

THE IMPACT OF AN INTRODUCED AVIAN PREDATOR, THE BARN OWL *TYTO ALBA*, ON HAWAIIAN SEABIRDS

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ABSTRACT

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The Barn Owl *Tyto alba* was introduced to the Hawaiian Islands in the late 1950s as a biological control for rats *Rattus* spp. and has since become common throughout the main Hawaiian Islands. Herein, we address the impact on Hawaiian seabirds by summarizing the number of seabird depredations recorded in the database of the Kaua'i Endangered Seabird Recovery Project. Data were collected on Kaua'i and the neighboring islets of Lehua and Moku'ae'ae between January 2011 and October 2018 as part of ongoing seabird survey work; 379 Barn Owl depredations were recorded of eight seabird species, the most common of which were Wedge-tailed Shearwater *Ardenna pacifica*, Black Noddy *Anous minutus*, and Bulwer's Petrel *Bulweria bulwerii*. Included were 21 depredations on federally listed Newell's Shearwater *Puffinus newelli* and Hawaiian Petrel *Pterodroma sandwichensis*. Most depredations were on adult birds. The effectiveness of Barn Owl control was also evident, with depredations on Lehua Islet decreasing significantly after dedicated control operations were initiated. Barn Owl control should be considered as an integral part of all Hawaiian seabird management programs.

Key words: Hawai'i, Barn Owl, *Tyto alba*, seabird, depredation, introduced predator

INTRODUCTION

The impact of introduced predators on seabirds is well known, particularly on islands (Croxall *et al.* 2012, Towns *et al.* 2012, Spatz *et al.* 2014). However, most information on this impact relates to terrestrial predators such as cats *Felis catus*, rats *Rattus* spp., and wild pigs *Sus scrofa*. Fewer examples in the literature relate to the impact of introduced avian predators, e.g. Weka *Gallirallus australis* on Sooty Shearwaters *Ardenna grisea* (Harper 2007) and Chatham Island Taiko *Pterodroma magentae* (also known as the Magenta Petrel) on islands in New Zealand (Imber *et al.* 1994, Johnston *et al.* 2003).

In Hawai'i, the vast majority of native avian predators, including the Kaua'i Stilt-Owl *Grallistrix auceps*, went extinct shortly after human settlement (Walther & Hume 2016). The only remaining native avian predators are the Hawaiian Hawk *Buteo solitarius* (restricted to the island of Hawai'i) and the Hawaiian Short-eared Owl *Asio flammeus sandwichensis* (found throughout the main Hawaiian Islands). In the late 1950s, the Hawai'i Department of Agriculture introduced a new avian predator, the Barn Owl *Tyto alba*, as a biological control for rats, which were considered a significant threat to the cane sugar industry. Releases of Barn Owls occurred initially on Kaua'i, O'ahu, and Hawai'i (Tomich 1962, Au & Swedberg 1966) and later on the island of Moloka'i (Berger 1981). Barn Owl populations have since grown steadily, with the species colonizing Maui, Lāna'i, and Ni'ihau through their own dispersal, becoming common throughout the main Hawaiian Islands (Pyle & Pyle 2017).

The Barn Owl was confirmed as an established breeding species on Kaua'i by 1966 (Au & Swedberg 1966), and it was reported as a confirmed seabird predator in 1980 (Byrd & Telfer 1980). This

paper builds upon information provided in the latter, somewhat anecdotal, paper by assessing how significant a predator this species is to native Hawaiian seabirds on Kaua'i, as well as on neighboring Lehua and Moku'ae'ae. We also consider the importance of Barn Owl control and the complexities involved in implementing these efforts.

STUDY AREA

The Kaua'i Endangered Seabird Recovery Project (KESRP) is focused primarily on research and conservation of the island's threatened and endangered seabirds: Newell's Shearwater *Puffinus newelli*, Hawaiian Petrel *Pterodroma sandwichensis*, and Band-rumped Storm-Petrel *Oceanodroma castro*. As part of this work, the Project undertakes colony monitoring at seven sites in the northwestern portion of Kaua'i. There is one site in the Upper Limahuli Preserve (owned by the National Tropical Botanical Garden (NTBG)), one in the Upper Mānoa Valley (privately owned), and five sites in the Hono O Nā Pali Natural Area Reserve System (NARS): Pihea, Pōhākea, North Bog, Hanakāpī'ai, and Hanakoa (Fig. 1). The project also conducts regular surveys of two additional sites, on the islets adjacent to nearby Lehua and Moku'ae'ae, to monitor endangered and non-listed seabirds.

METHODS

For our purposes, all species names (scientific and English) are as per Avibase (Lepage 2018).

As part of surveys and monitoring for threatened and endangered seabirds, data were collected for any seabird depredation that was encountered at any of the nine monitored sites. Depredated seabird carcasses and predator scat/pellets were photographed *in situ*, then

collected and removed, to prevent double-counting on future trips. All locations were logged using a GPS (Garmin Rino 650). All predator scat/pellets were collected and subsequently examined in the lab for the presence of seabird feathers/bones indicative of a depredation event. All events were reported immediately to predator control teams (including those from the Hawai'i Division of Forestry and Wildlife (DOFAW), the NARS, or the NTBG) to facilitate pin-pointing of predator control activities.

For the purposes of this study, all Barn Owl depredation incidents recorded by the KESRP between January 2011 and October 2018 have been considered. Data are presented on the number of each species depredated, the age groups of the individuals targeted, and the locations of depredations. A known Barn Owl nest site on Lehua Islet was also routinely visited as part of control efforts; any seabird skulls found in pellets and within the nest site were counted and collected on each occasion.

Barn Owl control

A dedicated Barn Owl control effort was initiated on Lehua Islet by DOFAW under a Depredation Permit issued by the US Fish and Wildlife Service (50 CFR § 21.41) between May 2015 and September 2016, during which time nine trips were carried out and 11 individual Barn Owls were removed (G. Reid, DOFAW, unpubl. data). Lethal control measures were implemented during several multi-day hunting trips, using a caller (playing both territorial Barn Owl calls and prey calls), spotlight, and shotgun. The effectiveness of these control measures was assessed by counting the number

of Barn Owl depredations found on KESRP seabird monitoring trips to Lehua Islet between December 2011 and October 2018 (excluding 2014, when data were not collected) and comparing values from before control measures, during active control, and after control work had ceased.

Although Barn Owl control has also recently been included as part of ongoing predator control and management operations within the threatened and endangered seabird colonies in the northwest portion of Kaua'i, methods and techniques that are considered suitable for these areas are still evolving; to date, no Barn Owls have been removed. Therefore, these sites are not included in our comparative analysis evaluating the overall effectiveness of Barn Owl control.

RESULTS

A total of 379 Barn Owl depredations of seabirds, including eight different species, was recorded between January 2011 and October 2018 (Table 1). Depredations of two migratory waders were also recorded: five Pacific Golden-Plovers *Pluvialis fulva* and one Ruddy Turnstone *Arenaria interpres*. Depredations were recorded in seven of the nine study sites (77.8 %) that we examined, with the highest numbers on the two offshore islets (Table 2). The most common species predated were Wedge-tailed Shearwater *Ardenna pacifica* (45.4 % of records), Black Noddy *Anous minutus* (29.8 %), and Bulwer's Petrel *Bulweria bulwerii* (15.6 %). Also included were 21 threatened or endangered seabirds (13 Newell's Shearwaters and eight Hawaiian Petrels).

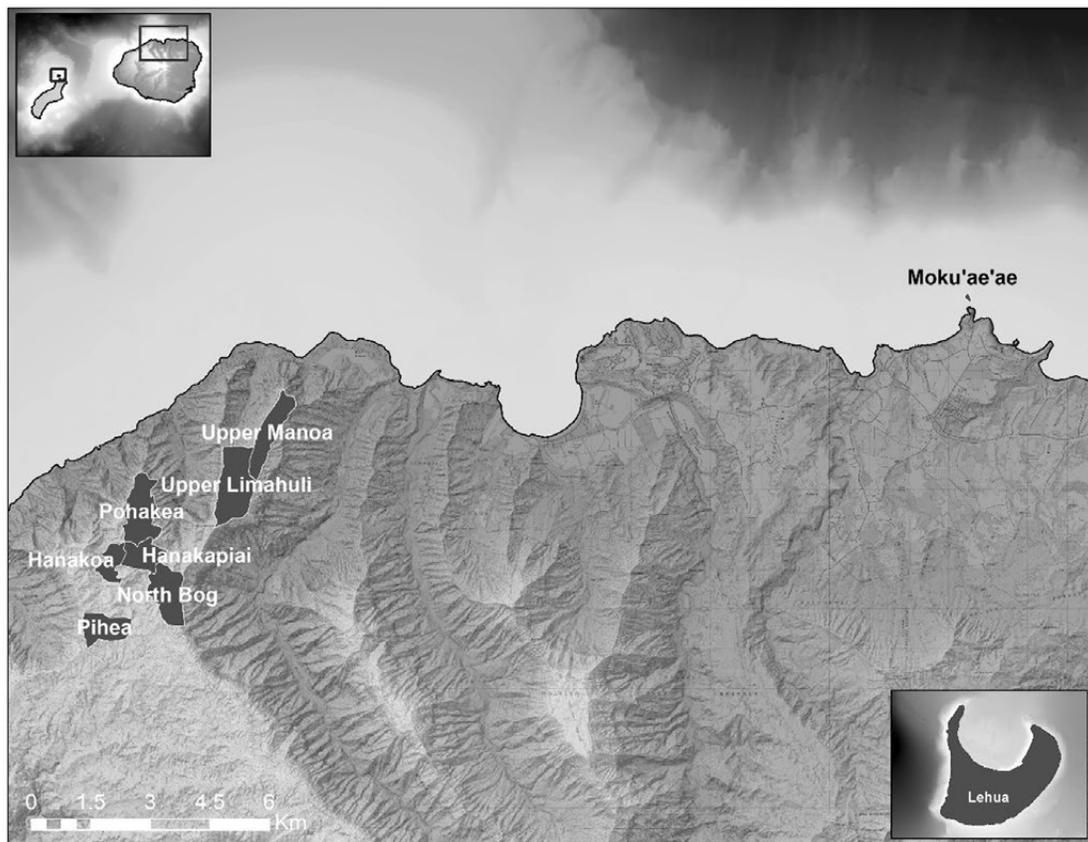


Fig. 1. Study sites on Kaua'i, and the location of Moku'ae'ae and Lehua Islets in relation to Kaua'i.

We also examined the age class of depredated birds. For the 353 depredations where age was estimated or known, 94.3 % were adults (i.e., After Hatch Year) and 5.7 % were chicks (i.e., Local) (Table 1). For some species (such as Bulwer's Petrel, Black Noddy, Hawaiian Petrel, and Newell's Shearwater), all the depredations were of adult birds. For others, such as Red-footed Booby *Sula sula* and Brown Booby *Sula leucogaster*, all the depredations were of chicks.

To assess the effectiveness of Barn Owl control on Lehua Islet, we compared the number of seabird depredations prior to control, during control, and after Barn Owl control work on the islet ceased. Seabird depredations decreased dramatically once Barn Owl control measures were initiated, with significantly more depredated seabirds found before control operations began (48.8 ± 11.5 SE) than during (6.5 ± 3.3 SE) or after (10.3 ± 3.0 SE) control (Kruskall-Wallis, $X^2 = 8.58$, $df = 2$, $P = 0.016$) (Fig. 2).

DISCUSSION

This analysis highlights the impact of introduced Barn Owl depredation on Hawaiian seabirds. The number of depredations detected represents a minimum number of depredations in these areas, as Barn Owls frequently carry their prey to be consumed elsewhere (such as at perches or nest sites). Wedge-tailed Shearwater,

Bulwer's Petrel, and Black Noddy on the islets of Lehua and Moku'ae'ae were particularly common among prey items.

Barn Owls also preyed on two of the three Hawaiian seabirds listed under the Endangered Species Act (ESA)—the Newell's Shearwater and Hawaiian Petrel—but we found no evidence of depredated Band-rumped Storm-Petrel. Considering the small population size of these storm-petrels (Raine *et al.* 2017a) and the fact that Barn Owls prey on storm-petrels on other islands (e.g., Velarde *et al.* 2007), it is more than likely that Barn Owls take this species as well. Barn Owls have also been recorded in the Hawaiian Islands depredating Sooty Tern *Onychoprion fuscatus*, Grey-backed Tern *Onychoprion lunatus*, and Brown Noddy *Anous stolidus* (Byrd & Telfer 1980, VanderWerf *et al.* 2007). Combined with the results presented in this paper, Barn Owls are now known to depredate 11 seabird species in the Hawaiian Islands, or about half of the islands' breeding seabird avifauna.

Barn Owls in this study predominantly targeted adult birds. The loss of adults is of special conservation concern, as these are survivors of subadult years and thus represent a loss of future breeding potential and a decline in the population growth rate. Barn Owls have been observed actively hunting incoming Hawaiian Petrel and Newell's Shearwater adults in flight (AFR, pers. obs.), are regularly attracted to storm-petrel calls (AFR, pers. obs.) and Newell's Shearwater calls at mist-netting sites (D. Ainley, pers. comm.), and have been recorded on burrow cameras both killing adult birds in front of their burrows (Fig. 3) and entering burrows to kill chicks (Fig. 4 and 5). Owls have also been observed to exhibit targeted hunting behavior where there are concentrations of breeding seabirds. For example, many freshly depredated Black Noddies on Lehua Islet were found above a sea cave, where they were breeding. Prior to the initiation of control work, it was common to find 20 or more dead Black Noddies in this single area on any given trip to the islet. Another example of targeted predation was at Moku'ae'ae Islet, where a total of 21 adult Bulwer's Petrel carcasses were discovered on one trip. Similar discoveries of large numbers of depredated Bulwer's Petrel were made on survey trips to Moku'ae'ae prior to this study (Byrd & Zeillemaker 1981, Eijzenga & Preston 2008), indicating that Barn Owl depredation is significant on Moku'ae'ae and may threaten the stability of the Bulwer's Petrel colony on this small islet.

TABLE 1

Number of seabird depredations by Barn Owls, by species

Species	Total	Percentage Total	Adult	Chick
Wedge-tailed Shearwater	172	45.4 %	90.1 %	9.9 %
Black Noddy	113	29.8 %	100.0 %	0.0 %
Bulwer's Petrel	59	15.6 %	100.0 %	0.0 %
Newell's Shearwater	13	3.4 %	100.0 %	0.0 %
Hawaiian Petrel	8	2.1 %	100.0 %	0.0 %
Red-tailed Tropicbird (<i>Phaethon rubricauda</i>)	8	2.1 %	33.3 %	66.6 %
Red-footed Booby	4	1.1 %	0.0 %	100.0 %
Brown Booby	2	0.5 %	0.0 %	100.0 %

TABLE 2

Number of seabird depredations by Barn Owls, by site

Site	Total	Percentage Total
Lehua Islet	327	86.3 %
Moku'ae'ae Islet	31	8.2 %
Upper Limahuli Preserve	14	3.7 %
Hanakāpī'ai	4	1.1 %
Hanakoa	1	0.3 %
Pihea	1	0.3 %
Upper Mānoa	1	0.3 %
Pōhākea	0	0.0 %
North Bog	0	0.0 %

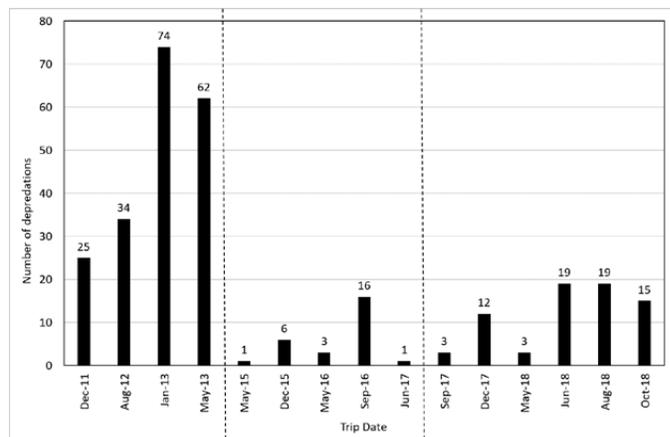


Fig. 2. Number of seabird depredations by Barn Owl recorded during each trip to Lehua Islet. The Barn Owl control period is contained between the two vertical lines on the figure.

Barn Owl control measures, when implemented in a concentrated and systematic fashion, were successful. When control work was undertaken on Lehua Islet by DOFAW, the number of seabird depredations declined significantly. Considering the large numbers of depredations of Wedge-tailed Shearwater, Bulwer's Petrel, and Black Noddy prior to the start of management actions, these control measures would be expected to result in immediate and lasting conservation benefit. However, the work undertaken by the control team also indicated that, despite its small size (113 hectares,

or 1.13 km²), Lehua Islet could support a large number of owls (11 were removed in a single year while several individuals were known to be present after the control treatment ended). Our data suggest that Barn Owls are resilient and are capable of rapid recolonization on the islet, probably from source populations on neighboring Ni'ihau or Kaua'i. A Barn Owl nest site on Lehua that was regularly targeted for control work yielded clutches of eggs or chicks within a few months of control operations on multiple occasions, highlighting how quickly owl pairs can re-lay on the



Fig. 3. Burrow camera footage of a Barn Owl depredate a Newell's Shearwater adult at its burrow in the Upper Limahuli Preserve.



Fig. 4. Burrow camera footage of a Barn Owl entering a Wedge-tailed Shearwater burrow on Lehua Islet to depredate a chick.



Fig. 5. Burrow camera footage of a Barn Owl pulling a Wedge-tailed Shearwater chick out of its burrow on Lehua Islet and depredate it.

islet. Furthermore, considering the short distance between Ni'ihau and Lehua (~ 1 km), it is highly probable that Barn Owls belonging to established populations on Ni'ihau can transit each night from Ni'ihau to hunt on Lehua.

Rapid recolonization potential highlights one of the critical challenges in controlling this introduced predator in Hawai'i. The species is capable of breeding in high density, can have multiple clutches in any given year, and produces large brood sizes (del Hoyo *et al.* 1999), meaning that recolonization can be rapid when a territorial bird is removed. Furthermore, Barn Owls can be very hard to hunt or trap, particularly if they have been the target of a failed previous attempt (G. Reid, DOFAW, pers. comm). Also, unlike terrestrial introduced predators, they are not excluded by predator-proof fences (and in fact, use fences as perching posts from which to hunt), can have large home ranges (meaning they can target multiple colonies), and, as this study indicates, exhibit the capacity to kill large numbers of seabirds in a relatively short period of time.

Barn Owl control, therefore, is an important aspect of seabird conservation management in Hawai'i and its significance should not be overlooked. Barn Owl control projects need to consider multiple hunting and trapping techniques to target particularly difficult individuals and should include the use of callers and spotlights for hunting, and bal-chattris, pole traps, and Swedish Goshawk traps for trapping. Two of the three ESA-listed seabird species breeding on Kaua'i—Newell's Shearwater and Hawaiian Petrel—have exhibited steep population declines in recent decades due to a range of factors (Raine *et al.* 2017b), and the loss of breeding adults to Barn Owls can have a serious additive impact on the long-term persistence of their colonies. Attempts to use social stimuli such as call playbacks to establish new colonies of these seabird species within predator-proof fences must therefore also contend with potential owl attraction. The impact of Barn Owls on other species, such as Black Noddy and Bulwer's Petrel, can affect specific breeding sites, particularly when the number of depredations regularly occurs on the order of dozens of adults. Depredation by Barn Owls was also implicated as a potential factor in the extirpation of Brown Noddy from Lehua Islet (VanderWerf *et al.* 2007). Lastly, with rat eradication projects underway on Lehua Islet and rat control projects at many endangered seabird colonies on Kaua'i, the removal of what is considered a significant prey item for owls may have the unintended consequence of exacerbating seabird depredation events if Barn Owl control work is not carried out in tandem. Indeed, Barn Owl kills on Lehua Islet have been increasing again since control work ceased. This trend has been seen in other areas, such as a 15-fold increase of Barn Owl kills on Scripps's Murrelet *Synthliboramphus scrippsi* following steep declines of rodent prey on Santa Barbara Island (Thomsen *et al.* 2018). Resources and staff need to be dedicated to this work to help ensure that seabird management objectives are successful.

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