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The vulnerability of skinks to predation by introduced mongoose in the Fiji Islands

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Abstract

Skinks are successful colonisers and are commonly found throughout the Pacific islands, but, the presence of introduced predators such as mongoose are known to threaten their survival. The two most abundant skinks found within the Fiji Islands are *Emoia cyanura* and *E. impar*; the abundance of these species encountered during visual transect counts on 16 islands within four habitats formed the basis of this study. Half of these islands had mongoose present whilst the other half were known to be mongoose free. Our results showed that skink abundances on mongoose free islands were approximately five times higher than when mongoose were present, irrespective of habitat type. We conclude that it was very likely that mongoose severely supressed even commonly found skink species across all the habitat types on these small islands. Conservation actions that could protect these native species include biosecurity mechanisms to prevent secondary invasion of introduced predators, habitat protection and management, and captive rearing programs. Failure to implement such actions now could result in even common species being at risk of extirpation.

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Introduction

Emoia skinks, to which *Emoia cyanura* (the brown-tailed copper-striped skink) and *E. impar* (the blue or azure-tailed skink) belong, are a large group with marked radiation on Pacific islands (Zug 1991). Skinks can reach extremely high densities on islands (Rodda et al. 2001) and *E. cyanura* is recognised as the most abundant and widespread skink throughout the Pacific (Ineich and Zug 1991). About 19% of the world's reptiles are considered to be threatened with extinction, and those found within tropical oceanic islands and freshwater ecosystems are particularly at risk (Böhm et al. 2013). Concerted conservation action is needed if reptiles are to be protected and conserved (Gibbons et al. 2000), especially as general extinction rates are estimated to be occurring at least 1000 times faster than the background rate prior to the impact of humans (Pimm et al. 2014). It is possible, therefore, that even seemingly abundant species such as *E. impar* and *E. cyanura* may be at risk of extirpation due to the effects of predation by invasive species, habitat loss and other environmental drivers.

One of the key agents for decline of native and endemic species on tropical oceanic islands are introduced predators (Case et al. 1992). The ecological status of the Fiji Islands has been severely affected by the introduction of feral mammals such as rats (*Rattus* sp.), cats (*Felis catus*), dogs (*Canis lupus familiaris*), and small Indian mongoose (*Urva auropunctatus* synonyms *Herpestes auropunctatus*, and *H. javanicus*), hereafter called mongoose (Patou et al. 2009). The small Indian mongoose was introduced to the Fiji Islands in 1883 to control rats (Gorman 1975), and has been implicated in the decline of skinks, frogs and ground birds (Pernetta and Watling 1978). A second mongoose species, *H. fusca* was recently discovered in Fiji, further compounding the problem of this introduced predator (Morley et al. 2007). Mongoose are found on many tropical islands throughout the world, and the precise impact of their introduction is not always clear (Hays and Conant 2007). The focus of this study was on the effects that mongoose have on the commonly found skinks *E. cyanura* and *E. impar*.

Materials and Methods

The Fiji Islands consist of more than 300 islands and the country's territorial limits cover 1.3 million km^2, of which 18,333 km^2 is land (Ryan 2000). There are two main islands; Viti Levu (10,390 km^2) and Vanua Levu (5,535 km^2). This study was carried out on 16 small offshore islands selected *a priori*, where half of the islands had known mongoose populations (**Table 1**) and was done simultaneously with a study that focused on birds (Morley and Winder 2013).

<TABLE 1 NEAR HERE>

Islands were selected following extensive preliminary research and the *a priori* categorization was confirmed by setting 40–60 mongoose traps (at 200 m intervals) on each island for an eight day period during the study, in order to confirm whether mongoose were present on each island (**Table 1**). The overall quality of each island with respect to disturbance due to human activity was also assessed (Morley and Winder 2013). Island quality was scored by the investigator when each island was surveyed using a 1–10 interval-based scale. A score of 1 represented the poorest quality, where the island habitat was highly modified with exotic species dominating the vegetation. A score of 10 represented the highest quality, where there was comparatively little evidence of anthropogenic habitat disturbance and significant tracts of intact primary forest were evident.

The surveys took place during the wet season (Jan-May) in 2002-03 and involved completing four transects within each of the 16 islands (64 transect lines in total). Observations were made using a visual encounter transect technique and were carried out in the morning (8-10am) within four habitat types that were suitable for skinks: (i) village – areas that consisted of dwellings with open grassland areas and ornamental plants and trees; (ii) inland open exposed rocky outcrops or sites away from human disturbance; (iii) grassland or disturbed agricultural areas; (iv) shoreline - within the short vegetation. The order in which the four habitat types were surveyed on each island was randomized. The starting location of each transect was randomly selected within each habitat, was 25m in length and was marked with a rope because each transect was then surveyed for five consecutive dry-weather days. All skinks seen within the 2 m of the transect line were counted (and any individuals >2 m noted). The two skink species (*E. cyanura,* and *E. impar*) were counted together to form one overall skink count as it was not always possible in this study to definitively distinguish between the two species by sight (because of the limited time that individuals were visible). It should be noted that *E. cyanura,* and *E. impar* have distinct ecologies. *E. impar* is a typical forest species and more arboreal than *E. cyanura* and differences in egg-laying habits probably exist (Ineich 1997).

Data were pooled from the five days of sampling and a single count recorded. These data were analyzed using a two-factor mixed factorial ANOVA (SPSS, version 18), with habitat defined as a within-subject factor, mongoose presence defined as a between-subject factor and island quality defined as a covariate. Island quality was included as a covariate because we knew that it had a substantial effect on bird communities from our previous study (Morley and Winder 2013) and hypothesized that it would also affect skinks.

Results

In total, 4311 skink sightings were made across the 16 islands and four habitats. Data were $\log_{10}$ transformed prior to analysis and Mauchly's test was non-significant ($P=0.972$), demonstrating no evidence of heterogeneity of covariance. The presence of mongoose had a significant effect on skink counts ($F=10.4$, $P<0.001$, d.f. =1, 13). No habitat ($F=1.7$, $P=0.18$, d.f. =3, 39), habitat*quality interaction ($F=1.9$, $P=0.13$, d.f. =3, 39) or habitat*mongoose interaction ($F=1.6$, P=0.21, d.f. =3, 39) effects were evident. Similarly, the covariate, Island Quality, had no measurable effect (F=0.2, P=0.7, d.f. =1, 13). Hence, results from the study demonstrated that skinks were distributed across all habitat types surveyed equitably but the presence of mongoose appeared to substantially suppress their abundance (**Table 1; Fig. 1**).

<FIGURE 1 NEAR HERE>

Discussion

Introduced mongoose have long been considered the causal agent for the decline of endemic species on many small tropical islands (Ulrich 1931; Corke 1987; Hays and Conant 2007; Barun et al. 2011). Whilst being unable to prove causality (because a *post hoc* survey rather than an experimental study was done), our results were consistent with mongoose severely supressing skink populations across all the habitat types studied. This finding was consistent with the study by Case and Bolger (1991) who surveyed 18 islands within the wider South Pacific and with studies on Kyushu and Amami-Oshima Islands in Southern Japan (Watari et al. 2008; Watari, Nagata and Funakoshi 2011). Other studies that indicate skink decline include those conducted in Puerto Rico where mongoose were recorded eating *Anolis* spp. lizards, the extirpation of the ground lizard (*Ameiva polops*) in St. Croix, and, on the main islands of Fiji, the extirpation of *E. nigra* and *E. trossula* (Baskin and Williams 1966; Zug 1991). Similarly, on Christmas Island, Smith et al. (2012) found that five of the six native skink species declined to near extinction due to predation from introduced mammals, centipedes and the yellow crazy ant (*Anoplolepis gracilipes*) whilst the extirpation of the Pacific skink *E. impar* in Hawai'i was attributed to the introduced big-headed ant *Pheidole megacephala* (Fisher and Ineich 2012). Skinks also face a multitude of other agents responsible for their decline; the grand skink (*Oligosoma grande*) and Otago skink (*O. otagense*) have declined in New Zealand due to habitat degradation, for example (Houghton and Linkhorn 2002).

Species are becoming extinct at an alarming rate (Böhm et al. 2013; Pimm et al. 2014), and mongoose are clearly a causal agent of decline of native reptiles within the Pacific and beyond. Unless there is a concerted effort to stem the tide of this invasive pest, then we are probably merely documenting the decline of this ecologically important group of small terrestrial vertebrates. In terms of priority, the adoption of biosecurity strategies to prevent mongoose from reaching other islands appears vital (Morley 2004; Morley and Winder 2013), whilst the use of technology to control and possibly eradicate mongoose from infested islands (Barun et al. 2011) should also be considered. Prioritisation of the prevention of mongoose from invading islands is pragmatic, given that controlling mongoose is fraught with problems and so prevention costs are likely to be much lower than attempting removal. If resources were available, eradication of mongoose on islands would also clearly provide substantial conservation benefit. Mongoose control and eradication could be trialled: in this study the biologically diverse and rich Kioa Island and the small yet degraded island of Yanuca would be ideal candidate islands. Yanuca Island is close to Suva, Fiji's capital, where labour and resources could be accessed so reinvasion would be less likely. Yanuca could provide an excellent opportunity to test if mongoose can be successfully eradicated. Kioa is a short distance from Vanua Levu and mongoose had never invaded the island until they were deliberately introduced. Watari et al (2013) and Fukasawa et al (2013) showed that when mongoose were controlled on other Pacific islands, the density of several native species recovered to the level of the carrying capacity of the island, so such an experiment could prove fruitful in Fiji.

Other actions such as trapping or poisoning mongoose by implementing bounty systems, developing on-site management techniques to improve habitat quality, and rearing skinks in captive management programmes should also be evaluated. However, bounty systems, even when using professional hunters, do not always work as demonstrated by attempts in New Zealand with the Rabbit Boards (Nightingale 1992). Nevertheless, because of the documented impact of mongoose (Case and Bolger 1991; this contribution), we call for a concerted attempt within the Pacific to improve biosecurity measures between the inner islands of Fiji and advocate a feasibility study to control or eradicate mongoose. Implementation of prevention and management strategies is needed now, before some stochastic event or additional invasion occurs to extirpate skinks or other affected species on these small offshore islands.

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Table 1. Islands included in the study (Morley & Winder, 2013). Island quality was scored on a 1-10 scale by the investigator. Total skink count records overall number of individuals observed across all habitats. Number of mongoose trapped records number of individuals caught on each island over an eight day period using 40–60 traps.

Island	Island Size (km^2)	Elevation (m)	Distance to mainland island (km)	Island quality	Total skink count	Number of mongoose trapped
Mongoose absent						
Moturiki	10.9	132	2.5	7	483	0
Viwa	0.6	49	0.95	7	463	0
Dravuni	0.8	111	12.8	2	673	0
Laucala	12.2	265	0.5	9	400	0
Vatulele	31.3	33	31.8	7	409	0
Koro	104	561	48	8	352	0
Naviti	34	338	49.6	3	455	0
Waya	22	502	12.1	3	467	0
Mongoose present						
Beqa	36.2	439	9.63	3	36	78
Nananu-i-ra	2.7	73	0.78	2	157	23
Malake	4.5	219	2	1	22	78
Kioa	18.6	305	0.8	9	104	43
Yanuca	1.5	137	9.8	1	40	13
Nananu-i-cake	3	73	0.63	3	168	13
Macuata-i-wai	3	184	1.76	1	35	46
Rabi	68.8	463	5.4	6	47	45

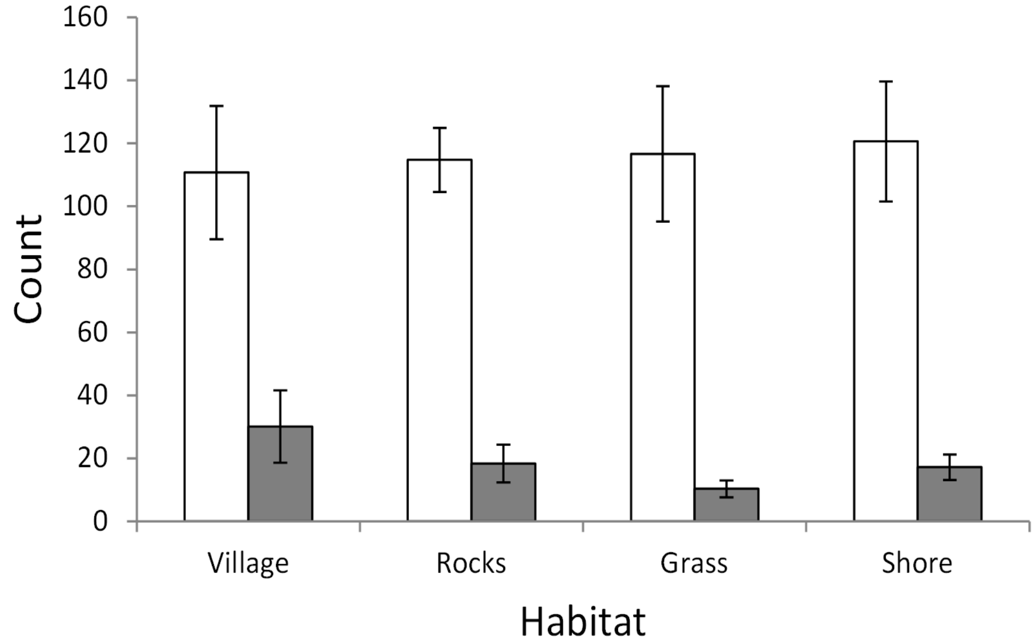
160
140
120
100
80
60
40
20
0
Count
Village
Rocks
Grass
Shore
Habitat

Figure 1. Skink counts recorded over a five day period (mean transect^{-1} ± 1 s.e.) within four habitat types on islands where mongoose were absent (open bars) and present (filled bars).

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