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The conservation value of secondary vegetation for Fijian woodland birds

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Half of Fiji’s 66 land bird species are endemic and 15 species are threatened with extinction following ~70% deforestation. Under conditions of large-scale habitat loss, secondary vegetation can be important for woodland biodiversity conservation. This study compares avian abundance and diversity in secondary vegetation on Viti Levu, Fiji. We use avian point surveys at replicate sites in regenerating mahogany plantation (Colo-i-Suva; eastern lowlands), regenerating native forest (Koroyanitu National Heritage Park; western highlands) and grassland (Koroyanitu National Heritage Park). We ask if there are differences in avian abundance and species richness across habitat types. In total, we recorded 1063 birds from 33 bird species. Regenerating forest sites had the greatest species richness with mostly endemic and native woodland bird species and few introduced species. Regenerating plantation sites harboured a comparable number of endemic species and threatened species as regenerating forest sites but had significantly fewer native species and no introduced species. We recorded the most birds at grassland sites as well as the most introduced species. The findings of this study underscore the importance of regenerating native forest and regenerating plantation as habitats for Fiji’s endemic woodland birds. Increasing the expanse of regenerating forest sites should be considered for conservation planning to sustain Fiji’s extant birds.

KEYWORDS: Pacific Island; avian; biodiversity; point survey; introduced species; Swietenia macrophylla

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Introduction

Island systems are generally characterised by high levels of endemism and geographical isolation that provide opportunity to interrogate how biodiversity is generated and/or lost (Loope and Giambelluca 1998; Lomolino 2001; Cowie and Holland 2006). Islands in the Pacific region in particular have inspired naturalists working in Papua New Guinea (Ernst Mayr from 1928 to 1929), Indonesia (Alfred Russel Wallace 1854 to 1862), the Galapagos Islands (Charles Darwin in 1835) and Fiji (Ernst Mayr in 1927). These islands are known to have biodiversity with high endemism (Kier et al. 2009; Keppel et al. 2018) and high vulnerability to extinction (Steadman and Franklin 2000; Keppel et al. 2014), and are hence considered biodiversity hotspots (Mittermeier et al. 2004).

Over the past 400 years, avian species extinctions on islands have been disproportionately high and 90% of bird extinctions during historical times occurred on islands (Carew-Reid 1990; Johnson and Stattersfield 1990; Steadman and Franklin 2000). Island species have 40-fold higher extinction risk than mainland species and 39% of threatened bird species are restricted to islands (Johnson and Stattersfield 1990). Of these, more than 90% are endemic to a single geopolitical unit (Johnson and Stattersfield 1990), which further increases extinction risk. Islands in the Pacific region currently harbour ~150 of the world’s threatened bird species (Morrison 2012), including almost half the species currently considered Endangered and Vulnerable (Johnson and Stattersfield 1990).

Fiji has 66 extant land bird species (Watling 2001). Of these, and depending on taxonomic classification, there are either 32 (48%) (Watling 2001) or 34 (52%) (BirdLife Datazone 2017) endemic species. Therefore, Fiji has more endemic land bird species than the Galapagos Islands (29 endemic species), an area famous for inspiring biologists to develop evolutionary theory. However, the Galapagos avifauna has been intensively sampled (California Academy of Sciences expedition 1899–1906) and studied (e.g. Grant and Grant 2011), whereas the birds of Fiji have been little studied since the visit by the Whitney South Seas.
expedition in the 1920s (Chapman 1935). Published avian research on Fiji is limited to field notes (Brown and Child 1975; Holyoak 1979), two species-specific accounts (Clunie 1973, 1976), studies into morphometry and moult (Langham 1987; Naikatini 2009), the impact of Red-vented Bulbul (Pyconotus cafer) on avian behaviour, and bird surveys (Gorman 1975; BirdLife 2006; Jackson and Jit 2007; Naikatini et al. 2017). As a result, little is known about the nesting habits, behaviour, or population dynamics of Fiji’s land birds.

Of particular concern is that none of the 32–34 endemic forest species found in Fiji have accurate estimates of population density (Jackson and Jit 2007). In Fiji, 99% of the endemic species occur in forests (Dinerstein and Wikramanayake 1993) and protecting remaining primary forest is a priority conservation concern (Olson et al. 2010; Keppel 2014). However, given that about 70% of Fiji’s forests have been cleared (Olson et al. 2010), the current landscape is a mosaic of primary forest, secondary forest at various stages of regrowth, grasslands and exotic timber plantations (Mueller-Dombois and Fosberg 1998). There is growing evidence that old-growth secondary forest could help sustain woodland flora and fauna (Powell et al. 2015; Edwards et al. 2017; Latta et al. 2017), which would make these forests valuable for conservation in Fiji. However, no study has explicitly compared avian abundance, diversity or conservation status in secondary vegetation.

This study uses bird survey data from regenerating mahogany (Swietenia macrophylla) plantation, regenerating native forest, and grassland of anthropogenic origin on Viti Levu. The main research aim is to test the effects of habitat type on patterns of diversity, endemism, and the number of threatened species. We predict that we will find greater species diversity in regenerating native forest sites compared with regenerating plantation sites or grassland. Given the ever-present trade-off in resource allocation between repeating surveys at fewer sites vs. surveying more sites at least once, another aim is to test whether there is reliability in avian abundance and diversity estimates across days at the same site.

Materials and methods

Study area

This study was done on Viti Levu, Fiji. We conducted a total of 54 bird surveys in three habitats: old-growth mahogany (Swietenia macrophylla) plantation forest (Colo-i-Suva Forest Reserve), secondary old-growth forest, and anthropogenically modified grassland (both in the Koroyanitu National Heritage Park). Colo-i-Suva Forest Reserve and Mount Koroyanitu National Heritage Park are both protected areas that were established in 1963 and 1993, respectively (Waqaisavou 1997). The Colo-i-Suva habitat was sampled at seven sites (hereafter referred to as plantation). The Koroyanitu National Heritage forest (hereafter referred to as forest) and grassland in the Mount Koroyanitu National Heritage Park (hereafter referred to as grassland) were sampled at seven and four sites, respectively, within 2 km of Abaca Village (Table S1). In a study by Naikatini (2009), five survey sites were sufficient to capture 95% of the avian diversity in the forest sites. In this study, each survey was repeated per site on 3 consecutive days.

Regenerating plantation: Colo-i-Suva sites

The Colo-i-Suva Forest Reserve (3.7 km²) was established as a mahogany plantation in the mid-1960s (Waqaisavou 1997) and is now an important recreational area (Malani 2002). Colo-i-Suva Forest Reserve is adjacent to Maranisaqa-Wainiveiota Forest Reserve (0.77 km²), Savura Forest Reserve (4.48 km²), and Vago Forest Reserve (0.25 km²), which are covered mostly by native lowland rainforest (Tuiwawa and Keppel 2012; Dyer et al. 2018). In addition to mahogany, some of the main native tree species recorded in mahogany plantations in the area include Balaka macrocarpa, Aglia sp., Myristica casteneifolia, M. gillespiana, Calophyllum vitiensis, Syzygium sp., Palaquium porphyreum and P. vitilevuense (Tuiwawa and Keppel 2012). The Colo-i-Suva plantation has never been harvested for mahogany and the plantation forest is now ~55 years old (Tuiwawa and Keppel 2012).

Regenerating forest: Mount Koroyanitu National Heritage Park sites

The Koroyanitu National Heritage Park (170 km²) includes and surrounds the Mount Koroyanitu Range, which encompasses Mount Koroyanitu (in colonial times known as Mount Evans), the third tallest peak in Fiji (1195 m) (BirdLife International 2006; Anderson et al. 2018). The Heritage Park is a community-managed initiative for conservation and ecotourism (Smith 1948; Thaman 1996; Olson et al. 2010). The park encompasses 25 000 ha with over 700 plant species, 11 species endemic to the area (Olson et al. 2010; Anderson et al. 2018), and many plants of cultural importance (Thaman 1996). The area is listed as one of Fiji’s Important Bird Areas and a Site of National Significance (BirdLife International 2006). Our survey sites were located in secondary forest at various stages...
of regrowth after initial shifting agriculture and selective removal of trees for construction, but these have ceased since park establishment in 1993. The dominant plant species at our survey sites were *Pterocymbium oceanicum* (Malvaceae), *Dendrocnide harveyi* (Urticaceae), *Syzygium malaccense* (Myrtaceae), *Bischofia javanica* (Euphorbiaceae), and *Veitchia joannis* (Arecaceae).

**Anthropogenically modified grasslands**

The *talasiga* grasslands are a degraded vegetation type as a consequence of land clearing, agriculture and repeated burning (Gorman 1975; Latham 1983; Morrison 2019). The grasslands around Abaca Village have existed at least since the 1940s (Smith 1948). The survey sites (Table S1) were dominated by the invasive grass *Pennisetum polystachyon*, which has replaced native reed grass (*Miscanthus floridulus*) (Pernetta and Watling 1978; Ash 1992), with occasional shrubs or small trees of *Bischofia javanica* (Euphorbiaceae) and guava (*Psidium guajava*, Myrtaceae). Burning and fires in these grasslands were controlled with the establishment of the Mount Koroyanitu National Heritage Park ~25 years ago.

**Avian survey**

We used the variable circular plot method to survey bird abundance and diversity (Martin et al. 1997). This is commonly used to survey birds on Pacific Islands (Conant et al. 1981; Fancy 1997; Nelson and Fancy 1999; Jackson and Jit 2007; O’Connor et al. 2010; Peters and Kleindorfer 2017). The method uses visual and acoustic cues to record birds. Each survey site was separated by 200 m to prevent cross-over scorings between sites. Survey sites were located along established walking trails. The survey was done immediately after arrival at the site, and did not use a settling down period to avoid evasive movement by birds present (Gale et al. 2009). At each point, a group of four biologists conducted a 10 min survey, which was previously shown to be an optimal sampling duration in Fijian rainforest (Naikatini 2009). We recorded the following information: location (GPS coordinates) (Table S1), time of day, species, and estimated distance of bird from the observer (estimated to the nearest 10 m). During each survey, the group of observers faced different orientations (0° = N, 90° = E, 180° = S, and 270° = W) to ensure 360° coverage. All surveys were done in July 2016 between 0600 and 1100 h. The surveys were done during the early breeding season as most breeding activity in woodland birds of Fiji occurs during June to November (Watling 2001; Naikatini 2009). Each survey site was sampled three times on consecutive days. The observers calibrated distance estimates and bird song identification for 2 days prior to conducting the surveys.

**Species status and conservation listing**

We categorised each species as endemic (E), native (N) or introduced (I) according to Watling (2001). Of the 50 land bird species on Viti Levu, 19 are endemic and 31 are native; there are four introduced species (Watling 2001). We used the conservation status per species according to BirdLife Datazone (2017), whereby conservation status was assigned using the IUCN’s Red List categories (Critically Endangered, CR; Endangered, E; Vulnerable, V; Near Threatened, NT; Least Concern, LC) (IUCN 2001). Of the 50 land bird species on Viti Levu, six are IUCN listed and one is extinct (BirdLife Datazone 2017).

**Statistical analysis**

The data were analysed using SPSS version 23. We used a multivariate analysis of variance (MANOVA) to test the effect of habitat type on avian abundance and conservation status. In the first MANOVA exploring avian abundance and species richness, the fixed factor was habitat type (plantation, forest, grassland) and the dependent continuous variables were number of birds, number of bird species, number of endemic, native or introduced species, and number of species of conservation concern. In the second MANOVA, we tested for differences across habitat type in the percentage of endemic, native or introduced species and species of conservation concern. In the third MANOVA, we tested for the effect of survey day on survey outcomes. We statistically examined the effect of ‘survey day’ (1, 2, 3) on abundance and species richness. In this small-scale study we analyse data for presence/absence after calculating the inflection-point-per-species as outlined by Reynolds et al. (1980). We did not analyse avian density.

**Results**

**Overview of avian abundance and conservation status**

We surveyed 1063 birds from 33 bird species and 20 families (Table 1). Most individuals surveyed were endemic to Fiji (N = 592; 56%), 27% were native (N = 282) and 18% introduced (N = 189). At the species level, we surveyed 15 endemic species, 15 native species, and three introduced species (Table 1).
In the Colo-i-Suva plantation, we surveyed a total of 130 individuals from 17 species and 12 families (Table 1). We recorded 10 endemic species, two near threatened species, and zero introduced species. The Island Thrush (N) was only recorded in this habitat and was not detected by us in Abaca forest or Abaca grassland (Table 1).

In Abaca forest, we surveyed a total of 350 individuals from 28 species and 16 families (Table 1). We recorded 14 endemic species, one endangered species, three near threatened species, and two introduced species. Four species were only recorded in Abaca forest: Many-coloured Fruit Dove (N), Collared Lory (E), Black-throated Shrikebill (N) and the endangered Long-legged Thicketbird (E), which was previously unknown from the area.

In the Abaca grassland, we surveyed a total of 583 individuals from 18 species and 14 families (Table 1). We recorded six endemic species, one near threatened species, and three introduced species. Four species were only recorded in Abaca grassland: Red Avadavat (I), Fiji Parrotfinch (E), Pacific Harrier (N) and White-rumped Swiftlet (N).

**Habitat effects on species richness, abundance, and conservation status**

Species richness differed across habitat type (ANOVA: $F = 37.32, P < 0.001$). Tukey post-hoc pairwise tests showed significantly more species in the forest than plantation ($P < 0.001$) and grassland ($P < 0.001$), but comparable species richness between plantation and grassland sites ($P = 0.67$) (Table S2). Abundance also differed across habitat types (ANOVA: abundance: $F = 7.39, P = 0.002$). Tukey post-hoc pairwise tests showed significantly more birds in grassland than forest ($P = 0.021$) and grassland than plantation ($P < 0.001$), but no significant difference in abundance between forest and plantation ($P = 0.47$).

The number of endemic, native and introduced species and species of conservation concern differed across habitat type (MANOVA: number of endemic species: $F = 7.87, P = 0.001$; number of native species: $F = 43.25, P < 0.001$; number of introduced species: $F = 17.79, P < 0.001$; number of species of conservation concern: $F = 7.08, P = 0.002$) (Table S2). Tukey post-hoc pairwise

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**Table 1.** Bird species list (Present = bird seen or heard) for the Colo-i-Suva plantation, Abaca regenerating forest and Abaca grassland surveyed in July 2016 on Viti Levu, Fiji. The species status is shown as Endemic (E), Native (N) or Introduced (I) based on Watling (2001). The species conservation status is shown as Least Concern (LC), Near Threatened (NT), Vulnerable (V), or Endangered (E) based on the IUCN Red List used in BirdLife International (2017).

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Common name</th>
<th>Conservation status</th>
<th>Native status</th>
<th>Plantation</th>
<th>Forest</th>
<th>Grassland</th>
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<td>Accipiter</td>
<td>ruftorques</td>
<td>Fiji Goshawk</td>
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<td>Present</td>
<td>Present</td>
<td>Present</td>
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<td>approximans</td>
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<td>–</td>
<td>–</td>
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<td>–</td>
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<td>peroussi</td>
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<td>N</td>
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<td>–</td>
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<td>E</td>
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<td>Present</td>
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<td>Present</td>
<td>Present</td>
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<td>E</td>
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</table>

* This endangered species was heard and seen opportunistically after crossing a stream in thicket between woodland and grassland sites near Abaca EcoLodge.
tests showed significantly more endemic species in forest than grassland ($P = 0.001$), but a comparable number of endemic species in forest and plantation ($P = 0.19$). Forest sites had more native species compared with plantation ($P < 0.001$) and grassland ($P < 0.001$) sites. Grassland sites had more introduced species compared with forest ($P < 0.001$) and plantation ($P < 0.001$) sites. Finally, grassland sites had the fewest species of conservation concern compared with the forest ($P = 0.017$) and plantation ($P = 0.002$) sites.

The percentage of endemic, native and introduced species and species of conservation concern differed across habitat type (MANOVA: % endemic species: $F = 9.98$, $P < 0.001$; % native species: $F = 7.10$, $P = 0.002$; % introduced species: $F = 20.55$, $P < 0.001$; % species of conservation concern: $F = 8.03$, $P = 0.001$) (Figure 1). Tukey post-hoc pairwise tests showed a significantly higher percentage of endemic species in the plantation sites compared with either forest ($P = 0.005$) or grassland ($P < 0.001$) sites. Forest sites had a greater percentage of native species compared with plantation ($P = 0.001$) but not grassland ($P = 0.33$) sites. Grassland sites had a greater percentage of introduced species compared with forest ($P < 0.001$) and plantation ($P < 0.001$) sites. Finally, the plantation sites had the greatest percentage of species of conservation concern compared with both forest ($P = 0.009$) and grassland ($P = 0.002$) sites.

**Rare bird sighting**

Using opportunistic sampling, the Long-legged Thicketbird, *Megalurus rufus* (cited in earlier literature as *Trichocichla rufa*), was sighted near a riverine survey site at 1500 h and again the next day (−17.670157, 177.541011).

**Reliability of bird surveys**

At the same survey site on different days, we counted similar numbers of birds and species (Table 2). All Tukey post-hoc pairwise tests showed no significant difference comparing results from one day to another (all $P > 0.5$).

Table 2. Statistical results (MANOVA, $F$-values and $P$-values) for the effect of survey day on survey outcomes. Each survey site was sampled three times on consecutive days. We statistically examined the effect of ‘survey day’ (1, 2, 3) on abundance and species richness. None of the variables was significantly different across survey days.

<table>
<thead>
<tr>
<th>Survey variables</th>
<th>Plantation</th>
<th>Forest</th>
<th>Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of birds</td>
<td>2.285</td>
<td>0.131</td>
<td>2.733</td>
</tr>
<tr>
<td>Number of species</td>
<td>2.211</td>
<td>0.138</td>
<td>0.0679</td>
</tr>
<tr>
<td>% Endemic species</td>
<td>0.841</td>
<td>0.448</td>
<td>1.778</td>
</tr>
<tr>
<td>% Native species</td>
<td>0.841</td>
<td>N/A</td>
<td>1.621</td>
</tr>
<tr>
<td>% Introduced species</td>
<td>N/A</td>
<td>N/A</td>
<td>1.125</td>
</tr>
</tbody>
</table>

**Figure 1.** The percentage (mean ± SE) of species observed in each habitat type (plantation, forest, grassland) that were of conservation concern, endemic, native or introduced on Viti Levu, Fiji. Regenerating plantation and regenerating native forest sustained a greater percentage of endemic species and species of conservation concern. In contrast, grassland harboured the most introduced species (see Results).
Discussion

Our primary research aim was to test the effect of habitat type on avian abundance, diversity, and conservation status in secondary vegetation. Despite the small sample size for number of surveys per habitat, and the fact that each habitat type had only one replicate, our approach sampled a considerable proportion of Fiji’s bird diversity and surveys were reliable (repeatable) within habitats. Regenerating forest sites had the greatest species richness with mostly endemic and native woodland bird species and few introduced species. Regenerating plantation sites harboured a comparable number of endemic species and threatened species as regenerating forest sites but had significantly fewer native species and no introduced species. We recorded the most birds, the most introduced species, and the least number of threatened species at grassland sites. The findings of this study underscore the relevance of regenerating native forest and regenerating plantation forest for the occurrence of Fiji’s endemic woodland birds.

While the importance of secondary forests is being increasingly realised (Mukul et al. 2016; Latta et al. 2017; Rembold et al. 2017; Thompson and Donnelly 2018), plantations are often considered poor-quality habitats when compared with non-plantation forest (Rembold et al. 2017). However, there is growing evidence that habitat diversity in secondary forests and plantations can be maintained with human activity (Bradshaw et al. 2015; Ferreira et al. 2017; Wu et al. 2017), and that avian biodiversity recovers as regenerating forests age (e.g. Latta et al. 2017). Furthermore, the mahogany plantations at our study site have had abundant regeneration of native species (Tuiwawa and Keppel 2012) and the retention of native tree species has been shown to improve the biodiversity value of plantations (Rembold et al. 2017). The fact that the plantation forest, a Queen’s Commonwealth Canopy site (Kuson 2018), sustained many endemic species and harboured many threatened species further supports the significance of both regenerating plantations and regenerating native forest to contribute to the conservation of Fiji’s woodland birds at a landscape scale.

Our results highlight that secondary forests may play a crucial role in biodiversity conservation by providing key habitat for flora and fauna as well as ecosystem services. Indeed, large-scale comparative studies of tropical secondary forest have found no evidence that disturbance specialists dominated secondary forest sites compared with old-growth sites (Dent and Wright 2009). Furthermore, as predicted by island biogeography theory, secondary forests had greater species richness when old-growth forests were nearby (Dent and Wright 2009). While we did not sample primary forests in this study, the bird diversity recorded in our regenerating native forest sites is comparable to that of Fijian primary forest (cf. Naikatini 2009), and all our sites were located within 1 km of primary vegetation.

Despite our key finding of high avian biodiversity in regenerating forest, there are still many challenges in assessing the conservation value of secondary vegetation (Barlow et al. 2007; Chazdon et al. 2009). One issue that has hampered interpretation of the biodiversity value of primary vs. secondary forest is a bias towards examining differences in species richness rather than comparing species composition (Barlow et al. 2007; Chazdon et al. 2009). In this study, regenerating native forest had more bird species (28) than the regenerating plantation (17) or grassland (18). Yet, focusing only on species number overlooks the biodiversity value of plantation sites that harboured a high percentage of threatened species, and grassland sites that harboured an endemic granivore not present in the forest or plantation.

A different approach to assess the conservation value of habitat is to model community similarity. For example, Su et al. (2004) showed that patterns of species richness varied between taxa across habitats, but there was a consistent positive correlation in community similarity. For example, sites with similar bird communities also had similar butterfly communities (Su et al. 2004). There is growing consensus among researchers that a community-level approach with cross-taxon congruency may more effectively capture the biodiversity value of a site (Barlow et al. 2007). Birds are relatively easy to sample and have high ecological congruence with other taxonomical groups (Howard et al. 1998; Gardner et al. 2008). Future studies in the plantation, forest and grassland systems on Viti Levu could apply community-level approaches to sample associations between bird, plant and invertebrate communities, for example, to interpret community similarity across systems. Preliminary studies by members of our group found high species diversity in the regenerating native forest for invertebrates (Westwood et al. 2018), similar to the pattern we found in birds.

There is growing evidence that the age of a regenerating forest is vital for species persistence and biodiversity. A radiotelemetry study in Amazonia, for example, showed that forest age predicted habitat fidelity in insectivorous birds, but there were differences across species (Powell et al. 2015). In some birds, site fidelity was comparable between 12–18-year-old secondary forest and primary forest, but in others site fidelity was comparable only when secondary forest was 30+ years old.
(Powell et al. 2015). In a study using phylogenetic diversity, phylogenetic richness corrected for species richness recovered to old-growth forest levels after ~30 years, but phylogenetic distance between individuals recovered to old-growth levels by ~20 years (Edwards et al. 2017). Using multiple lines of enquiry spanning ecological, behavioural, and phylogenetic approaches, there is growing evidence that regenerating secondary forest, even as young as 12–30 years, can play a vital role in biodiversity conservation. These patterns are encouraging because they suggest that regeneration activities now could have positive biodiversity impact within decades.

Given the accelerated rate of habitat loss globally, there are urgent efforts to regenerate altered landscapes to secondary forests (Smith et al. 2017). In some cases, enrichment planting (Yeong et al. 2016) has been effective in creating buffer zones, and could help safeguard endemic woodland forest birds from invasive grassland species. While primary forest has been shown to sustain 12% more bird species than secondary forest (Sayer et al. 2017), secondary forests can help to revert faunal declines in fragmented tropical landscapes (Sayer et al. 2017; Rocha et al. 2018). Specifically, old-growth bat specialists may be great beneficiaries of secondary forest maturation (Rocha et al. 2018), and bird species increased across one decade in regenerating secondary forest in Costa Rica (Latta et al. 2017). In studies into amphibians and reptiles, researchers found higher species richness in secondary forests than altered habitats, but greatest diversity in old-growth forest (Thompson and Donnelly 2018).

Conclusion

Of Fiji’s 66 land bird species, 15 species are threatened with extinction (1 CR, 1 EN, 5 VU, 8 NT) and the Bar-winged Rail (Hypotaenidia poeciloptera) is considered extinct (BirdLife Datazone 2017). The biggest threats to the survival of Fiji’s birds are habitat loss, introduced mammals (rats, mongoose, feral cats, goats, dogs), introduced birds (mynahs, bulbuls, magpies), hunting and harvesting (Watling 2001). Our findings show that secondary vegetation provides important habitats for Fiji’s avifauna, and understanding how secondary forest can mitigate for species loss is therefore an urgent area of research, especially for the relatively unstudied birds of Fiji. Future research could identify the behavioural and ecological phenotypes of individuals that persist in secondary forests, given the possibility that widespread, abundant, habitat generalists might dominate similarity analyses and overshadow local endemic extinctions. In combination with predator and pest control, reforestation can create important habitats for Fiji’s avifauna and help mitigate local extinction. Such reforestation would likely be most effective if it increases landscape-scale habitat connectivity, linking secondary and old-growth forests (Perault and Lomolino 2000; Jones et al. 2016).

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References


