

SHORT NOTE

Introduced predators and seabird predation on Mo'orea, French Polynesia

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Historically most Pacific islands lacked vertebrate predators (Steadman 2006). With the arrival of humans came the introduction of rats (*Rattus norvegicus*, *R. rattus*, *R. exulans*), pigs (*Sus scrofa*), dogs (*Canis lupus*), cats (*Felis catus*) and predatory birds. Some of these introductions were accidental, such as rats transferred by ship or feral pets, while others were introduced intentionally as biological controls. Understanding the interactions between introduced species and native species can help determine their impact on native ecosystems and aid effective management decisions that help preserve island ecosystems.

Introduced predators threaten seabirds on islands throughout the Pacific (Steadman 2006). Seabirds are particularly susceptible to predators because they have a strong scent and are large, noisy and clumsy on land (Bonnaud *et al.* 2007). With the presence of terrestrial predators and human development, seabird nests and burrows often become restricted to cliffs or ridges, which

are accessible to aerial as well as some species of ground predators. This study investigated the relative impact of introduced swamp harriers (*Circus approximans*) and feral cats on local seabird and introduced songbird populations on the island of Mo'orea, French Polynesia (17°30'S, 149°50'W). We focused on the Tahiti petrel (*Pseudobulweria rostrata*) and Audubon's shearwater (*Puffinus lherminieri*) (Thibault 1974). The main aim was to determine which predator has a greater impact on seabird populations and what role introduced songbirds play in that interaction. Knowing which predator is having a greater impact on seabirds will help managers determine where they should focus conservation efforts and further research.

Before humans arrived, the island of Mo'orea had no native vertebrate predators. Since the arrival of humans all of the mammals listed above can be found on the island, along with the only avian predator, the swamp harrier. Europeans introduced swamp harriers in 1885 to control rat populations (Gouni & Zysman 2007). In their native range in the marshlands of Australia, their diet consists primarily of small mammals and land- and freshwater birds

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Table 1. Remains of birds found in waste samples of predators on Mo'orea I. Swamp harrier and feral cat columns show number of waste samples analysed and the type of bird, Passeriformes or Procellariidae, found in the sample. The prey type found in each kill site is also listed.

Prey Item	Swamp harrier	Feral cat	Number of kill sites	Total
Passeriformes (songbirds)	0	6	1	7
Procellariidae (petrels)	7	31	19	57
Total	7	37	20	64

(Baker-Gabb 1984; Marchant & Higgins 1993; Ferguson-Lees & Christie 2001). Swamp harriers are known predators of seabirds (Hawk *et al.* 2005) and are now widespread across Mo'orea.

Cats are common pets on Mo'orea, but have also become feral across the island. Cats have been introduced to islands around the world and are known predators of birds of all sizes (Nogales *et al.* 2004). Feral cats are partially nocturnal, agile predators which commonly return to successful hunting sites (Fitzgerald 1988). Mainland populations of feral cats prey primarily on small mammals (Fitzgerald 1988), while island populations are known predators of seabirds (Fitzgerald 1988; Steadman 2006; Bonnaud *et al.* 2007).

Introduced songbirds are common on Mo'orea, and include such species as: common myna (*Acridotheres tristis*), red-vented bulbul (*Molpastes cafer*), and silvereye (*Zosterops lateralis*). Introduced songbird presence on the island is important because they can be found in residential areas at low elevation and on ridge tops near seabird colonies. Also because of their abundance, introduced songbirds are a potential source of food for predators when seabirds are not breeding, and most likely help support a larger population of predators than would otherwise exist.

This study examined the diets of swamp harriers and feral cats at different elevations to determine the relative occurrence of songbirds and seabirds in their diets during the seabird-breeding season. Because seabirds nest only at high elevation and songbirds are found at all elevations, we expected predators to feed on songbirds at lower elevations and switch to the larger and more energetically rewarding seabirds at higher elevations. Swamp harriers, like other raptors, regurgitate pellets after meals and these can be used to determine diet (Bird *et al.* 2008). The diet of feral cats is usually determined by behavioural observations and the analysis of scat samples (Bonnaud *et al.* 2007).

Mo'orea is located in the Society I chain of French Polynesia. It is a 1.8 million-year-old high basaltic island (Guillou *et al.* 2005) and 132 km² in area. The island was 1st colonised by Polynesians around 600 AD, and then by Europeans beginning in 1769. Many avian species have gone extinct since

human arrival, and while no palaeo-ornithological record exists for Mo'orea, evidence from the nearby island of Huahine suggests that prehistoric seabird populations were probably much higher on many of the high islands in the Society Archipelago (Steadman 2006).

During the period 14 Sep to 15 Nov 2009, regurgitated pellets of swamp harriers and scats of feral cats were collected in open areas along pre-established trails on Mount Rotui (2 collection days) and Mount Mou'aputa (1 collection day). Samples were taken at 490 to 1,000 m on Mount Rotui and 600 to 800 m at Mount Mou'aputa. GPS points were taken at each collection site to record elevation and location. Samples ranged from loose to densely packed groups of feathers, debris and bones. Through information from the literature, surrounding evidence, and consultation with local experts it was determined that the smaller densely packed samples were swamp harrier pellets while loose feather and organic matter samples were assigned as cat scats. Piles of feathers were also examined along the trail and were assumed to be kill sites, where the carcass had been taken by rats or cats. Feather samples were taken at each kill site to aide in bird identification. Each kill site was marked with flagging to prevent recounting on future site visits. Each swamp harrier pellet, cat scat, and kill site was assumed to be representative of only 1 bird during analysis (Faulquier *et al.* 2009). Seabird burrow locations were also mapped using a GPS whenever encountered along the trails.

Kill-site feathers and waste samples were taken back to the laboratory for analysis. Waste samples were dried and dissected (Redpath *et al.* 2001). Each sample was weighed, measured and then dissected to analyse feathers and bones. Bird remains were divided into 2 groups: Procellariidae (petrels) and Passeriformes (songbirds) (Table 1) based on feather size and colour and the size of bones. To analyse the animal waste samples, a Pearson's χ^2 test was used to determine if seabird kills were related to seabird burrow locations at high elevation. A Spearman's test was used to see if there was a significant trend in elevation between where seabird and songbird remains were found.

Table 2. Possible prey species found at kill sites and waste sample on Mo'orea. Also listed are prey masses (g) and whether species are native or introduced. This list was compiled from the species observed during collection events and by the seabirds known to nest on Mo'orea (Thibault 1974).

Name	Mass (g)	Introduced/ native	Reference
Passeriformes (songbird)			
Red-vented bulbul (<i>Molpastes cafer</i>)	34*	Introduced	Lal & Thabliyal 1981
Silvereye (<i>Zosterops lateralis</i>)	13	Introduced	Bird <i>et al.</i> 2008
Common myna (<i>Acridotheres tristis</i>)	125	Introduced	Bird <i>et al.</i> 2008
Procellariidae (petrels)			
Tahiti petrel (<i>Pseudobulweria rostrata</i>)	405*	Native	Villard <i>et al.</i> 2006
Audubon's shearwater (<i>Puffinus lherminieri</i>)	200*	Native	Bretagnolle <i>et al.</i> 2000

* Obtained by averaging values found in the referenced literature.

A total of 20 kill sites and 44 animal waste samples was collected and analysed. All samples contained bird remains (Table 2). Seven samples were the remains of songbirds and 57 of the samples were the remains of seabirds. Of the animal waste samples, 7 (16%) were swamp harrier pellets while 37 (84%) were from feral cats. There was a significant difference between the mean number of birds eaten at different elevations ($\chi^2 = 11.7$, $d.f. = 3$, $P = 0.006$). The mean number of seabirds eaten at higher elevations was greater than that of the songbirds (Fig. 1). Seabird remains were also significantly more abundant when seabird burrow sites were present (Fig. 1) ($\rho = 0.918$, $P = 0.028$).

Our survey of pellets, scats and kill sites confirmed that both songbirds and petrels were consumed by feral cats and swamp harriers at elevations of >400 m (Fig 1). Even though introduced songbird species are present from sea level to over 1000 m on Mo'orea (Gouni & Zysman 2007), the 2 species of introduced predators seemed to preferentially consume petrels at higher elevations. This could be because predators prefer seabirds, they are easier to catch, or they are eating more songbirds but they are catching them off trail. The presence of songbird remains at low and mid elevations does suggest that predators are not entirely dependant on seabirds, and that their diet is supplemented by other introduced species.

In the 4-week period between the 2 sample collection days on Mount Rotui, 25 new samples were documented. This shows that there could be nearly 1 bird being killed each day. This study took place during the breeding season of the Tahiti petrel (Thibault 1974), which is when they are most abundant and most vulnerable. The breeding season is a crucial time for seabird population growth and this predation pressure could limit seabird success on Mo'orea.

Our samples show that cat predation is apparently higher than swamp harrier predation

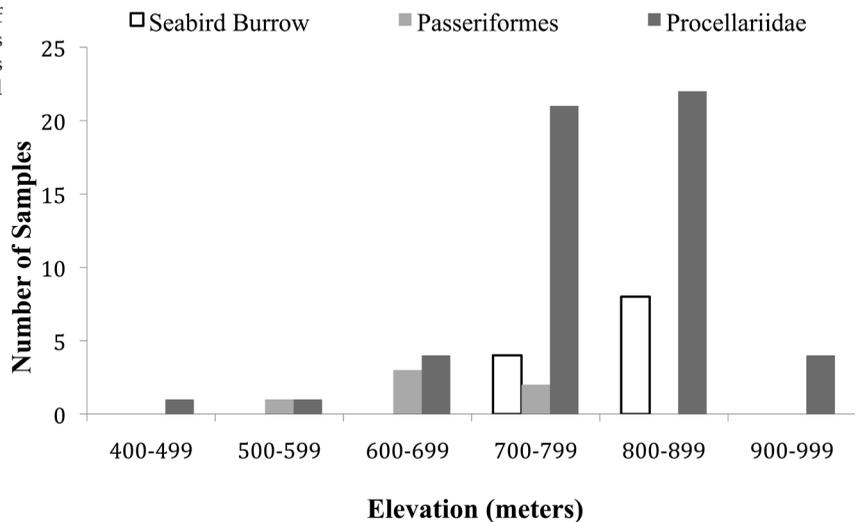
on Mo'orea, assuming samples were collected randomly with respect to their natural occurrence. The cat scat samples represented 84% of our samples while harrier pellets represented only 16%. This might indicate that feral cats are the major predator of seabirds on Mount Rotui and Mount Mou'aputa. However, this figure does not account for animal waste samples that are off the surveyed trails. For example, swamp harriers often regurgitate pellets at their roosting sites (Redpath *et al.* 2001), which could not be examined in this study, because roosting sites were generally inaccessible.

Seabird populations on islands with swamp harriers are known to be sustainable (Powlesland *et al.* 2002) while evidence suggests that many seabird populations cannot succeed in the presence of feral cats (Bonnaud *et al.* 2007; Faulquier *et al.* 2009). Cats are a versatile generalist predator and their introduction onto Mo'orea adds it to the long list of islands whose native fauna are being extirpated due to their presence (Fitzgerald 1988). Cats have been successfully removed on other islands (Nogales *et al.* 2004) but with Mo'orea's size and human population it would be a daunting task to remove all of the cats and prevent reintroduction from the urban sector. It is remarkable how seabirds have been able to persist in the presence of so many introduced predators on Mo'orea. If the number of predators continues to increase though, predator control may be needed to maintain viable seabird breeding populations. Periodic monitoring of the seabird breeding sites should be undertaken to evaluate seabird population trends, predation rates, and determine if management actions would be useful to minimise predation.

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Fig. 1. The distribution of seabird and songbird remains and seabird burrow locations along Mount Mou'aputa and Mount Rotui, Mo'orea.



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