Comparison of Managed and Unmanaged Wedge-Tailed Shearwater Colonies on O'ahu: Effects of Predation[1]

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Abstract: On O'ahu, Wedge-tailed Shearwaters (*Puffinus pacificus*) and other seabirds nest primarily on small offshore islets, but fossil evidence shows that many seabirds formerly bred on O'ahu itself. Predation by introduced mammals is suspected to be the primary factor preventing shearwaters and other seabirds from reestablishing large nesting colonies on O'ahu. We investigated the effects of predation on Wedge-tailed Shearwaters by comparing three small unmanaged colonies at Mālaekahana State Recreation Area on O'ahu, where feral cats are fed by the public, with a large managed colony at nearby Moku'auia Island State Seabird Sanctuary, where predators are absent. During three visits on 19 April, 16 June, and 23 October 2000, we located 69 occupied burrows in three colonies at Mālaekahana and 85 occupied burrows in four monitoring plots at Moku'auia. Many more nests produced chicks at Moku'auia (62%) than at Mālaekahana (20%). Among plots at Mālaekahana, reproductive success was lowest (zero) at the colony closest to the cat feeding site. In addition, 44 adult shearwater carcasses were found at Mālaekahana near the cat feeding site. Predation, most likely by cats attracted to supplemental food, had a devastating impact on shearwaters at Mālaekahana. At one colony there was complete reproductive failure and almost all adults were killed. Populations of long-lived species like seabirds are sensitive to adult mortality, and Mālaekahana may act as a sink, draining birds away from other areas.

THE WEDGE-TAILED SHEARWATER (*Puffinus pacificus*) is a common seabird that occurs throughout most of the tropical and subtropical Pacific and Indian Oceans (Harrison 1983, Harrison 1990, Whittow 1997). Wedge-tailed Shearwaters are pelagic for much of the year, occurring on the open ocean far from land, but during the breeding season they return to coastal areas and nest in underground burrows, sometimes forming large colonies. On O'ahu, the majority of shearwater nesting colonies currently are located on small offshore islands, but fossil evidence shows that they and several other seabird species were once abundant on O'ahu proper (Olson and James 1982). The ground-nesting habits of most seabirds and their relative clumsiness on land make them vulnerable to predation, and it is thought that predation by humans and by other mammals introduced by humans, such as dogs (*Canis familiaris*), cats (*Felis domesticus*), small Indian mongooses (*Herpestes auropunctatus*), and rats (*Rattus* sp.), has reduced or extirpated seabird populations on many Pacific Islands (Olson and James 1982, Steadman 1995). Predation by introduced mammals is the most serious threat to the endangered Hawaiian Petrel (*Pterodroma sandwichensis*) (Simons 1985, Simons and Hodges 1998, Hodges and Nagata 2001, Hu et al. 2001) and the threatened Newell's Shearwater (*Puffinus auricularis newelli*) (Ainley et al. 1997) and may be the primary factor preventing seabirds from re-

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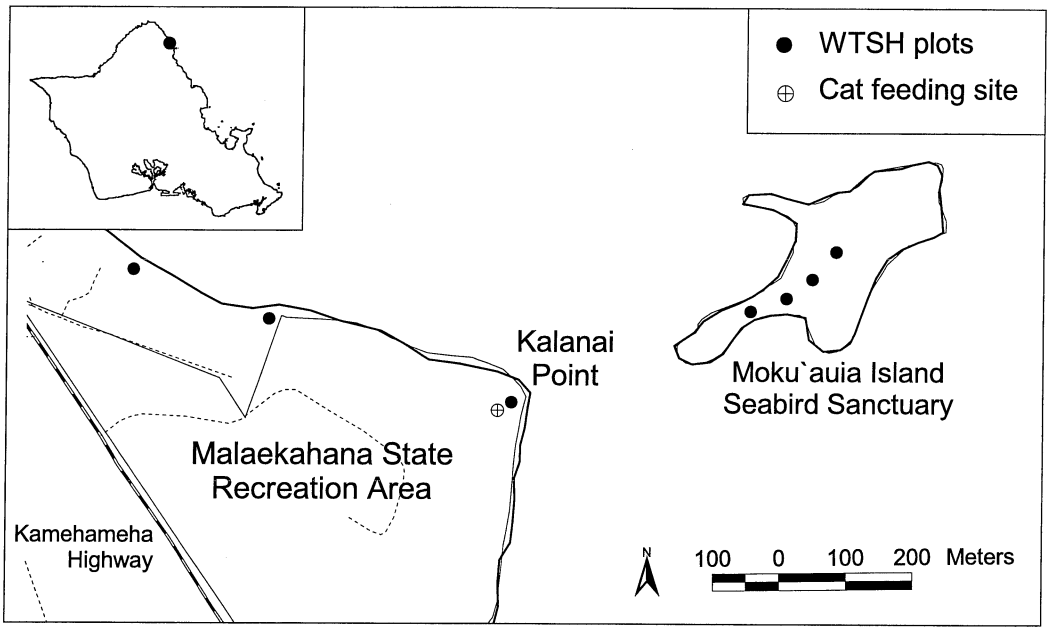

FIGURE 1. Location of Wedge-tailed Shearwater (WTSH) study sites at Mālaekahana State Recreation Area and Moku'auia Island State Seabird Sanctuary.

establishing large nesting colonies on O'ahu. Most of the islets in the main Hawaiian Islands where Wedge-tailed Shearwaters currently nest are managed as seabird sanctuaries by the Hawai'i State Department of Land and Natural Resources, Division of Forestry and Wildlife. Management activities on these offshore islands include predator control, educational signs, enforcement of sanctuary rules, and seabird surveys and monitoring. The few Wedge-tailed Shearwater colonies on O'ahu proper do not benefit from these management techniques and have remained small. The purpose of this study was to investigate the effects of predation on Wedge-tailed Shearwaters by comparing unmanaged colonies at Mālaekahana State Recreation Area with a managed colony on nearby Moku'auia Island State Seabird Sanctuary.

Study Sites

Mālaekahana State Recreation Area, located near Lā'ie on the windward side of O'ahu (Figure 1), contains a campground and other facilities that are operated by the Hawai'i Division of State Parks. Mālaekahana and private lands to the west support three small Wedge-tailed Shearwater colonies, which we monitored during the nesting season for this study. Plot 1 was located within the recreation area on Kalanai Point. Plots 2 and 3 were situated on private beachfront land 400 and 600 m, respectively, northwest of Kalanai Point. Plant species common to all plots were 'aki'aki (*Sporobolus virginicus*), morning glory (*Ipomoea indica*), tree heliotrope (*Tournefortia argentea*), and ironwood (*Casuarina* sp.). In addition, plot 1 contained naupaka kahakai (*Scaevola sericea*) and hala (*Pandanus tectorius*), and plot 2 contained hau (*Hibiscus tiliaceus*), 'ākulikuli (*Sesuvium portulacastrum*), and sea grape (*Coccoloba uvifera*). In plot 1 most shearwater burrows were concealed under dense thickets of naupaka. In plots 2 and 3 burrows were located in bare sand, under clumps of 'aki'aki grass, and at the base of ironwood and heliotrope trees.

Several species of introduced mammalian predators are found at Mālaekahana, including dogs, cats, and presumably rats. Surprisingly, mongooses proved to be rare or absent in the area (see Results). Mālaekahana State Recreation Area is also the site of a feral cat feeding colony, where cat food is provided to feral cats on a daily basis by members of the public. The cat feeding site was located 30 m from the shearwater nesting colony in plot 1 (Figure 1).

Moku'auia Island State Seabird Sanctuary is located 230 m offshore from Kalanai Point and contains a large nesting colony of Wedge-tailed Shearwaters. Division of Forestry and Wildlife staff have monitored reproduction of shearwaters at Moku'auia since 1995 using 4-m radius circular plots. The mean ($\pm$SD) number of chicks produced per year at Moku'auia was 3448 ± 130 from 1995 to 2000. Four plots distributed systematically along the length of the island were used for this study and monitored concurrently with plots at Mālaekahana (Figure 1). Vegetation varied among plots and included 'aki'aki, 'ākulikuli, alena (*Boerhavia* sp.), pōpolo (*Solanum americanum*), *Portulaca* sp., sea grape, and Bermuda grass. Shearwater burrows occurred in bare sand, under clumps of 'aki'aki, at the base of sea grape trees, and under brush piles created from pruning sea grape trees. Polynesian rats (*Rattus exulans*) occur on the island, but all other mammalian predators are absent.

MATERIALS AND METHODS

Wedge-tailed Shearwaters typically return to nesting areas on O'ahu in April and establish a nesting burrow. A single egg is laid in mid-June and is incubated continuously for about 53 days by both parents in alternating shifts lasting several days (Byrd et al. 1983, Floyd and Swanson 1983, Whittow 1997). Chicks are fed by both parents and fledge after 100–115 days, most often in November (Byrd et al. 1983, Whittow 1997; Division of Forestry and Wildlife, unpubl. data). We visited each study plot three times, on 19 April, 16 June, and 23 October 2000, timed to monitor different stages of the nesting cycle. During the first visit we counted the number of occupied burrows in each plot by using a flashlight to look into the burrow, or if necessary by reaching into the burrow and feeling for a bird. Although no eggs were present at that time, we assumed each occupied burrow would be used for nesting. It is possible that some burrows were occupied by nonbreeding birds, but nonbreeding adults also could be subject to predation, and there was no reason to suspect that the proportion of nonbreeders differed among the study plots. On the second visit we counted the number of burrows that contained an egg or a bird that was incubating an egg. On the final visit, close to the typical fledging period, we checked each burrow for the presence of a chick, which we assumed would fledge. Nest success among sites was compared with a chi-square test of the numbers of failed and successful nests.

During each visit we also looked for signs of predation on eggs, chicks, or adults, such as burrows that were dug up, broken eggs, clumps of feathers, or bird carcasses. Carcasses were examined and, depending on their condition, a few were collected for necropsy. We knew from personal observations and from conversations with State Parks staff and private landowners that feral cats occurred at Mālaekahana and that several feral dogs also frequented the area. To determine the abundance of mongooses, we deployed 20 live traps (Tomahawk Model no. 201) (12.5 by 12.5 by 40 cm [5 by 5 by 16 inches], single door) throughout the area over a four-night period (80 trap nights) from 2 to 5 May. This method has been effective for trapping mongooses in other areas of O'ahu (Smith et al. 2000). Trap openings were small enough that cats would not be captured.

RESULTS

On 19 April, we located a total of 69 occupied burrows in the three nesting colonies at Mālaekahana and a total of 85 occupied burrows in the four monitoring plots at Moku'auia Island (Table 1). On 16 June, incubating adults were present in 26 burrows at the three Mālaekahana colonies and in 63 burrows in the

four plots at Moku'auia. The final survey on 23 October yielded 14 fully grown chicks in the three colonies at Mālaekahana and 53 chicks in the four plots at Moku'auia.

TABLE 1

Number of Occupied Wedge-tailed Shearwater Burrows at Mālaekahana State Recreation Area and Vicinity and at Moku'auia Island State Seabird Sanctuary during Different Stages of the Nesting Season

	No. of Occupied Burrows		
Study Sites	19 April[a]	16 June[b]	23 October[c]
Mālaekahana			
Plot 1	23	3	0
Plot 2	33	15	6
Plot 3	13	8	8
Total	69	26	14
Moku'auia Island			
Plot 1	8	6	3
Plot 2	21	21	14
Plot 3	21	12	17
Plot 4	35	24	19
Total	85	63	53

[a] During burrow establishment.
[b] During incubation.
[c] Just before fledging.

The nest survival rate was much higher at Moku'auia (62%) than at Mālaekahana (20% [Figure 2]), and significantly more nests fledged chicks at Moku'auia than at Mālaekahana ($\chi^2 = 27.4$, df = 1, $P < 0.001$ [Table 1]). Nest survival differed among colonies at Mālaekahana ($\chi^2 = 19.6$, df = 2, $P < 0.001$), with the lowest success (zero) at the colony closest to the cat feeding site (Figure 2). The colony farthest from the cat feeding site had a success rate almost as high as that at Moku'auia.

A total of 44 adult Wedge-tailed Shearwater carcasses was found at Mālaekahana by us and by park staff, most of them in and near plot 1. No carcasses were found in the other plots at Mālaekahana or on Moku'auia Island. Most carcasses were in poor condition by the time they were found; some were decapitated, some were missing one or both wings, and most had been partially eaten. All carcasses were found on the surface, not in burrows. We saw no evidence of burrows being dug up, suggesting that birds were caught on the surface as they entered or left their burrow.

On one visit we observed a minimum of 15

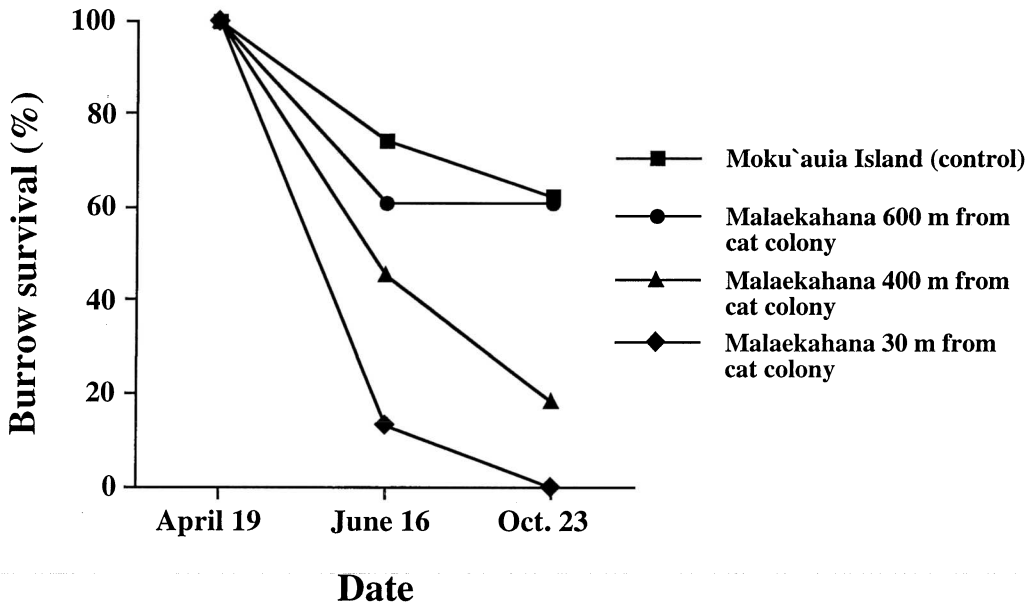

FIGURE 2. Survival of burrows over time at Mālaekahana State Recreation Area and Moku'auia Island State Seabird Sanctuary.

cats at the feeding site, and we saw at least one cat among the shearwater burrows in the naupaka thicket in plot 1 on every visit. On two visits we observed untagged, apparently feral dogs ranging up and down the shoreline at Mālaekahana and on adjacent land near plots 2 and 3. Surprisingly, no mongooses were captured in the study area in 80 trap nights, indicating that few or perhaps no mongooses were present at Mālaekahana during the study.

DISCUSSION

Predation had a devastating impact on Wedge-tailed Shearwaters at Mālaekahana State Recreation Area. At one colony there was complete reproductive failure and almost all adults were killed (44 carcasses from 23 burrows). Wedge-tailed Shearwaters lay only a single egg each year and do not begin breeding until they are 4 yr old (Byrd et al. 1983, Floyd and Swanson 1983, Whittow 1997). If populations are to be stable, this low rate of reproduction must be balanced by a high rate of adult survival, making the breeding adults extremely valuable in a demographic sense. Consequently, populations of long-lived seabirds such as albatrosses, petrels, and shearwaters, and large raptors such as the California Condor (*Gymnogyps californianus*) are especially vulnerable to the loss of adults (Croxall and Rothery 1991, Meretsky et al. 2000). Predation on the threatened Newell's Shearwater is suspected to be one of the primary causes of recent population declines (Ainley et al. 1997). Dead shearwaters have been found at Mālaekahana in previous years; one resident near the park reported that several years ago there were over 50 shearwater carcasses in the area, indicating that our results do not represent an isolated event. In a follow-up visit on 25 April 2001, 17 of the burrows in plot 1 at Mālaekahana were occupied by shearwaters again. The source of these new birds is not known, but the high adult mortality rate must cause Mālaekahana to act as a sink, draining birds away from other areas, possibly including nearby Moku'auia Sanctuary.

There is strong circumstantial evidence that cats were the primary predators on Wedge-tailed Shearwaters at Mālaekahana. Cats were unusually abundant in the area because they were attracted to supplemental food provided by people. We saw cats among the nesting burrows in the naupaka thicket in plot 1 on every visit. Furthermore, shearwater carcasses were found only at the plot nearest the cat feeding site, and nest success was higher at plots farther from the cat feeding site, suggesting that cats concentrated by the supplemental food were responsible for much of the predation.

It is unlikely that mongooses were responsible for the observed predation because our trapping showed that few or no mongooses were present in the area during the study. Dogs can be serious predators on nesting seabirds, and a resident near the park suspected dogs to be the predator in a previous year. In our study, however, the shearwater carcasses were concentrated in the area most densely occupied by cats. If the dogs we observed ranging along the shoreline were responsible for the predation, all three shearwater colonies at Mālaekahana should have been affected similarly, but that was not the case.

Three additional observations are worth noting. First, in plot 3 at Mālaekahana we found four newly occupied burrows on our second visit, which apparently were dug after our first visit. The total number of burrows in plot 3 was thus actually 17, but not all burrows were occupied simultaneously and some could have been renesting attempts. Inclusion of these burrows would have lowered the estimate of nest success at plot 3 to 47% (8 out of 17) and increased the difference in success between colonies at Mālaekahana and Moku'auia. Second, the stake marking the location of plot 4 at Moku'auia was covered by shifting sand between visits and we were not able to relocate it. The plot may have moved by approximately 1 m between visits, possibly accounting for some of the decrease in number of active burrows. Third, we found several burrows in plot 1 at Moku'auia and one burrow in plot 2 at Mālaekahana that appeared to have been collapsed by human

traffic. Plot 1 at Moku'auia contained the lowest density of burrows and had the lowest success rate of any plot on the island. This plot lies at the narrowest part of the island and is often traversed by people to reach the far side of the island (Figure 1). It is likely that human traffic decreased success of burrows in this area and discourages birds from nesting there. Similar human traffic at both sites makes Moku'auia an even more appropriate control for Mālaekahana.

Wedge-tailed Shearwaters and other seabirds in Hawai'i are protected by the federal Migratory Bird Treaty Act (50 CFR 10) and by State law under Title 13, Part 2, Chapter 125 of the Hawai'i Administrative Rules, which prohibit the hunting, capturing, killing, possession, shipping, etc., of migratory birds, unless authorized by a permit. Results of this study show that providing supplemental food to feral cats may lead to the killing of shearwaters by maintaining these predators at unusually high densities. Removal of feral cats, particularly those attracted by supplemental food, or at least relocating the feeding site to an area where cats would do less damage likely would increase the survival and reproduction of Wedge-tailed Shearwaters at Mālaekahana.

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