The distribution of the Fiji frogs, *Platymantis* spp.: New records and ramifications

TAMARA OSBORNE[1,2], ALIVERETI NAIKATINI[1,3], CLARE MORRISON[4,5], and NUNIA THOMAS[6,7]

The present study reports new records of the distribution of Fiji frogs from extensive geographic sampling on islands where both species were previously reported to persist. *Platymantis vitianus* is found in populations of varying sizes on six islands (Viwa, Ovalau, Taveuni, Gau, Vanua Levu and Viti Levu). Its congener, *P. vitiensis* has extant populations on the two largest islands, Viti Levu and Vanua Levu. Based on these recent surveys, our findings suggest that the current IUCN Red List status for *P. vitiensis* needs to be reclassified from 'near threatened' (NT) to 'vulnerable' (VU B1b[i]c[ii]). The discovery of a much wider geographic distribution for *P. vitianus* in recent surveys than recorded in the latter half of the 20th century is encouraging and reveals the need to re-examine known conservation threats. Recommendations for frog conservation in Fiji, with regard to current land-use practices are discussed.

Key words: *Platymantis*, distribution, habitat, Fiji Islands, IUCN Red Listing

INTRODUCTION

THE genus of *Platymantis* to date includes 71 known species (AmphibiaWeb 2012), although the number of species is increasing as further surveys in the Indo-Pacific and Melanesian regions are published (Kraus and Allison 2007; Siler *et al*. 2009). *Platymantis* is of taxonomic interest as several species (and species groups) within the genus are being reviewed using molecular tools, and new "species" are emerging from these studies. Additionally, congeners exhibit a bewildering array of morphologies and ecologies, which implies much genotypic variation (Brown and Gonzalez 2007).

Fiji, the easternmost extent of the genus, was prehistorically home to three platymantid species, which might have existed in sympatric populations: *Platymantis megabotovitiensis*, *P. vitianus*, and *P. vitiensis* (Worthy 2001). Climate-induced vegetation shifts and predation pressure are the likeliest causes for the extinction of the megaboto *P. megabotoniviti* on Viti Levu. *P. vitianus* is considered endangered (EN B1ab[v]) and *P. vitiensis* near threatened (NT) under the IUCN classification system (IUCN 2011).

Girard and Duméril originally described both the Fiji tree frog *P. vitiensis* and Fiji ground frog *P. vitianus* in 1853. Seventy years and several taxonomists later, Barbour (1923) reviewed both scientific literature and museum specimens, and reduced the number of described species to two *Cornufer vitiensis* and *Platymantis vitianus*. Zweifel's (1967) treatise resulted in the suppression of the generic name *Cornufer* and the application of *Platymantis* to all species previously within that genus.

Very little was known about the distribution of the two species in Fiji, until Gorham's fieldwork (1968, 1971) around the main islands of Taveuni, Ovalau, Viti Levu and Vanua Levu. Since then, several of Gorham's and earlier explorers' sampling sites have been re-visited and new locations reported (Zug 1983; Ryan 1984; Morrison *et al*. 2004a).The range of P. *vitiensis* is thought to have been greater throughout the western and central parts of the Fiji group before human arrival (Gorham 1968; Pernetta and Goldman 1977), but is now reportedly reduced to four islands: Viti Levu, Vanua Levu, Taveuni, and Ovalau (Osborne *et al*. 2008).

Museum records of *P. vitianus* suggest that it was once present on the largest island in the Fiji group, Viti Levu (Gorham 1965) as well as Vanua Levu, Taveuni, Gau, Ovalau, and Viwa. Populations on Koro, Beqa and Kadavu Island have been recorded (Morrison 2003), although these have not been verified in recent field studies. Gorham's accounts of his 1965 surveys suggested that *P. vitianus* had been extirpated from mainland Fiji (Viti Levu and Vanua Levu). However, in 2004 *P. vitianus* was 'rediscovered' on Vanua Levu by Morrison and colleagues. This finding undermined the previously well-accepted theory that the introduction of the small Indian mongoose *Herpestes javanicus*, and possibly the Indian brown mongoose *H. fuscus*, were the major reasons for the extirpation of the ground frog populations on these islands (Veron *et al*. 2010).

Based on current records, the distribution of *P. vitianus* is much more widespread and might possibly rival that of its congener. We present the results of the most recent frog surveys, and review possible ramifications for the conservation and population management of Fijian platymantids.

[1]Faculty of Science and Technology, University of the South Pacific, PO Box 1168, Suva, Fiji.
[2]Email: osborne_t@usp.ac.fj
[3]Email: naikatini_a@usp.ac.fj
[4]International Centre for Ecotourism Research, Griffith University, QLD 4222, Australia.
[5]Email: c.morrison@griffith.edu.au
[6]NatureFiji-MareqetiViti, P. O. Box 2041, Government Buildings, Suva, Fiji.
[7]Email: nuniat@naturefiji.org

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METHODS

Study area

Thirty-two independent sites (each site separated by >10 km intra-island) from the six islands were surveyed (Fig. 1). Sampling sites were selected based on the following criteria: primary or secondary re-growth forest, moderate to high tree density, proximity to water bodies (i.e., streams or ponds), anecdotal reports of frog populations present, and proximity to other areas sampled (Table 1). Primary rainforest sites were preferred to secondary vegetation as populations were presumed to be greater in less disturbed habitat (Osborne 2006). Surveys were conducted in more disturbed vegetation if there were anecdotal reports of frog populations. The primary purpose for surveying was to collect DNA samples for genetic analysis, which will be published in a later article. As a result, site choice was also based on criteria required to assess population structure across the range of both species. We endeavoured to collect as extensively as possible at known and new sites to produce a detailed geographic sample.

Field methods

Surveys were conducted on the islands of Viwa, Ovalau, Taveuni, Vanua Levu, Viti Levu and Gau. Each site was surveyed for two to three hours at night by a sampling team of four to five researchers (2–2.5 man hours of survey effort). Searches were made in vegetation, leaf litter and along stream banks for either species. Where both species were found in sympatric populations, some searchers focussed efforts on the arboreal *P. vitiensis*, while others searched for the ground-dwelling *P. vitianus*. Frogs were caught by hand and placed in click-seal plastic bags for processing, by the principal researcher to standardize potential bias in observer error. Frogs were kept in bags for no more than 30 minutes to minimize distress. The body weights of all frogs were measured using a Pesola scale to the nearest gram. Body length was measured as snout-urostyle length (SUL) in millimetres using Vernier callipers.

Frog abundance

Factors affecting detectability such as weather variables and visibility due to habitat were not

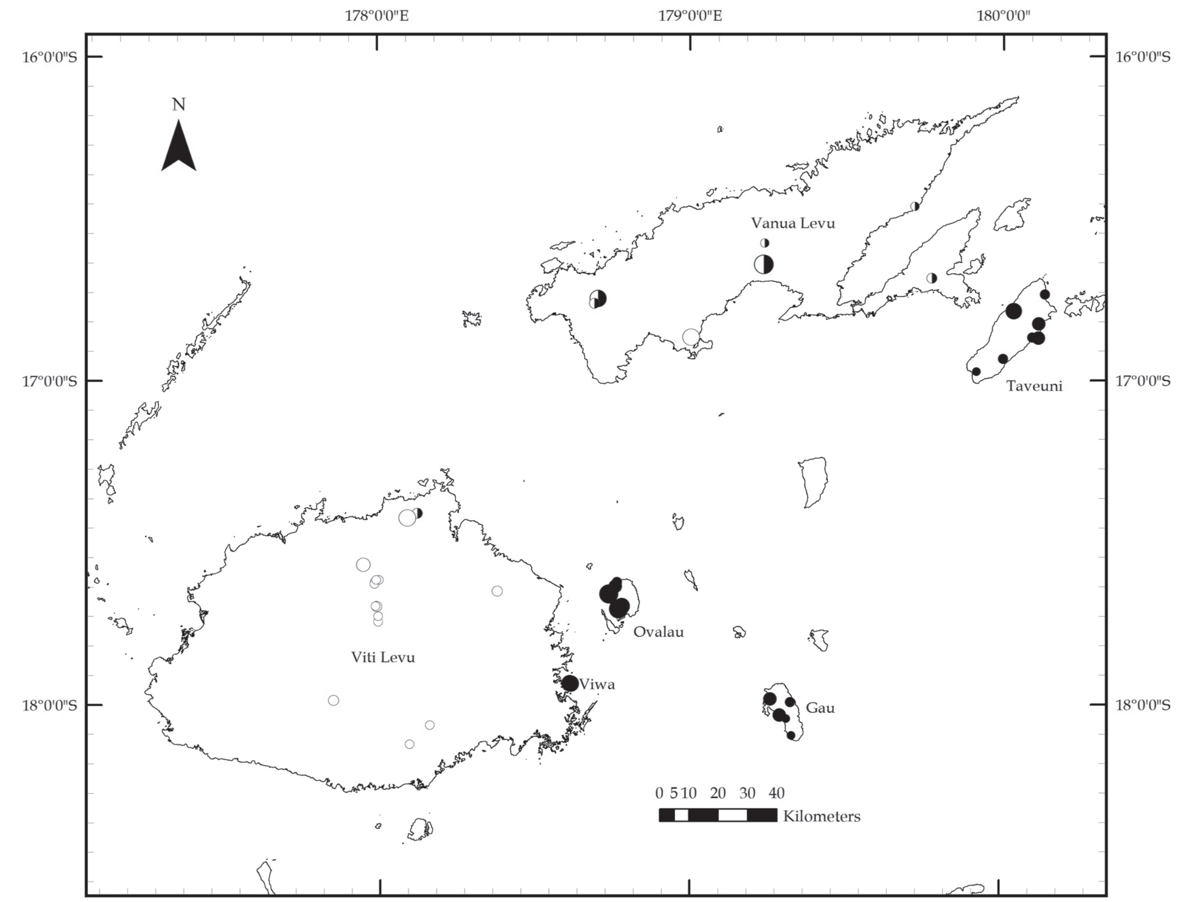

Fig. 1. Site records and sampling counts for *Platymantis* species, *P. vitiensis* (filled black circles) and *P. vitianus* (hollow circles), in the Fijian archipelago. Sympatric populations are denoted by half tone circles and circle sizes are proportional to frog counts. Survey effort was standardized at 2.5 man hours per site.

Table 1. Site descriptions of sampled populations of Fijian *Platymantis*.

Island	Village	Site	Habitat	Vegetation	Canopy Cover	Disturbance	Stream Width (m)	Frog Species	Count
Viwa	Viwa	Naururu	Coastal beach forest	Inocarpus fagifer (Ivi) dominated backswamp forest	>90%	Moderate	None	*P. vitianus*	16
	Viwa	Solevu	Littoral scrub and mangroves	Beach forest and mangroves (*Rhizophora* dominant)	<20%	Moderate to high	None	*P. vitianus*	3
	Viwa	Tovuni	Plantations and human habitation	Mixed species plantations on slope and in riparian strip	20-40%	Moderate to high	None	*P. vitianus*	29
	Viwa	Naivituka	Plantations	Colocasia esculenta (dalo), Carica papaya (Pawpaw) and Musa spp. (Banana)	<20%	High	None	*P. vitianus*	32
Ovalau	Taveya	Damu	Coastal beach forest and plantations	Mixed species plantations; coastal littoral forest dominated by *I. fagifer*	20-40%	High	None	*P. vitianus*	11
	Rukuruku	Naikatini	Secondary lowland rainforest	Mixed species riparian and slope forest with grassy patches	40-60%	Moderate	3.0	*P. vitianus*	15
	Viro	Loru	Primary highland rainforest	Mixed species slope to ridge forest	>90%	Low	None	*P. vitianus*	47
	Nasaga	Koromakawa	Secondary lowland rainforest	Mixed species riparian strip; *I. fagifer* common	40-60%	Moderate to high	2.0	*P. vitianus*	19
	Nasaga	Gusuniwai	Secondary lowland rainforest	Mixed species riparian, slope and ridge forest; I. fagifer common	>90%	Low	3.0	*P. vitianus*	32
	Lovoni	Dakuinamara	Secondary lowland rainforest	Mixed species river valley with Bamboo patches and *Marattia smithii* common	40-60%	Moderate to high	None	*P. vitianus*	20
	Lovoni	Namalata	Primary highland rainforest	Mixed species riparian and slope forest	>90%	Low	4.0	*P. vitianus*	28
Taveuni	Korovou (Bouma)	Tavoro	Secondary lowland rainforest	Mixed species riparian and slope forest	40-60%	Low to moderate	3.0	*P. vitianus*	14
	Lavena	Wainiserei	Coastal beach forest	Mixed species riparian scrub on coastal flat	20-40%	Low to moderate	4.0	*P. vitianus*	12
	Lavena	Tua	Secondary mid-highland rainforest	Mixed species riparian and slope forest	40-60%	Low	2.0	*P. vitianus*	15
	Qeleni	Qeleni Ck	Primary lowland rainforest	Mixed species riparian and slope forest	20-40%	Low to moderate	3.0	*P. vitianus*	6
	Qeleni	Solove	Secondary lowland rainforest	Mixed species riparian forest from lowland to mid-highland; *Mirammia* sp. common	20-40%	High	2.0	*P. vitianus*	5
	Lamini (Somosomo)	Lomalagi	Primary mid-highland rainforest	Mixed species slope and ridgetop forest; large endemic trees with sparse understorey	>90%	Low	Ephemeral	*P. vitianus*	30
	Vuna	Tavuyago	Secondary mid-highland rainforest	Mixed species slope forest; patches of grassland and weeds	20-40%	Moderate	None	*P. vitianus*	1
Vanua Levu	Nadivakarua	Nadi-i-cake	Primary highland rainforest	Mixed species ridgetop forest; mainly endemic canopy trees with *Pandanus* spp. understorey	80%	Low to moderate	None	*P. vitiensis*	29
	Driti	Devodamudamu	Primary highland rainforest	Mixed species riparian and slope forest with small plantation patches at forest edge	80%	Low	2.0	Both	33

Table 1. — continued overleaf

Table 1. — continued

Island	Village	Site	Habitat	Vegetation	Canopy Cover	Disturbance	Stream Width (m)	Frog Species	Count
Vanua Levu	Driti	Driti	Secondary lowland rainforest	Mixed species riparian and slope forest; small plantation patches along slope	>90%	Low	4.0	Both	8
	Nasealevu	Nasealevu	Secondary lowland rainforest	Mixed species riparian, slope and ridge forest; logging and cultivation in some places	80%	Moderate	3.0	Both	5
	Saqani	Veuku	Primary lowland rainforest	Mixed species riparian and slope forest	40-60%	Moderate	5.0	Both	2
	Waisali	Nailusi	Secondary lowland rainforest	Mixed species riparian and slope forest	40-60%	Moderate to high	4.0	Both	52
	Waisali	Waisali Reserve	Primary highland rainforest	Mixed species riparian and slope forest; fern understorey	>90%	Low	5.0	Both	5
	Navonu	Naururu	Secondary lowland rainforest	Mixed species riparian scrub with plantations and grassy patches; *Croton* spp. common	20-40%	High	2.0	Both	8
	Navonu	Waitulagasai	Secondary lowland rainforest	Mixed species riparian forest with plantations and grassy patches at forest edge	20-40%	Moderate	3.0	Both	4
Gau	Lovu	Kawakawanokonoko	Secondary lowland rainforest	Mixed species ridge forest	20-40%	High	2.0	*P. vitianus*	2
	Lovu	Nabodua	Coastal beach forest	I. fagifer and bamboo stands; fern-dominated understory; Cocos nucifera, Mirammia sp., common	20-40%	Moderate to high	3.0	*P. vitianus*	3
	Nukuloa	Ivitakalai	Coastal beach forest	Mixed species coastal flat with mainly fruit trees, bamboo and *I. fagifer* stands	40-60%	Moderate to high	4.0	*P. vitianus*	4
	Nawaikama	Navasa	Secondary lowland rainforest	Mixed species slope forest; *I. fagifer*,*Artocarpus utilis* and ferns are dominant species	40-60%	Moderate to high	1.0	*P. vitianus*	16
	Sawaieke	Nakalirau	Secondary lowland rainforest	Mixed species slope forest dominated by *I. fagifer* in canopy and ferns understory	40-60%	Moderate	None	*P. vitianus*	16
	Malawai	Valeibi	Secondary lowland rainforest and plantations	Mixed species coastal scrub (fruit trees and plantations of *C. esculenta*, *Piper methysticum* and *Manihot esculenta*) and slope forest (*C. nucifera* and *I. fagifer*)	20-40%	High	4.0	*P. vitianus*	7
Viti Levu	Vunisea	Nakauvadra	Primary highland rainforest	Mixed species riparian and slope forest	>90%	Low	6.5	Both	11
	Nalidi	Nababa	Secondary lowland rainforest	Mixed species river valley flat with small plantation patches	20-40%	Moderate	Ephemeral	*P. vitiensis*	8
	Nukusere	Wainiveigasau	Secondary highland rainforest	Mixed species slope, riparian and ridgetop forest; large grassland and plantation patches on slope	20-40%	High	3.0	*P. vitiensis*	3
	Wainamakutu	Wainamakutu	Primary lowland rainforest	*Cyrtosperma chamissonnis* and *Pandanus* spp. dominated riparian scrub	>90%	Low	3.0	*P. vitiensis*	27

Table 1. — continued

Island	Village	Site	Habitat	Vegetation	Canopy Cover	Disturbance	Stream Width (m)	Frog Species	Count
Viti Levu	Navunibau	Nasebale	Secondary lowland rainforest and plantations	Mixed species riparian, slope to ridgetop forest with small grassland patches	20-40%	High	2.0	*P. vitiensis*	5
	Nadarivatu	Forestry Reserve	Primary highland rainforest	Mixed species riparian forest with occasional *Pandanus* sp.	>90%	Low to moderate	4.0	*P. vitiensis*	22
	Navai	Sonusonunauluvatu	Primary highland rainforest	Mixed species riparian and slope forest	80%	Low	3.0	*P. vitiensis*	6
	Naga	Lomolomolevu	Secondary highland rainforest	Mixed species riparian and slope forest; *Pandanus* sp. common	<20%	Low to moderate	Swamp	*P. vitiensis*	7
	Monasavu	Kawa ni yavato	Primary highland rainforest	Mixed species riparian and slope forest; *Pandanus* sp. common	<20%	Low	Swamp	*P. vitiensis*	8
	Matokana	Burotu	Secondary highland rainforest	Mixed species riparian forest with large *Pandanus* spp. stand	>90%	Low	1.0	*P. vitiensis*	12

accounted for as sampling was restricted by time and funding. However, survey effort was standardized where possible by keeping constant the number of searchers and the length of time surveying. We therefore present the count data primarily as evidence of presence, and additionally as approximate indicators of population abundance on each island.

RESULTS

Distribution and habitat

P. vitianus populations were distributed widely throughout all of the five smaller islands, with a small remnant population on the mainland. Combined, the land area of the smaller islands form a landmass of 6261.1 km^2, of which approximately 44.6% (2792.05 km^2) is forested. The ground frog was found in a diverse range of habitats, from primary lowland to highland rainforest, secondary re-growth forests, plantations, and coastal littoral forest with relatively moderate disturbance levels. We found new populations at eight sites (three on Ovalau, two on Taveuni and three on Vanua Levu) where this species has never been recorded (Fig. 1). In addition, a recent survey on Qamea Island reported an extant population of *P. vitianus* on this 34 km^2 outlier of Taveuni Island (Naikatini *et al*. 2009). The size and distribution of the ground frog population on Qamea is unknown.

P. vitiensis was found on only two of the four islands (Vanua Levu and Viti Levu) where this species is purported to occur. Interestingly, *P. vitiensis* was recorded in the interior of the island (Lovoni Valley) during a previous survey of Ovalau in 2003 by the main author (Kuruyawa *et al*. 2004). Although two sites in the Lovoni area were searched during the present study, we did not encounter any tree frogs. A relatively large population of *P. vitiensis* was found in the Waisali Reserve, on Vanua Levu Island. *P. vitianus* are found sympatrically in this area. Fewer ground frogs than tree frogs were found in these surveys (Morrison *et al*. 2004a).

P. vitiensis populations persist in less disturbed habitat and cultivated forestry reserves (such as the Colo-i-Suva mahogany reserve) on the main island of Viti Levu (Osborne *et al*. 2008). We recorded populations of tree frogs at 10 sites ranging from western Viti Levu to the south east of the island. Several populations were found in isolated remnant rainforest fragments in the drier western zone of the main island.

There was increasing evidence of changes in the extent and intensity of land-use by traditional landowners on all the islands compared to findings in a previous study (Kuruyawa *et al*. 2004), particularly on Taveuni Island. A greater area of native land under

Table 2. Past surveys of Fijian *Platymantis* — count data and location.

Species	Island	Site	Count	Source
P. vitianus	Ovalau	Lovoni	11	Gorham (1968)
		Lovoni	59	Kuruyawa *et al*. (2004)
		Viro	43	Kuruyawa *et al*. (2004)
		Loru	29	Kuruyawa *et al*. (2004)
		Un-named	1	Gorham (1968)
P. vitianus	Taveuni	Korovou	38	Kuruyawa *et al*. (2004)
		Somosomo	2	Gorham (1968)
		Somosomo	95	Kuruyawa *et al*. (2004)
P. vitianus	Gau	Navukailagi	26	Kuruyawa *et al*. (2004)
		Malawai	19	Kuruyawa *et al*. (2004)
		Nawaikama	50	Kuruyawa *et al*. (2004)
		Nukuloa	37	Kuruyawa *et al*. (2004)
		Lovu	3	Kuruyawa *et al*. (2004)
P. vitianus	Vanua Levu	Navonu	2	Gorham (1968)
		Waisali	20	Morrison *et al.* (2004a)
P. vitianus	Viwa	Naleba	31	Kuruyawa *et al*. (2004)
		Naisigasiga	10	Kuruyawa *et al*. (2004)
		Matasa	17	Kuruyawa *et al*. (2004)
		Naivituku	19	Kuruyawa *et al*. (2004)
		Tovuni	23	Kuruyawa *et al*. (2004)
		Un-named	27	Kuruyawa *et al*. (2004)
		Un-named	1	Gorham (1968)
P. vitiensis	Ovalau	Lovoni	1	Gorham (1968)
		Lovoni	1	Kuruyawa *et al*. (2004)
		Un-named	1	Gorham (1968)
P. vitiensis	Taveuni	Somosomo	1	Gorham (1968)
P. vitiensis	Vanua Levu	Navonu	3	Gorham (1968)
		Waisali	9	Morrison *et al.* (2004a)
P. vitiensis	Viti Levu	Nadarivatu	6	Gorham (1968)

forest has since been converted to cultivations of taro *Colocasia esculenta*, cassava *Manihot esculenta*, and yaqona *Piper methysticum*. Conversion of forest patches to plantation occurs both at the forest edge and within the forest, and ranges in scale from small (10 x 10 m) plots to larger (50 x 50 m) dalo fields at the edges of forests. What is of concern, is that these plots are not limited to flat terrain, but often extend upslope to the edge of highland rainforest, as is the case on Taveuni Island.

Frog abundance

In total, 638 individuals (441 *P. vitianus* and 197 *P. vitiensis*) were captured and recorded from six islands (Table 1). Considering the size of the island, the Viwa population is relatively large. This is likely due to conservation efforts, which included the eradication of predators such as rats and cane toads (Thomas *et al*. 2011). The number of frog encounters on Taveuni was surprisingly lower than expected, which is probably an effect of a cyclone that had passed directly over the island a month before we were scheduled to sample. Slight differences in search effort between the island surveys as a result of prior exposure of field assistants to the search objects prevent us from making statistical comparisons between the island counts. However, it is interesting to note that there are possibly large populations at specific sites, such as Loru (Viro, Ovalau), Lomalagi (Somosomo, Taveuni), Savuqoro (Waisali, Vanua Levu), Wainamakutu (Viti Levu) and the Nadarivatu Forestry Reserve (Viti Levu). Although the results might be limited in terms of their interpretation, they provide a basis for future monitoring.

DISCUSSION

P. vitianus occupies more mesic habitats than *P. vitiensis*, and unlike the tree frog, may be found in brackish habitats. This apparent lack of habitat selectivity would make it less vulnerable to forest reduction on the smaller islands in its range than *P. vitiensis*. Individuals of *P. vitianus* are primarily ground dwelling, although smaller individuals are often found on foliage less than three metres off the ground. They hide in earthen burrows or rotting plant material during the day (Morrison 2003).

P. vitiensis inhabits primary lowland and highland rainforest as well as semi-disturbed vegetation, such as plantations of mahogany. They are less common in mesic habitats with high levels of human activity. Individuals are often found within or perched on *Pandanus* plants and their distribution might be closely related to the presence or absence of *Pandanus* in an area (Osborne *et al*. 2008).

P. vitiensis was not encountered on either Taveuni or Ovalau Island at ten independent sites. This suggests a possible decline in abundance of tree frog populations on these islands at sites where the tree frog was previously recorded (Table 2). Due to the increasing intensity of land modification, *P. vitiensis* might well be extirpated from Ovalau Island. The recorded presence of the tree frog on Taveuni Island is somewhat questionable. Prior to Gorham's (1968) distribution data, there are no records of *P. vitiensis* on Taveuni. Since his publication of B. Palmer's photograph of the *P. vitiensis* specimen from Somosomo, Taveuni, there have been no actual reports of field encounters with the tree frog on Taveuni.

The main agents of decline for *P. vitiensis* are likely to be (1) a loss of forest habitat due to increased exploitation of forest resources by landowners; (2) increased predation at forest edges due to an increase in edge area resulting from forest fragmentation; and/or (3) climate change leading to shifts in the range of forest plant species. The natural cyclical change in distribution of vegetation types is hard to measure over the short term and requires reliable long-term climatic data from sources such as pollen cores. Range shifts are likely to be influenced by the differential habitat preferences of either of Fiji's platymantids (Osborne *et al*., 2008).

The ground frog is likely maintaining (in several sites, very healthy) populations on six islands — Viti Levu, Vanua Levu, Taveuni, Gau, Ovalau and Viwa; with an unknown population on Qamea. Our records provide evidence for a greater distribution of *P. vitianus* on Vanua Levu than previously thought (Pernetta and Watling 1978; Morrison *et al*. 2004b). The current extent of *P. vitianus* occurrence is approximately 6300 km^2 (based on the surface area of all the islands in its range not including the mainland); however, the species' area of occupancy is much more difficult to estimate due to its habitat generalisation. We cautiously predict an area of occupancy less than, but close to, its extent of occurrence.

There are several implications of the recent surveys with regards to conservation management, and the first concerns the purported agent of decline, the mongoose. As this predator is common on Vanua Levu (Morley *et al*. 2007) the potential impact of mongoose on frog populations is important to evaluate, particularly in relation to other factors that might have also contributed to decline and expansion of Viti Levu ground frog populations. Predation by the mongoose might have led to an initial drop in abundance and subsequent reduction in the range of *P. vitianus* on Vanua Levu, followed by a gradual recovery and expansion to areas within its former range. However, the extent to which populations have contracted and possibly expanded in recent times is difficult to determine from abundance information alone, and might only be answered with the tools of molecular ecology. Such a study investigating the population history of the Fiji platymantids is in progress.

Secondly, the history of the ground frog populations on Vanua Levu is very important in terms of how this information can be applied to other populations of *P. vitianus* with regards to their conservation and management (Morrison 2005). As these populations have persisted in the presence of the mongoose and cane toad, we might presume that *P. vitianus* on other islands inhabited by these introduced predators will persist provided their habitat is protected from logging and other destructive land-use practices. We therefore recommend that the Viti Levu, Vanua Levu and Taveuni populations of *P. vitianus* are monitored for demographic and biogeographic changes.

Additionally, we recommend that the status of *P. vitiensis* be revised with respect to the species' current distribution. Currently, the IUCN red list status of *P. vitianus* suggests that this species' extent of occurrence is less than 5000 km^2, and that of *P. vitiensis* is between 5000–20 000 km^2 respectively. The tree frog has often been described as more adaptable as it has maintained populations on mongoose-infested islands. If recent surveys are indicative of current population trends in *P. vitiensis* populations, then there is a strong possibility that the tree frog's extent of occurrence is approximately 16 000 km^2 (based on the combined surface area of Viti Levu and Vanua Levu).

Available habitat (in tropical rainforest with > 50% canopy cover) would then provide an estimated 7100 km^2 for the occupancy of *P. vitiensis* (extracted from FAO 2007 forest data). We therefore propose that *P. vitiensis* should be re-classified as "Vulnerable" (VU B1b[i]c[ii]) according to the present IUCN Red List criteria. Our hypothesis is that a reduction in the distribution of *P. vitiensis* is due to major changes in forest cover on the other islands within its former range. The Fiji Lands Department are currently reviewing their vegetation cover maps and these will be accessible in 2013. Once this data is available, more robust analyses should be performed to correlate the reduction in habitat of *P. vitiensis* to reduced primary forest cover.

Thirdly, annual systematic surveys are suggested for *P. vitianus* to better understand the previously reported decline in Ground frog populations. Monitoring at several sites on Vanua Levu should give us a more accurate picture of this species' conservation status, as sub-populations on this island continue to remain viable even under the twin pressures of predation and competition by introduced pests. Future conservation efforts on other islands in the *P. vitianus* range would be best informed by data generated from monitoring the Vanua Levu sub-populations. Our hypothesis of the influence of forest habitat loss might be similarly applied to *P. vitianus*. Once further information is available to strengthen this correlation, we then propose the following conservation measures:

a) Border protection of existing forest and nature reserves on the islands of Viti Levu, Vanua Levu and Taveuni, where healthy *P. vitianus* populations were recorded.

b) Discussions with i Taukei landowners to establish a forest/ nature reserve(s) on the islands of Ovalau (particularly in the Lovoni valley), Gau and Viwa.

c) Discussions with the relevant government authorities to intensify land-use awareness campaigns on the islands of Gau, and Taveuni, where limited space has encouraged unsustainable agricultural practices (such as slope farming).

An "umbrella approach" in the form of conserving forested areas, on the islands where the Fijian platymantids persist, is likely to be the most effective tool to prevent these species from joining the global trend in amphibian extinctions (Morrison 2005). It will ensure a variety of forested habitats remain inhabitable for Fiji's frogs, given future climatic uncertainty in the region.

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BOOK REVIEW

Exploring the final frontiers: Cruise tourism in polar regions

Lück, M., Maher, P.T. and Stewart, E.J. (Editors)
Cruise Tourism in Polar Regions: Promoting Environmental and Social Sustainability?
Earthscan, London, UK.
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AYESHA TULLOCH[1]

CRUISE ship tourism is expanding rapidly in both the Arctic and Antarctic, with increased numbers and types of vessels, more demanding routes, and year-round activity as the final frontiers are opened to all types of visitors. The increase in access and in cruise activities, risks of accidents and negative impacts, and the effects of the large numbers of tourists in the polar regions bring significant management challenges for sustainable use of polar regions. In this timely context, Lück, Maher and Stewart have collected a range of discussions and viewpoints of the environmental and social sustainability issues concerning the cruise industry in polar regions.

The book consists of 14 chapters. In a well-crafted introductory chapter, the editors note the difficulties inherent in tourism research, the conflicts between tourism and environmental and social sustainability, and problems encountered when attempting to tackle these conflicts due to the lack of quantitative tourism-related research in polar regions. They introduce the question at the heart of this book: '*can cruise activities in the polar regions ever be synonymous with environmental and social sustainability?* '(p.7). The editors admit from the beginning that the book will raise more questions than answers, but their intention is to raise awareness of these issues and questions, in the hope that it will lead to action on solutions.

The remainder of the book is divided into a section on Market Dimensions, followed by Human Dimensions, then Environmental Dimensions, with Policy and Governance Dimensions logically falling at the end before a good concluding chapter that summarizes the individual works and gives well thought-out research directions that flow from the discussions. However, with such a strong emphasis on the need for systematic monitoring of tourism activities and their impacts throughout many of the chapters, more guidance could have been provided on the types of data required and indeed how these data could be gathered when funding for monitoring and evaluation of activities is limited.

Readers interested in quantitative market analyses would be disappointed by mostly anecdotal chapters in Part I (Market Dimensions), and the few tie-ins to the question of environmental and social sustainanbility, which the authors tout as the main difference with those books that have come before. With few real economic data presented, it is difficult to make any conclusions, and the authors unfortunately fail to provide leads for future researchers interested in this area. Berger's Chapter 4 asks an important question that resounds in tourism and social science research: Why is seeing Antarctica so important to people? The next obvious question that is left unasked is of course, how do we go about answering this? Some directions here would be beneficial, such as through encouraging questionnaires for tourists about their motivations for travel, and promoting sharing of this material with social science researchers, economists, and conservation scientists. For example, a useful extension for those wishing to follow on from this book would be to analyse the amount of time cruises and their passengers spend in different polar regions to investigate potential impact hotspots. Greater emphasis in this section could have been placed on the importance of integrative research, in particular the benefits from linking social science research of tourist demographics and 'environmentalism' to market research.

One key issue for planning sustainable futures is the unsustainable actions of humans in the past and

[1]The Ecology Centre, School of Biological Sciences, University of Queensland, St Lucia, QLD 4072.

today. Researchers desiring to deal with sustainability issues, whether they be social or environmental, ideally need to analyse trends over time to be able to have any idea of what will happen in the future. This means collaborating with tourism operators and government agencies, collating data that are already available (e.g. cruise passenger numbers), and if real impacts data are not available, selecting surrogates (e.g. energy used per cruise ship, or kilometres travelled) to measure trends and come closer to predicting future cruise tourism and its impacts. It is good to see Klein's Chapter 5 in Part II (Human Dimensions) approaching this by showing the dramatic increase of visitors to Antarctica. However, it stops short of calculating a rate of change and would have benefitted from some more in-depth analysis of what is undoubtedly a key factor that needs to be incorporated into evaluations of tourism impacts and sustainability. Despite the lack of quantitative analysis, Part II does provide real and interesting anecdotal case studies linked strongly to the concept of sustainability (or unsustainability) of cruise tourism, and offers simple and practical solutions, through youth education (Chapter 7), setting a carrying capacity at port communities, and determining the optimal ship size to minimize negative impacts such as pollution (Chapter 5).

One of the highlights of the book is the overview by Stewart and colleagues (Chapter 9, Part III) of current monitoring and problems associated with evaluation of cruise activities. Using a simple approach, they have managed to compile a real dataset of intended cruises and locations visited, which is an important start to analysing the impacts of this data-poor industry, allowing a priori evaluation of tourism hotspots and areas of growth. This kind of research is accessible to anyone, and has important implications for policy and governance design, as well as dealing with the impacts of climate change. This section on environmental dimensions also deals well with highlighting the implications of climate change and gauging the relevance of various impacts, adding a few cruise-specific and other issues to the discussion that have not been included in previous assessments (Scott et al. 2008).

Much of the growing body of research on sustainability points to the need to create local institutional organisations and encourage collaboration between stakeholders. This is highlighted by Part IV which focuses on policy and governance. The authors offer some practical and conceptual ways forward for designing policy for polar region tourism; most of these are not new (e.g. Haase 2008), but deserve reiteration. With excellent examples from Canada, USA, Australia and New Zealand, where the majority of the book's authors are based, one limitation is restricted case studies (in particular on policy, region-specific environmental impacts and human dimensions) from the rest of the Arctic regions, despite markets such as the Russian and northern European polar regions being highlighted as important sectors by Chapter 3.

This book is a valuable resource to anyone working in or planning research in the polar region tourism industry. All chapters are well-referenced, and it should be noted that the low number of peer-reviewed articles in some sections is not due to a lack of research by the authors, but rather to a serious lack in the literature that needs to be addressed urgently. Coming from a range of backgrounds and fields, the authors bring expert knowledge and critical perspectives to the subject, but with almost universal acknowledgement that much more needs to be done. We need more quantitative research and collaboration between researchers and tourism agencies and operators, before we can really begin to answer the question of whether cruise tourism, and indeed other types of tourism, are really environmentally and socially sustainable in the long-term.

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