: 1 = smoke drifts, 2 = leaves rustle, 3 = leaves and twigs move

DISCUSSION

We recorded the presence of non-native small mammals throughout the study area using a variety of censusing and removal methods. Black rats were the most ubiquitous species, followed by mongooses, house mice, and feral cats. However, mongooses had the most captures and the most evidence recorded of all four species. The presence of any of these species was not surprising; the absence of data for other common rat species was unexpected.

Black rats were found at every transect from low to high elevation areas. Snap traps, glue boards, and tracking tunnels recorded black rat sign or capture. Although Polynesian rats were not identified during this survey, they are known from all the main islands (Kramer

1971) and have been documented in high-elevation, native forests on Maui and Hawai`i (Stone et al. 1984, Sugihara 1997, Bailey 2007). When snap trapping was conducted on Mōkapu Islet just outside the KALA boundary in 2002, a Polynesian rat was collected (Wood and Legrande 2002). Since no other rodent surveys have been performed on Moloka`i, we compared our findings to other trapping programs conducted on Maui (Table 8). As Table 8 illustrates, the lack of Polynesian rats in KALA could be due to the relatively low elevation of the island. At KALA, even the highest elevation transect areas are below the lowest elevations of the studies that captured Polynesian rats on Maui. At similar elevations at Ka`āpahu on Maui, no Polynesian rats were caught. Another suggestion for the lack of Polynesian rat captures was the relatively low number of trap nights, both at KALA and at Ka`āpahu. More importantly, however, is that Polynesian rats are often not caught until black rat numbers have been reduced. It is possible that we did not remove sufficient black rats to have detected Polynesian rats at KALA.

Table 8. Comparison of captures per 100 trap nights for black rats and Polynesian rats among areas on Maui and Moloka`i.

Area	Black Rats	Polynesian Rats	Trap Nights	Elevation (m)
Wakamoi Nature Preserve & Hanawī NAR, Maui (Sugihara 1997)	11.25	6.37	2479	1,500–2,125
Kīpahulu Valley, Maui (Stone et al. 1984)	21.4	29.4	2100	1,240–2,050
Ka`āpahu, Haleakalā NP, Maui (Bailey 2007)	2.8	0	288	548–927
Kalaupapa NHP, Moloka`i (this study)	3.48	0	418.5 ¹	20–1180

¹Corrected trap nights

Given that we only caught 15 rats, the lack of Norway rats was not surprising. Similar data have resulted from work on Maui and the island of Hawai`i. In a four-year study of Hawai`i Island wet montane forests, Lindsey et al. (1999) captured 1,251 rats of which only 13 (one percent) were Norway rats. In a study of Waikamoi and Hanawī NARS on Maui, no Norway rats were among the 437 rat captures which occurred in forest habitat similar to that on Hawai`i Island (Table 8, Sugihara 1997).

Ecological impacts from non-native rodents vary with regards to bird species. Rodents can affect populations of native forest birds through predation, competition for resources, habitat degradation, and subsidization of predators on forest birds (Ebenhard 1988, Moors et al. 1992). The primary effect of small mammals such as rats on forest birds is predation of eggs, nestlings, fledglings, and sometimes adults (Atkinson 1977, Scott et al. 1986). Among the three rat species that inhabit Hawai`i, black rats are thought to be the most threatening agent in forest bird declines, mostly due to their arboreal nature (Atkinson 1977).

Black rats can have destructive effects on native plants. They have been known to strip the bark from koa trees (*Acacia koa*; Hess et al. 2004). We observed similar stripping of ohe makai (*Reynoldsia sandwicensis*) trees by rats at Kauhakō Crater in Kalaupapa. This

behavior inhibits the growth of koa; the effect on ohe makai is unknown. Rats and mice are known to prey on sandalwood seeds on West Maui (Hughes unpubl. data). Rodent populations present a significant threat to the reproduction of some plants on Moloka`i, and are a particular management concern for the numerous threatened and endangered species found there. We have seen evidence of predation by rats on lama (*Diospyros sandwicensis*), hō`awa, and hala seeds in coastal forests at Kūka`iwa`a and Ka`aloa and on loulu palm seeds at higher elevation forest at the back of Wai`ale`ia Valley (Hughes unpubl. data). The evidence consisted of partially eaten seeds found in small piles under native trees. Rats also cache large piles of hala seeds in the coastal forests of Kūka`iwa`a.

House mouse captures were infrequent and focused mainly in the higher elevation transects (above 730 m) except for the Kauhakō Crater (30–100 m), which is the survey site closest to human habitation. House mice are usually associated with drier grassland habitats (Tomich 1986). However, substantial mouse populations have been found in high elevation rain forests on Maui (Sugihara 1997), which supports our presence data at the higher elevation transects. This inventory did not record the presence of a considerable house mouse population. It does not seem that house mice pose much of a threat to native plant species in these numbers, though they do occur in primarily native and mixed habitats where damage to sensitive species is likely to occur.

Mongoose were by far the most often caught or recorded species in this survey. Even though mongooses are commonly found in higher elevations on Moloka`i, mongoose populations are highest in vegetation types below 610 m (2,000 ft) (Tomich 1986, Stone and Loope 1987). This is evident in our study as more captures were recorded at the lowest elevation areas, Kūka`iwa`a and Kauhakō Crater, than at the other study areas. Though this study found no evidence of mongooses at the lower Waikolu transect, we cannot assume that they are absent from this area.

Mongoose and cats are primary predators of endangered Nēnē and Hawaiian Petrel at Haleakalā National Historical Park (Simons 1983, Banko 1988, Natividad Hodges 1994, Baker and Baker 1996; Natividad Hodges and Nagata 2001). Laboratory tests show that mongooses are good tree climbers (Stone and Loope 1987) and may also depredate native forest bird species. The Nature Conservancy has documented the impacts of cats and mongooses on native seabird populations at Mo`omomi Preserve (Tachibana 2007). With the implementation of small mammal control programs, healthy shearwater nesting colonies were reestablished at the preserve. Wedge-tailed Shearwaters and Red-tailed Tropicbirds, both ground nesting species, were detected in KALA during the 2005 shoreline bird inventory (Kozar et al. in review) and are vulnerable to predation by mongooses and cats.

Cats were detected infrequently by live trap and tracking tunnels. They are difficult to capture and detect because of their stealthy nature. Data from Haleakalā National Park's trapping program from 1989 to 2004 found it took 936 to 19,635 trap nights to capture one cat (Bailey 2007) in forested subalpine habitat. The disparity in capture rate compared to this study (108 trap nights per cat) could be due to a larger cat population in KALA, differences in elevation and proximity to human settlement, or chance. More sampling is necessary to arrive at an accurate estimate of the feral cat population in KALA.

Feral cats are a culturally sensitive issue within the Kalaupapa Settlement, and any program to remove or reduce the feral cat population park-wide would require great

delicacy. Cats are regularly captured in the Kalaupapa settlement area for neutering and release. National Park Service staff and volunteer veterinarians captured and spayed or neutered 481 cats between January 1998 and March 2007 (NPS unpublished data). This informal program could account for trap shyness, especially close to the settlement. Cats have never been trapped in the backcountry.

Though this study was an inventory of small mammals, comparing the different censusing and trapping methods used provides worthwhile discussion for aiding future monitoring projects. The number of tracking tunnel signs for mongooses and cats was proportionally higher than the overall capture rate. On three occasions, cats visited the tracking tunnels, but only at the site located closest to houses and human settlement. On 24 occasions there were both tracking tunnel sign and a mongoose captured in a cage trap at the same station, suggesting the possibility that mongooses were more inclined to enter the tunnel before entering the trap.

Rats and mice had more captures or sign at the glue and snap traps baited with peanut butter than at the tracking tunnels baited with hot dog. For rats the number of tracking tunnel signs was low even on transects where the capture rate by snap or cage traps was high, and for mice there was no sign at the tracking tunnels. These discrepancies could be due to differences in the baits, the devices, the locations of the device, or some other factor. The peanut butter bait proved to be a poor choice in wet weather as it easily dissolved from the glue boards and the bait pedals on the snap traps. Isopods and ants were attracted to the peanut butter bait, and rebaiting was necessary in several instances. Logistics and cost prevented effective experimentation with different baits, which might have helped determine the best possible bait. This also prevented prebaiting at each site to allow animals to investigate the introduction of foreign objects and food sources into their territories. Instead, we experimented with several methods of gathering presence/absence information to help address this deficiency.

Glue traps were more effective as a censusing tool than as a removal method. Even if rats were not captured on the boards, the glue traps were especially successful in recording rat presence through hair or feces sign. Though most transects had rat snap trap captures as well, only glue boards recorded rat presence in the upper Waikolu Valley. Glue boards proved to be somewhat ineffectual in capturing rodents, with 28 instances of rodents freeing themselves from the traps compared to only seven captures. On one board we found a partially eaten mouse carcass, indicating that some of the “freed” captures may have been depredated while incapacitated. Leaves and twigs were often found stuck to the traps, creating areas where rodents could access the bait without getting trapped themselves. The weather also caused some malfunctions. During the survey session in lower Waikolu Valley, incessant precipitation caused the glue traps to be ineffective at catching individuals or capturing sign.

Dogs were detected throughout Pu`u Ali`i NAR. Pu`u Ali`i NAR as well as the adjacent Kamakou and Pelekunu Valley Nature Conservancy Preserves (The Nature Conservancy) are primarily managed using dog-assisted pig hunts. This creates a plausible scenario where stray hunting dogs could travel into and subsequently reside in Pu`u Ali`i NAR.