

DEPREDATION OF ENDANGERED BURROWING SEABIRDS IN HAWAII: MANAGEMENT PRIORITIES

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SUMMARY

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Small Indian Mongooses *Herpestes javanicus* have until recently been absent from the island of Kaua'i, Hawai'i. In anticipation of required management, we examine evidence that mongooses may be a significantly more dangerous predator than cats *Felis catus* for burrowing seabirds, particularly the endangered Hawaiian Petrel *Pterodroma sandwichensis* and threatened Newell's Shearwater *Puffinus newelli*. Mongooses are small enough to enter burrows, allowing them to take eggs, nestlings and adults. In contrast, cats appear too broad to enter any but the widest burrows, so they tend to attack adults and young when these come to the burrow mouth. Given that these seabird species no longer persist in any numbers at low elevations on islands where mongooses are present, and that Kaua'i is one of the lowest of the main Hawaiian islands, if resources are limited, local control or eradication of mongooses would be a higher priority for management than control of cats or rats *Rattus* spp., although control of just one predator might result in increases in the others. The most important management action is to keep mongooses off islands where they are not already established.

Keywords: cat, *Felis catus*, Hawaii, *Herpestes javanicus*, islands, mongoose, nesting burrows, *Pterodroma sandwichensis*, *Puffinus newelli*

INTRODUCTION

The introduction of mammalian predators onto islands with terrestrially breeding seabirds can result in profoundly negative effects for breeding success and eventually for populations of the birds (e.g. Moors & Atkinson 1984). The preferred response is to remove such predators, and there are numerous successful examples (Townes *et al.* 1997, Nogales *et al.* 2004, Parkes *et al.* 2014). However, if complete predator removal is logistically impossible and complicated by the presence of multiple introduced predators, effective management may become more problematic. In such instances, knowledge of the relative damage contributed by each predator species may be helpful, so that limited resources can be directed at the species and management efforts that would be likely to have the greatest positive effect on seabirds and other native fauna.

This note examines the relative roles of two predators of endangered burrowing seabirds in Hawai'i, the feral cat *Felis catus* and small Indian mongoose *Herpestes javanicus* {syn. *H. auropunctatus*}, on two species of burrowing procellariids: the Hawaiian Petrel *Pterodroma sandwichensis* and Newell's Shearwater *Puffinus newelli*. We consider whether differences in body size could determine the predators' relative efficiencies in accessing seabird nesting burrows and thus their degree of threat to the birds.

Hawaiian Petrels and Newell's Shearwaters were formerly abundant on all Hawaiian islands (Olson & James 1982). A combination of overharvesting by humans, habitat destruction, and predation by introduced mammals have so reduced populations that the petrel is now listed as Endangered and the shearwater is listed as Threatened under the *Endangered Species Act* (Ainley *et al.* 1997, Simons & Hodges 1998). While there is a small breeding population of

Hawaiian Petrels on Hawai'i, the main populations are on Kaua'i, Maui and Lana'i (Simons & Hodges 1998, J. Penniman pers. comm.). Similarly, while small populations of Newell's Shearwaters remain on the island of Hawai'i and some may still persist on Maui and O'ahu, the main breeding population is on Kaua'i (Ainley *et al.* 1997, Reynolds & Richotte 1997, Cooper & Day 2003).

Cats, long known to be significant predators of seabirds (Moors and Atkinson 1984), are present on all the main Hawaiian islands at almost all elevations (Tomich 1969, Duffy & Capece 2012). They are the main source of human-assisted mortality of breeding Newell's Shearwaters on Kaua'i, annually killing 5% of adults (Ainley *et al.* 2001). On Maui, Simons (1983) and Hodges & Nagata (2001) reported predation to be variable, but greatly reduced when study colonies were protected from cats and mongoose by trapping.

The small Indian mongoose is present on all main islands except Lana'i and Kaholo'awe and may have recently colonized Kaua'i (Tomich 1969, Nuwer 2012). Hodges & Nagata (2001) reported that the mongoose was the "major" predator of Hawaiian Petrels at the Haleakala colony, Maui at 2400–3055 m elevation, with cats being "secondary," although very rare above 2550 m (C. Bailey, National Park Service, pers. comm.). Similarly, Hu *et al.* (2001) reported that cats are the only predator atop Mauna Loa at >2400m.

At least one species of rat (*Rattus exulans*, *R. rattus* and/or *R. norvegicus*) is present on each of the main islands (Tomich 1969) and, in addition to being prey for cats and mongooses, may be responsible for predation of Newell's Shearwater eggs and young (Ainley *et al.* 2001). Hodges & Nagata (2001) suggested that rats were responsible for 41% of depredations at the Haleakala Hawaiian Petrel colony, presumably on eggs and small young, but

Simons (1983) believed that rats were only scavengers, contributing indirectly to petrel mortality by providing an alternative food source for cats and mongooses.

METHODS

Internal dimensions of Hawaiian Petrel and Newell's Shearwater burrows are not known. We could not conduct experiments to examine whether predators could enter burrows without causing unacceptable disturbance for these two endangered seabirds. We considered indirect evidence to determine whether cats and mongoose differed in their access to burrows of the two seabird species.

Horizontal and vertical dimensions of burrow exits were measured on Lana'i for Hawaiian Petrels, and similar data were obtained for Newell's Shearwater on Kaua'i from the published literature (Ainley *et al.* 1997). Hawaiian Petrel burrows may narrow the farther in they extend, but we had no way to quantify this without disturbing or destroying burrows or without creating either a sampling bias or a bias in accuracy toward shallower burrows.

Maximum lateral skull dimensions (zygomatic breadth) of mongooses and cats were obtained from the specimen collection at the Bishop Museum in Honolulu. Carla Kishinami of the Bishop Museum provided helpful observations of behavior of a living cat.

RESULTS

Newell's Shearwater burrow entrance dimensions on Kaua'i were $9.9 \text{ cm} \pm 1.8 \text{ cm}$ (height; mean \pm SD) by $13.8 \text{ cm} \pm 3.1 \text{ cm}$ (width) by $87.7 \text{ cm} \pm 22.2 \text{ cm}$ (length) ($n = 19$, Telfer 1986 in Ainley *et al.* 1997). Hawaiian Petrel burrows on Lana'i averaged heights of $14.1 \text{ cm} \pm 3.6 \text{ cm}$ and widths of $19.5 \text{ cm} \pm 5.9 \text{ cm}$ ($n = 7$, data courtesy of J. Penniman). On Haleakala, many nests are not located in burrows but in crevices in lava formations. For burrows, average width was $19.14 \text{ cm} \pm 11.73 \text{ cm}$, but some were as small as 4 cm (Simons & Hodges 1998). Ten percent of burrows at Haleakala were less than 1 m in length, and 50% were greater than 2 m (Simons & Hodges 1998) (Table 1).

Cat skulls had a zygomatic breadth (skull diameter) of $6.61 \text{ cm} \pm 0.572 \text{ cm}$ (based on six samples), whereas mongoose skulls had a zygomatic breadth of only $3.09 \text{ cm} \pm 0.369 \text{ cm}$ (based on four samples, Figure 1). We measured one specimen of a mongoose from the collection at the Bernice Pauahi Bishop Museum in Honolulu. The specimen had skin removed, but musculature intact. We recorded its dimensions as skull breadth 3.52 cm, shoulder 3.51 cm and hip width 3.59 cm.

DISCUSSION

We suggest that mongooses, with skull and hip width of only 3–4 cm, can easily enter burrows of both the Hawaiian Petrel and the Newell's Shearwater almost anywhere in Hawai'i. On Haleakala, Simons (1983) reported without further details that mongooses could pass through 5 cm holes, "an ability which makes all Dark-rumped [Hawaiian] Petrel burrows accessible to them" and that mongooses appeared to prefer eggs and that "a single mongoose or pair of adults ... systematically searched out and killed many of the petrels over a wide area. In most cases the birds that were killed were not eaten or even removed from their burrow ... It appeared that mongooses killed many of the birds while searching for eggs."

Cats with skulls measuring 6.6 cm in diameter would be a tighter fit for burrows and nest cavities. We do not know the effective width of a cat, which would depend on age and sex, but C. Kishinami (pers. comm.) observed that her domestic cat could barely pass through a loop with a diameter of 11.7 cm, suggesting that cats would have difficulty entering many Newell's burrows and would have difficulty entering at least some Hawaiian Petrel burrows, assuming they could then crawl 1 or 2 m down a burrow to the nest cavity. Much of the depredation by cats may occur as they wait at burrow mouths to kill adult birds arriving and leaving the nests, a much less efficient process than entering burrows. For one such event caught on surveillance film (Judge *et al.* 2012), Hu (pers. comm.) reported "a cat waited outside for the chick to emerge. We do have a video of a cat getting about half-way into a burrow, but that's as far as it



Fig. 1. Comparative sizes of a mongoose and an adult cat with feral pelage, from the Bernice Pauahi Bishop Museum collection, Honolulu, HI.

TABLE 1
Recorded burrow dimensions for Hawaiian Petrel and Newell's Shearwater

| Species, Island | Burrow dimensions (cm) | | | N | Source |
|----------------------------|------------------------|-------------------|--|----|---------------------------|
| | Height | Width | Length | | |
| Hawaiian Petrel | | | | | |
| Lana'i | 14.1 ± 3.6 | 19.5 ± 5.9 | | 7 | J. Penniman, unpub. data |
| Maui | | 19.14 ± 11.73 | < 1 m (10% of burrows); > 2 m (50% of burrows) | | Simons & Hodges 1998 |
| Newell's Shearwater | | | | | |
| Kaua'i | 9.9 ± 1.8 | 13.8 ± 3.1 | 87.7 ± 22.2 | 19 | Ainley <i>et al.</i> 1997 |

could go. Mauna Loa burrows are mostly much longer than half a cat's length." On Haleakala, almost all petrel nests are more than a human's arm length, and in one instance a cat was observed waiting for the return of a satellite-tagged petrel in the nest cavity entrance; the petrel sensed this and refused to attempt re-entry (Ainley, pers. comm., based on J. Penniman crittercam video). Similar ambush tactics at burrow mouths have been reported for cats preying on Black-vented Shearwaters *Puffinus opisthomelas* on Natividad Island (B. Keitt, pers. comm.) and Wedge-tailed Shearwaters *Puffinus pacificus* on Maui (F. Duvall, pers. comm.).

Mongoose appear to be a more serious threat to burrowing Hawaiian seabirds than are cats (cf. Hodges & Nagata 2001). At the population level, it is significant that the main colonies of both Hawaiian Petrels and Newell's Shearwaters exist where cats are present, but mongooses are absent (Lana'i) or perhaps have only recently colonized (Kaua'i); are at an elevation and habitat where mongooses do not occur (Mauna Loa), or survive at upper elevations where mongooses are rare and intensely controlled (Haleakala). On Mauna Loa, mongooses are unknown at 2500–2926 m elevation, where most of the remaining Hawaiian Petrels nest, and cats are the only mammalian predators (D. Hu, pers. comm.). Simons (1983) reported there was no resident population of mongooses at Haleakala and that it was "well above the normal range of these animals," which might have expanded recently because of human activity.

Mongoose appear to be limited to ambient air temperatures above 10°C (Nellis & McManus 1974). Only the summits of Hawai'i and Maui have annual air temperatures below 10°C, although the summit of Kauai is below 11°C (Giambelluca *et al.* 2014). The 10°C isotherm occurs at roughly 2200–2300 m, and areas above this may be too cold for permanent mongoose populations. The other islands appear to be well within the thermal comfort range of the mongoose.

Eradication of predators from most Hawaiian islands appears currently infeasible because of the enormous investments needed in labor and funding (Parkes *et al.* 2014), so management will be limited to controlling predators around procellariid breeding sites. Current control methods for rats, cats and mongooses are limited to terrestrial applications, which limit the area they can cover. Trapping is the only effective, legal control method for cats at present in Hawai'i (Hodges & Nagata 2001). Live-trapping success is high for mongooses (Baldwin *et al.* 1952, Young *et al.* 2013) but less so for cats (Domm & Messersmith 1990). Traps that kill quickly have been developed for both cats and mongooses and are beginning to be used in Hawai'i (Poutu & Warburton 2001, Peters & Wilson 2007). Since such traps do not have to be checked daily, this should increase the area covered per unit effort. An anticoagulant toxicant, diphacinone (Ramik Minibars: All-Weather Rat and Mouse Killer, EPA Reg. No. 61282-26) is effective against both mongooses and rats (Stone *et al.* 1995, Smith 1998, Smith *et al.* 2000, Eisemann & Swift 2006). New baits, such as para-aminopropiophenone-based Curiosity Bait are in development and may be useful against both cats and mongooses (Johnston *et al.* 2011), but additional work is urgently needed (Barun *et al.* 2011).

Unfortunately, all current terrestrial applications rely on trail systems, which could actually increase predation by creating pathways for cats and mongooses into certain habitats. Aerial broadcast of poisons would minimize disturbance and cost and would be effective over wider areas, including extreme terrain that

restricts or excludes terrestrial management efforts. Unfortunately, aerial techniques remain extremely limited, especially as most remaining petrel and shearwater nesting areas are within watersheds providing water for Hawai'i's towns. Ramik Green, effective against both mongooses and rats, has been used for aerial control, but is currently restricted to ground use (Eisemann & Swift 2006).

Ideally, predator control should target all three mammals simultaneously, as the removal of only one predatory species may result in a "release" of populations of the other predators, potentially causing more damage than might have occurred without intervention (Courchamp *et al.* 1999, Zavaleta *et al.* 2001). However, until future research disproves the hypothesis offered herein that only mongooses can enter most burrows and are thus likely to be the most dangerous predator, control of mongooses should be the management priority in any anti-predator effort to protect these two endangered burrowing procellariids. Aerial delivery of Ramik Green appears the best short-term management solution if the pesticide can be approved for use, despite current government restrictions. However, no matter which new technologies emerge to control cats, rats and mongooses, keeping mongooses off Lana'i and from becoming established on Kaua'i are the two most critical population-level management measures needed to ensure the future of both the Hawaiian Petrel and Newell's Shearwater.

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