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Endemic avifaunal biodiversity and tropical forest loss in Makira, a mountainous Pacific island

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Anthropogenic habitat changes and the introduction of pigs, dogs, cats and rats have caused a catastrophic decline in the terrestrial biodiversity of Pacific archipelagos. At present, economic globalization and an increased demand for timber are promoting industrial logging and plantation expansion. Commercial logging can be sustainable but in practice it more often leads to land degradation, especially on small flat islands. On large and mountainous islands, however, more modest impacts can be expected as the narrowly endemic species tend to inhabit montane forests where logging is difficult. In this study we use ornithological data collected at different elevations to assess the extent to which the avifauna of Makira, a large mountainous island in Melanesia, will be affected by deforestation of the lowlands, most of which are under timber concessions. Our data suggest that a majority of the endemic bird species use lowland forest to some extent and that this may even apply to species hitherto associated with montane forest. If current commercial forestry programmes are continued, the forest habitat may be disturbed or lost over large parts of Makira, potentially undermining the natural resource base for the local subsistence economy, exacerbating climate change and threatening the integrity of one of the most important areas for biodiversity conservation on earth. Our study highlights the importance of understanding the habitat requirements of endemic species and the urgency of establishing and effectively managing community-based protected areas in suitable lowland forests of the Pacific.

Keywords: biodiversity, forestry, Galathea 3 expedition, montane fauna, Pacific Islands, Solomon Islands

Introduction

Biodiversity is an important environmental asset in a development context. It provides not only valuable resources for local people but also indirect values such as the high ecological resilience and good human health associated with mature and biologically complex habitats (Kinzag *et al.*, 2002), as well as services of global significance such as carbon storage. Tropical forests store around 46 per cent of the world's living terrestrial carbon (Soepadmo, 1993) while 25 per cent of total net global carbon emissions are thought to stem from deforestation. In recognition of the importance of biodiversity, the global community has agreed to arrest the decline in biodiversity by 2010. However, as long as tropical deforestation continues, the chances of achieving this goal are slim.

Globally, deforestation is among the greatest threats to biodiversity and such scenarios are particularly grim in tropical archipelagos. Based on excavated evidence of rich deposits with avian subfossils from Remote Oceania, it is estimated that 25 per cent of the regional avifauna died out as an immediate consequence of human colonization some 1000–3000 years ago (Steadman, 2006), when agriculture arrived with the Lapita culture (Spriggs, 2003). The situation is not as severe on the larger and mountainous islands of Melanesia, which with some exceptions still have extensive tracts of rainforest (see Hviding & Bayliss-Smith, 2000; Buchanan *et al.*, 2008). This difference in impact might be the result of Melanesia's wet, less seasonal climate, which does not necessitate shifting agriculture, but it could also be because the human populations practising agriculture have remained small, possibly as a result of malaria, which was absent in Remote Oceania (Spriggs, 1997; Kelly, 1999). However, it is still unclear how much of Melanesia's biodiversity has been lost as a consequence of the conversion of natural vegetation along the coasts and the introduction of pigs, dogs, cats and rats (Mayr & Diamond, 2001: 36–43; Steadman, 2006), and how much will be lost in the near future as a consequence of the large-scale logging and increasing populations. Hunter-gatherers existed on the Solomons at least as early as 28 000 years ago (Loy *et al.*, 1992) but probably had little direct environmental impact, and there is some evidence that pigs (Kirch, 2000) and rats (Matisoo-Smith & Robins, 2004) did not arrive in the region before the Neolithic colonization.

The Melanesian region is outstanding for its biological diversification. Studies here by Ernst Mayr (Mayr & Diamond, 2001) have informed the basis of our understanding of how new species evolve through geographical isolation, and the development of the biological species concept. It was generally assumed that new species evolved through a process of colonization from the mainland to islands further and further out in the ocean, with cycles of isolation and new colonizations. According to this view oceanic archipelagos are dead ends from an evolutionary perspective, although this is now changing as molecular studies suggest extensive radiations of species within archipelagos and even back to the continents (Filardi & Moyle, 2005). The geologically highly complex archipelagos that have developed in the transition between the Australo-Papuan plate and the Pacific plate (see Hall, 2002) thus appear to represent an incredible 'factory' in terms of global biological diversification.

Unfortunately, most knowledge of biodiversity in the Pacific archipelagic region derives from expeditionary exploration, and little has been done using modern methods such as quantitative biodiversity assessment and molecular studies of population structures. The Danish Galathea-3 expedition in 2006–07 provided an opportunity to collect new data (see background at http://www.galathea3.dk/uk). This paper focuses on birds in the most biologically outstanding of the Melanesian islands, Makira (formerly San Cristobal), and discusses the future prospects of this fauna in the light of the accelerating commercial logging activity. Makira (c. 10°30′ S, 161°55′ E; 3100 km^2), situated in the southeastern Solomon Islands and of global importance to biodiversity, is part of a high priority Endemic Bird Area (BirdLife, 2003) and included in the East Melanesian Islands Biodiversity Hotspot (Beehler *et al.*, 2004; also see http://www.biodiversityhotspots.org/xp/hotspots/east_melanesia/Pages/default.aspx) and the Global 200 Ecoregions (Olson & Dinerstein, 1998; see also http://www.worldwildlife.org/science/ecoregions/global200.html).

While it is evident that logging of small, flat islands will have serious consequences, just like the habitat changes caused by the historical migration of Polynesians throughout the Pacific archipelagos, less serious impacts can be expected on large, mountainous

islands such as Makira. Logging companies are mainly interested in the lowland and foothill forests that afford easy access to large trees with straight boles rather than in the steep terrain with stunted forest in the highlands. Furthermore, lowlands generally tend to be inhabited by dispersive and widespread species while the montane forests harbour the narrowly endemic species (Mayr & Diamond, 2001). Thus the island of Makira, with its near-complete forest cover and large areas of rugged highland terrain, could be expected to be a relatively safe sanctuary for biodiversity, even in the worst-case scenario of unabated logging, forest degradation and deforestation. In this paper we use ornithological data collected at different elevations to assess the extent to which the avifauna of Makira is likely to be negatively affected by logging of lowland and foothill forests.

Methods

Our fieldwork was carried out with local counterparts during 22 November–13 December 2006 as part of the Galathea 3 expedition project on collecting molecular data for analysing avian diversification across the Australasian archipelago (see http://www.galathea3.dk/uk/Menu/Science/Avian+diversification and www.monitoringmatters.org/galathea/ (in Danish)). We used remote image analyses of forest cover and helicopter reconnaissance, together with ground-based surveys of birds and semistructured interviews with local community members. Prior to the fieldwork, consultations were held with residents in villages in the central Bauro Highlands and with staff of a local nongovernmental organization (NGO), Makira Community Conservation Foundation (see http://portal.conservation.org/portal/server.pt/gateway/PTARGS_0_2_136413_0_0_18/Makira%20Solomon%20Islands-2007.pdf). Travelling by helicopter into the forested highlands, we landed near two villages Maraone and Materato, which represented the outposts of currently settled areas from where the uninhabited highland forests could be reached on foot.

Surveying and recording of birds was done during daylight hours, especially in the early morning and towards sunset (Fjeldså *et al*., 2008), and often hampered by heavy rain and conditions of steep terrain, vines and closed canopy. However a few places were found along the ridge tops where it was possible to obtain an overview after cutting away branches.

The first days were spent getting accustomed to the bird voices. Most passerines were easy to identify. Parrots, on the other hand, were difficult to record until we gained confidence in recognizing their flight calls. Likewise we spent time learning the voices of pigeons and doves. Most observations were made during slow walking along trails which, in the highlands, follow the ridge tops, and generally within 1 km of a campsite. It is possible to record birds in a semiquantitative manner even in very rugged terrain in tropical montane forest (Fjeldså, 1999) but, as we were not sufficiently familiar with Solomon bird vocalizations at the beginning of our study, we decided to use a more crude assessment. At camp every evening, team members discussed what had been seen in the study area during the course of the day and made a rough estimate of the number of individual birds detected (visually or from vocalizations). The resulting figures have low value *per se*, of course, but nevertheless allowed for a robust assessment of abundance categories.

Bird sounds were tape-recorded at any time of the day or night when vocal activity was noted (mostly by Niels Krabbe). These were recorded using a Sony TCM 5000 tape recorder and a Sennheisser ME 67 directional microphone, and referenced to species by

visual observation, on some occasions through use of playback when necessary. Recordings have been deposited with Macaulay Library Archive of the Cornell Lab of Ornithology in Ithaca, the British Library Sound Archive, London and the Natural History Museum of Denmark at the University of Copenhagen.

In earlier collecting efforts on Makira birds were mainly shot but this was no longer possible as the government had confiscated all firearms. We therefore captured birds in mist-nets and a few by using a slingshot. Mist-netting is a good supplement to the past practice of using guns, since skulking birds of the dark forest understorey are captured quite effectively, but its success was somewhat limited by the very low density of understorey birds in the Melanesian montane forest. On some occasions, we mounted mist-nets in the lower canopy but this yielded little. Photographs were taken of all bird species caught.

Semistructured interviews and discussions to obtain information about the presence/absence of wildlife species and the local utilization of species were carried out with forest product gatherers at the campsites, during evening meetings in the villages, or when forest users were encountered on forest paths. Additionally, the interviews aimed at discussing present and proposed future land use in the area and identifying key concerns of the local communities, and discussions were used for validating our observations. The preliminary results of our survey were presented and discussed at community meetings in Materato and Kirakira, the capital of Makira-Ulawa Province.

The locations of our nine study sites are shown in Figure 1 and the survey findings are summarized in Table 1. Overall, the survey efforts at three sites were limited: at Naara (site C) and Maraone village (site G), the ornithological work was conducted by only one person operating at the forest edges near a village; and efforts at Muu (degraded forest edges near a village; site B) were thwarted by insufficient time and heavy rain.

In order to distinguish the habitats most valuable for biodiversity conservation, we used the number of species recorded at each site plus a score reflecting the rarity of each species according to global distribution databases developed by the Natural History Museum of Denmark. Distributional data (breeding range) have been compiled from the literature and entered into a global grid with a resolution of 1×1 geographical degrees, using the WorldMap software for exploring patterns of diversity, rarity and conservation priorities (Williams, 2003). The global rarity of a species was scored as its inverse range-size, which means that a species recorded in a single grid cell is given the rarity score 1/1 = 1.0 while a species recorded in 1000 grid cells receives a score of 1/1000 = 0.001. When assessing a rarity sum for a local bird community, we also used the value 0.001 for species with a distribution range exceeding 1000 grid cells, thus avoiding classifying any species as less 'valuable' than this. The correlation between the altitude of the study sites and the rarity of the birds was assessed using Spearman's rank correlation coefficient (Fowler & Cohen, 1988).

Our data were supplemented with unpublished observations of the Cambridge University expedition led by Guy Dutson, which had surveyed birds on Makira for two weeks in 1990 (Buckingham *et al*., 1990), two weeks in 1998 and over four days in both 2002 and 2004 (Dutson, 2009). Using similar methods to our study they visited coastal coconut groves, gardens and forest along the road between Kirakira and Arohane; the lowland forest along the lower Ravo River at Hunari and Manipargeo; the lowland forest inland of Wango Point, west of Kirakira; and the hill and submontane forest around Hauta.

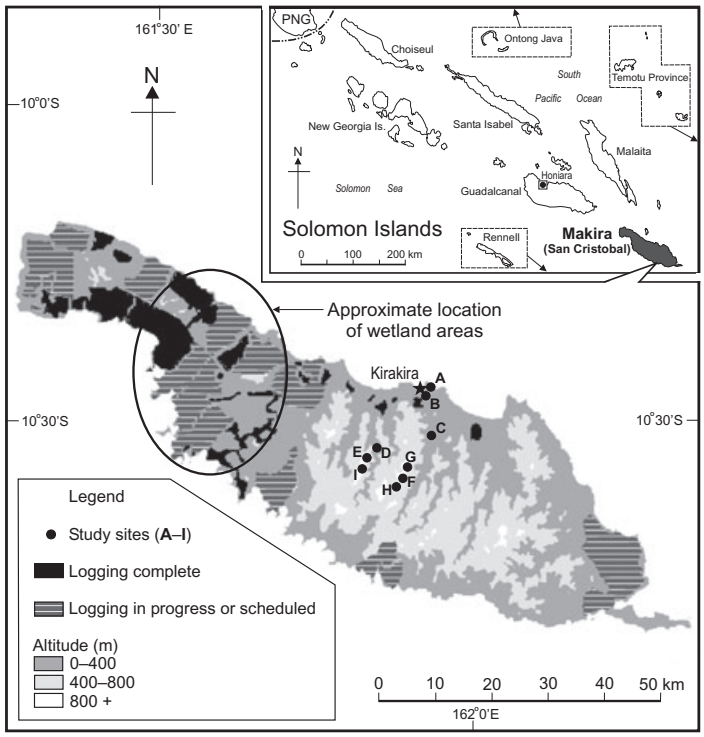

Figure 1. *Map of Makira, a Melanesian island in the Solomons, showing the locations of the nine study sites (A–I), the western swamps and logging licenses (SIFMP II, 2006).*

Table 1. Survey of bird species and rarity in study sites at varying altitudes in Makira Island, Melanesia, November–December 2006.

Study site location (A-I following Figure 1)	Altitude (m)	Duration (days)	Species recorded	Rarity (sum of inverse range-sizes)
A Tawaitara village, east of Kirakira (3–20 m)	10	3	52	5.69
B Muu village, southwest of Kirakira (10–30 m)	20	2	32	3.50
C Naara village (60 m)	60	3	33	4.98
D Baranaigasi ridge, above Materato village (camp at 350 m, records from 300–400 m)	350	5	40	6.86
E Baranaigasi ridge, above Materato village (camp at 550 m, records from 400–800 m)	600	5	41	7.57
F South of Maraone village, above Hauta (800 m)	800	10	51	7.71
G Maraone village (810 m)	810	3	38	6.05
H Maningara camp (820 m)	820	6	39	8.12
I Baranaigasi ridge, above Materato village (camp at 900 m, records from 800–1040 m)	920	5	37	7.81

Results and discussion: bird species on Makira

Altogether we collected 246 birds (with tissue samples) and obtained 425 sound recordings and photos of 41 species – thus documenting 82 species. Our data confirmed the presence of all resident bird species that had previously been documented for Makira, except two that are possibly extinct: the Thick-billed Ground-dove *Galli-*

columba salamonis and San Cristobal Moorhen *Gallinula silvestris*. The Thick-billed Ground-dove is assumed to be endemic to the eastern Solomons, with the type-specimen probably from Makira (BirdLife, 2000; Gibbs *et al.*, 2001) and the other specimen possibly from a small nearby island; however, there is uncertainty as to the origin of both specimens (Fjeldså *et al.*, 2008), and IUCN/BirdLife now considers this species extinct (BirdLife International, 2009).

The flight-impaired San Cristobal Moorhen is endemic to Makira and has been documented only from the type-specimen collected in 1929 at 580 m in central Makira (Taylor & van Perlo, 1998) and the reported sighting in 1953 (Cain & Galbraith, 1956), and possibly later (BirdLife, 2003). Based on our interviews, we conclude that the species has been extirpated from the area of the study sites but could persist in the vast areas of uninhabited wet hill forest on the southern weather coast slopes of the island. The cause of the disappearance of this species from known sites remains a mystery. Many of the people we met knew the species but had not seen it for decades. The introduction of dogs and cats has been suggested as a possible cause (BirdLife International, 2003) although we only heard a single account of one having been taken by a dog. There is also the possibility that fire ants (*Wasmannia auropunctata*), first noted in the Solomons in 1974 and said to have arrived in Makira soon after, could be the cause as these are known to attack the eyes of dogs, cats and ground-living birds, and often cause serious changes in local biodiversity (Wetterer & Porter, 2003). We found fire ants in most places we visited, including along trails in highland forest, and were told that it was the cause of dogs becoming blind; indeed we saw that many dogs had damaged eyes. The opening of logging roads would undoubtedly lead to further spreading of this ant, perhaps to all parts of the island.

As presented in Table 2, an astonishing 32 of the bird species we recorded in Makira are restricted-range species (global range < 50 000 km^2), which strengthens the call for conserving the island's biodiversity as a top global priority. With the exception of Sierra Nevada de Santa Marta in Colombia (Todd & Carriker, 1922), Makira holds more restricted-range bird species than any other area of comparable size on the planet. Twelve of the restricted-range species are endemic to Makira and its small offlying islands Ugi and Owaraha (Santa Anna), and four endemic subspecies are highly divergent, qualifying as phylogenetic species.

Aside from the low number of bird species recorded at three sites (B, C and G) where survey efforts were limited, the number of species recorded did not change greatly between the other six study sites (Table 1). We did, however, find a highly significant correlation between the altitude of the study sites and the relative role of range-restricted species as seen in Figure 2 (Spearman rank; $r_s = 0.833$; one-tailed; $P < 0.01$).

We assessed the altitudinal distribution of individual species and found that three of the restricted-range species – Shade Warbler *Cettia parens*, San Cristobal Leaf-warbler *Phylloscopus makirensis* and San Cristobal Thrush *Zoothera margaretae* – were confined to the highland study sites and thus probably safe from the potential forest destruction associated with logging in the lowlands (Table 2).

Two species, the vulnerable Yellow-legged Pigeon *Columba pallidiceps* and the vulnerable Chestnut-bellied Imperial-pigeon *Ducula brenchleyi*, were found in the valleys intersecting the central highlands but not below 550 m where they had earlier been observed by Dutson (see Table 2). Their absence at low altitudes may be because of persecution as favoured targets of subsistence hunting, which means that these two species would suffer if the establishment of logging roads in the lowlands were to facilitate hunting in the interior forests.

Table 2. Abundance and altitudinal distribution of restricted-range bird species (global range < 50 000 km^2) recorded at nine study sites at varying altitudes in Makira island, Melanesia, November–December 2006.

Species	Threat category	Study sites and survey altitude (m)									Distrib. by Dutson (2009) (0–900 m)
		A (10)	B (20)	C (60)	D (350)	E (600)	F (800)	G (810)	H (820)	I (920)	
Megapodius eremita	Rr	P	P	U	P	P	R	U		?	0–350
Haliaeetus sanfordi	VU, Rr	U	U	U	U	U					0–450
Accipiter albogularis	Rr	U	U	P	U	U	P	U	U		0–900
Columba pallidiceps	VU, Rr			P	P	U	R	U	R		50–650
Reinwardtoena crassirostris	Rr	U	P	P	U	U	Fc	+	U	Fc	50–900
Ptilinopus solomonensis	Rr	C	C	C	C	C	Fc	C	C	C	0–900
Ptilinopus eugeniae	Nt, Rr	P	P	R	Fc	Fc	Fc	Fc	U	U	0–700
Ducula rubricera	Rr	C	C	Fc	Fc	C	Fc	Fc	C	Fc	0–900
Ducula brenchleyi	VU, Rr	P	P	P	P	U	Fc	Fc	Fc		0–900
Micropsitta finschii	Rr	U	P	P	U	U	U	Fc	U		0–900
Lorius chlorocercus	Rr	Fc	Fc	Fc	C	C	C	Fc	Fc	Fc	0–900
Charmosyna meeki[1]	Rr						R		R		Not recorded
Charmosyna margarethae	Nt, Rr	P	P	P	P	P	C	C	U	Fc	0–700
Geoffroyus heteroclitus	Rr	U	U	U	U	U	Fc	Fc	Fc	U	0–900
Ninox jacquinoti	Rr	?	P	P	Fc	P	R		Fc	U	100–600
Ceyx [lepidus] gentiana	Rr	Fc	Fc	Fc	U	C	Fc	Fc	C	Fc	0–800
Melidectes sclateri	Rr	P	P	U	C	C	C	C	C	C	0–900
Myzomela cardinalis	Rr	C	Fc	U							0–100
Myzomela tristrami	Rr	C	Fc	Fc	U	Fc	R	Fc	Fc	U	0–900
Coracina [tenu.] solomonis	Rr	U	P	U	Fc	U	U	Fc	U	U	0–900
Lalage leucopyga	Rr	Fc	P	U	C	U	P	Fc	U	U	0–100
Rhipidura tenebrosa	Nt, Rr	U	U	U	U	U	R	U	U	U	50–700
Rhipidura rufifrons russata	[Rr]	C	Fc	C	Fc	Fc	Fc	Fc	Fc	C	0–900
Monarcha castaneiventris	Rr	C	C	C	Fc	Fc	U	C	Fc	Fc	0–900
Monarcha viduus	Rr	U	Fc	Fc	Fc	Fc	U	U	Fc	U	0–800
Myiagra cervinicauda	Nt, Rr	U	P	P	U	U	Fc		Fc	U	0–700
Cettia parens	Nt, Rr					U	Fc	Fc	Fc	Fc	500–900
Phylloscopus makirensis	Nt, Rr				U	U	Fc	C	C	Fc	600–900
Zosterops ugiensis	Rr			P	Fc	Fc	C	C	C	Fc	80–900
Aplonis dichroa	Rr	Fc	P	C	P	C	Fc	Fc	U	U	0–800
Zoothera margaretae	Nt, Rr				U	U	R	P	Fc	Fc	400–700
Dicaeum tristrami	Rr	C	Fc	Fc	Fc	C	Fc	Fc	C	Fc	0–900

Threat category abbreviations – EN=endangered; VU=vulnerable; Nt=near-threatened; and Rr=restricted range (range < 50 000 km^2).
Abundance category abbreviations – C=Common: recorded daily in moderate to large numbers (>10 individuals); Fc=Fairly common: recorded daily in small numbers (<10 individuals); U=Uncommon: recorded less than daily but at least once every 5 days, occurs in small numbers; R=Rare: recorded on one of 6 days or less often, occurs in small numbers; ?=doubtfully recorded; +=recorded but abundance not assessed; and P=not recorded in this 2006 survey but potentially present based on the altitudinal distribution found in this survey and by Dutson (2009).

Another 12 endemic taxa (*Ptilinopus solomonensis*, *Ducula rubricera*, *Micropsitta finschii*, *Lorius chlorocercus*, *Ceyx* [*lepidus*] *gentiana*, *Myzomela tristrami*, *Lalage leucopyga*, *Rhipidura rufifrons russata*, *Monarcha castaneiventris*, *Monarcha viduus*, *Aplonis dichroa*, *Dicaeum tristrami*) have a wide altitudinal range and were variously common, fairly common or uncommon at all elevations (Table 2); these may be affected by logging but may still have plentiful habitat in the central highlands of Makira. The genetically distinctive *Pachycephala (pectoralis) christophori* was mainly represented by territorial pairs in the highlands although immature birds were particularly abundant in the lowlands, suggesting seasonal population movements.

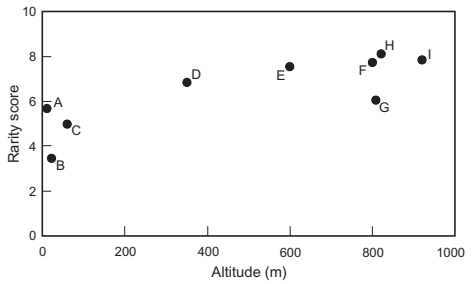

Figure 2. *Rarity scores (sum of inverse range-sizes) of birds recorded at varying altitudes in Makira island, Melanesia, November–December 2006.*

Nine species have their stronghold in the highlands but were also found (or potentially present inferring from observations by Dutson) in the lowlands: the Crested Cuckoo-dove *Reinwardtoena crassirostris*, White-headed Fruit-dove *Ptilinopus eugeniae*, Duchess Lorikeet *Charmosyna margarethae*, Singing Parrot *Geoffroyus heteroclitus*, Solomon Hawk-owl *Ninox jacquinoti* (the strictly endemic form *roseoaxillaris*), San Cristobal Melidectes *Melidectes sclateri*, San Cristobal Cicadabird *Coracina (tenuirostris) solomonis*, Ochre-headed Flycatcher *Myiagra cervinicauda* and Grey-throated White-eye *Zosterops ugiensis* (Table 2). Also generally considered a bird of the montane forest, the Dusky Fantail *Rhipidura tenebrosa*, was recorded (as uncommon or rare) at all study sites. Some of these 10 species may undertake seasonal movements to the lowlands and we do not know the extent to which they depend on lowland habitat for part of the year.

Only one restricted-range bird species was confined to the lowlands (below 60 m elevation) – Cardinal Myzomela *Myzomela cardinalis*, which frequents disturbed habitats such as coconut plantations and gardens and is therefore unlikely to be threatened by forest degradation. More importantly, the globally threatened Sanford's Fish-eagle *Haliaeetus sanfordi*, which was recorded (as uncommon) at all study sites in the lowlands and hills but not at altitudes above 600 m, could suffer from logging in the lowlands as it would probably prefer large trees for nesting and avoid areas with substantial human disturbance.

For the remaining three restricted-range species recorded – *Megapodius eremita*, *Accipiter albogularis*, *Charmosyna meeki*[1] – our data are insufficient to make any conclusions regarding their altitudinal distribution in Makira.

Two important caveats apply. Many parts of Makira have still not been surveyed, including the peat and freshwater swamps in the western part (Figure 1) and the uninhabited hill forests and highland areas near the south weather coast. Furthermore, we know little about the natural history of the species recorded and the extent to which these species depend on different habitats at different times of the year. Bird distributions on altitudinal gradients may involve source-sink dynamics, where a species can only maintain its presence in a particular zone as long as there is a surplus in another. Whether this applies to Makira – which has nearly no seasonality and only slightly lower rainfall in June and September to November (Kira Kira; no data for the highlands; see further at www.met.gov.sb) – remains unknown.

Second, we do not know how well our records reflect the true species distributions. The steep terrain and closed canopy sometimes limited the view, particularly when recording raptors and doves, though these species were observed even in the high areas with difficult views. Although the abundance criteria are intended to be clear, objective

and straightforward, consistent application is difficult. This problem was minimized in our study because all data were collected – and evaluated – by the same small group of people.

Despite these limitations, this study demonstrates several important points. Only a small proportion (13 per cent) of the present bird species that are considered of conservation concern are likely to be safe if the lowland forests are clear-felled, indicating that additional areas must be conserved if the avifauna of Makira is to be preserved.

Most (78 per cent) of the bird species of conservation concern in Makira will be negatively affected by clearing of the lowland and foothill forests, including one species, *Rhipidura tenebrosa*, that was generally assumed to be associated with montane forest. Of these affected species, most (100 per cent) will suffer from habitat degradation and some (12 per cent) also from potentially increased hunting or other disturbances. Eleven of the restricted-range bird species are considered particularly at risk because they occur in low numbers or are adversely affected by increased human access to the interior forests. The four bird species believed to be safe are either restricted to highland habitats (3 species) or are capable of surviving in second-growth lowland habitats (1 species).

Challenges for conservation

There is a long-term and a short-term perspective on conservation in the Pacific islands. Identification of bones in excavated sediments suggests a mass extinction of the original fauna in Remote Oceania caused by human colonization (James, 1995). Most notably, there has been an enormous loss of an estimated 1000 species of (often flightless) birds of the Rallidae family (Steadman, 2006) and also a considerable loss of ground-living doves and pigeons.

The impact of human activity and of introduced rats and pigs was probably most dramatic on small islands such as atolls, where the natural vegetation was rapidly destroyed and replaced by coconut plantations and food gardens, dramatically changing the conditions for birds. This would seem to be the case for the coastal lowland of Makira, although the effect is probably less dramatic because of the short distance from less disturbed hill forest that afford the possibility of recolonization of particular plant communities – and birds – that are lost locally. Nevertheless, a high level of disturbance of the natural vegetation near the coast will alter the structure of biological communities and favour certain species. This can be seen as a change in vegetation structure, as the disturbed coastal forest can become impenetrable with dense growth of vines and tall herbs, a habitat that would hold an avifauna different from that of the closed natural forest. Habitat disturbance thus favours the so-called supertramp species, which are dispersive and widespread, and often food generalists. And the invasive species introduced by humans, incidentally or purposely, will also mainly expand in the disturbed habitats, as they have most prominently in lowland disturbed areas and on disturbed islets, except for the house cat *Felis catus* and wild pig *Sus scrofa* x *S. celebensis* which have established populations in Makira's mountains. There may also be a small wild population of *Canis familiaris*, since local hunters report that dogs are routinely lost in the forest during pig hunting.

Fortunately, large parts of the hill forests in Makira are still largely intact (Figure 3), although this could change quickly. The highland forests are mostly virgin, even though as in other parts of Melanesia (Bayliss-Smith *et al*., 2003) there has been a human presence there for millennia. The human impact is a minor factor compared to the

Figure 3. *Hill forest habitat in Bauro Highlands that needs protecting, Makira island, Melanesia, December 2006 (photo courtesy of Finn Danielsen).*

natural perturbation caused by landslips on the steep slopes. In line with the general tendency in Melanesia (Mayr & Diamond, 2001), our observations confirm that the highland is home to most of the narrowly endemic species (Table 2). This environment may come close to being described as a climax community of co-adapted plants and animals.

Amongst the 32 restricted-range bird species we recorded, 10 are classified as globally threatened or near-threatened (Table 2). Makira is certainly also important for other organisms such as butterflies (Tennent, 2002) although this is less well-documented. We recorded five restricted-range mammal species – all bats (Filardi *et al.*, forthcoming).

Most of the lowlands of Makira (Figure 1) are under existing or planned timber licenses (SIFMP II, 2006). Representatives of foreign timber buyers in Makira (field interviews) predicted the depletion of the island's commercially valuable timber within 5–10 years (from 2006).

Large-scale forestry can potentially provide sustained benefits to human communities. The current logging activities on Makira however, as in other parts of Melanesia (Furusawa *et al.*, 2004; Wein & Chatterton, 2005), are undertaken with minimal attention to environmental issues, potentially threatening the natural resource base necessary to sustain the local subsistence economy. At least five reasons can be given following Wein & Chatterton (2005).

First, whole logs are exported, loaded onto ships at the nearest coast, without either generating any investment in local industries to encourage product development or providing job opportunities beyond short-term needs.

Second, the local Makira and national Solomons economy are to a large degree dependent on the commercial forestry sector activities. While some in the coastal areas benefit from logging in the short-run, the longer-run costs are paid by many others, the most serious and immediate of which are soil erosion and siltation of rivers and coastal waters causing a lowered water quality and potential damage to coral reefs and coastal fisheries. Additionally there may be changes in the local climate and the development of impenetrable vegetation of shrubs and climbers. The regeneration of valuable timber trees will likely take a long time, and not all may regenerate. Short-term and intensive logging (as anticipated by international timber buyers) is therefore not likely to benefit the local communities in the long run.

Third, the current legislation that regulates forestry operations in Solomon Islands, the Forest Resources and Timber Utilisation Act of 1969, is seriously outdated, unwieldy and difficult to interpret, lacks consistency and coherence, and offers very poor coverage of environmental issues, with, for instance, no allowances for compensation to landowners when waterways are disrupted by logging activities (Wein & Chatterton, 2005).

Fourth, enforcement of forestry legislation is poor because government departments suffer from a severe lack of capacity and financial resources. This has led to rampant illegal logging and abuses of regulations within the forest sector (Wein & Chatterton, 2005), also typical in many other countries (Laurance, 2004).

Fifth, logging companies negotiate directly with the local communities for access to timber in exchange for (often unfulfilled) promises of community-development facilities such as clinics and schools (Wein & Chatterton, 2005). Under the 1969 Act, the process of acquiring timber rights requires that the people be organized into 'tribes' in which they can be represented by 'chiefs', which does not conform to the reality in Solomon Islands where so-called 'tribal' divisions are imprecise and depend on social context, and where 'chiefs' are merely heads of lineages with, often, less power than socially appointed leaders. Timber concessions negotiated by such local 'chiefs' thus are often the cause of land disputes. At the same time, both 'chiefs' and other local decision makers are mistrustful of government attempts to administer the use of customarily-owned land.

If the current logging programmes are continued, we fear that the forest habitat will be disturbed or lost over large parts of Makira, except maybe in some waterlogged, flat areas in the west and in the steepest and highest parts of the central Bauro Highlands (Figure 1). In order to avoid the loss of unique biodiversity, it is essential to act quickly to set aside undisturbed areas of adequate size for conservation and as *in situ* seed banks.

Over the past 30 years, at least five studies have recommended the establishment of protected areas in Makira (Diamond, 1976; Dahl, 1980; SPREP, 1985; Lees *et al*., 1991; Leary, 1993). However, despite the global importance of the island to biodiversity and the mounting threats facing its forests, there is still no protected area on the island. Although none of the reserve proposals seem to have been discussed or followed up with the customary landowners, these studies have prompted the establishment of the Makira Community Conservation Foundation, an NGO that is working with the highland communities and the provincial authorities towards a sustainable use of the forests. However, the western swamp in Makira, which is reported to be 'clearly of international significance' (Leary, 1993: 338) and comprises one of the largest representations of freshwater swamp forest in the Solomon Islands (Leary, 1993), is immediately threatened by the logging of well-drained adjacent land (Figure 1).

Management of declining natural resources

Central concerns raised during the community meetings included the general decline in natural resources, the limited income from subsistence farming and minimal availability of health, education and communication services and facilities. The main reasons for the decline in natural resources were reportedly the lack of security of land tenure on the part of highland communities; population increase, poverty and lack of cash; the limited political will among government decision makers to effect changes; the unsustainable large-scale forestry schemes; large-scale expansions of agricultural schemes including cocoa, coconut, teak and mahogany plantations; cattle ranches and irrigated rice cultivation; and the inadequate coordination between; and minimal capacity of government agencies to monitor, enforce and provide e.g. legal follow-up.Villagers stressed the

importance of the wide range of forest plants and animals to their livelihoods. Forest and river resources collected almost daily include wild fruits, nuts, sweet potatoes, meat from feral pig, doves and pigeons, Makira Flying-fox *Pteropus cognatus* and other large bats, as well as water, firewood, building materials and medicines. Villagers also emphasized that customary resource management measures are still widely used, for instance, to regulate the use of wild betel palm *Areca catechu* and for the capture of river fish with traps (see also Johannes, 1978). Based on our findings and discussions with local people, we identified a number of actions that we believe to be essential to sustainable development in Makira.

There is an urgent need to identify the boundaries of potential protection zones in the Bauro Highland and in the swamps of western Makira. Our data suggest that the areas most important for conservation, those with the highest endemism, are found in the central highlands: these areas should be considered 'irreplaceable' from a conservation perspective because of the number of species found nowhere else.

At lower elevations, it is important to protect steep slopes where the risk of erosion is high. It is equally critical to maintain adequate 'seed banks' for forest regeneration and to maintain ecological processes. Therefore a conservation zone encompassing a full ecological gradient from the north coast, across the Bauro Highlands and south to the weather coast is strongly recommended. This conservation zone would need to be gazetted and legally recognized, and our proposal would be to accord this area the status of a community-managed World Heritage Site in order to foster its unique biological diversity as well as the local culture and livelihoods (for experiences in New Georgia see Hviding & Bayliss-Smith, 2000).

Within the conservation zone, the traditional rights to land and resources of the existing local communities need to be secured and formally recognized. One approach to this could be to establish conservation agreements between the government, an international environmental NGO and key villages. The agreements should describe activities that promote biodiversity conservation in this area, the external financial, technical or other assistance that could be provided, and how compliance would be monitored. The agreements should allow for inclusion of strict conservation zones (wildlife refuges and reference areas for research) as well as buffer zones outside the village land where extraction of natural resources within sustainable limits can continue based on existing measures for traditional community-based resource management.

Moreover, there is a need for the provincial government to strengthen coordination amongst the agencies involved in provincial development, forestry, agriculture, tourism and conservation. They should also encourage dissemination of information regarding environmental values and problems and solutions associated with loss of such values to key decision makers. It is also recommended that environmental NGOs encourage the establishment of locally-based schemes for monitoring natural resources and resource use in order to strengthen customary law and encourage local regulatory natural resource management actions (Danielsen *et al*., 2007; see also www.monitoringmatters.org).

The wider perspective

Makira still holds populations of 32 restricted-range bird species. Although the island's original fauna suffers from predation by introduced species and two bird species may have recently become extinct, Makira still constitutes one of the planet's most important areas for conservation of biological diversity. The majority of Makira's bird species of

global conservation concern will, however, be negatively affected by clearing of the island's lowland and hill forests. Our survey data suggest that the current and planned forestry programmes in Makira pose a serious threat to international biodiversity values as well as to the natural resource base for the local subsistence economy.

Solomon Islands export around 1.02 million m^3 of raw logs annually, or around four times the estimated sustainable yield (SIFMP II, 2006). Aside from the impacts on biodiversity and local livelihoods, this also has an effect on climate. If we assume that forests are not allowed to regenerate after logging – which is often the case even when so-called selective logging is undertaken, as the logged areas are degraded and converted to other land uses) – and that the wood density is 0.7 tonnes/m^3 and the carbon fraction 50 per cent of the biomass (cf. Intergovernmental Panel on Climate Change guidelines at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html), then the wood in this harvest alone represents 357 000 tonnes of carbon. Logging of the forests in the Solomons may thus constitute one of the most important emitters of greenhouse gases in Melanesia.

There is no reason to believe that the conservation status of the wildlife of other Melanesian islands is any better than in Makira (e.g., Buchanan *et al*., 2008). The proportion of Solomon Islands set aside as formally protected is among the lowest of any country (0.28 per cent, not including the eastern part of Rennell which has recently become a World Heritage Site). The only officially declared protected area is now largely devoid of tree vegetation (Queen Elizabeth National Park, Guadalcanal). Widespread forest clearance has been exacerbated by the outbreak of civil unrest (1999–2003) and the weak governance of people and resources, particularly after the 1996 abolition of the Area Councils. (These councils were impeding logging deals, particularly on Makira, the home island of the then Prime Minister Mamaloni.)

Many of the areas recommended as priorities for conservation in the 1980s have subsequently been logged or cleared. Unless action is taken soon, the same may happen in large parts of Makira. Conserving and sustainably using Makira's forests could mitigate climate change, secure the natural resource base for the local livelihoods and simultaneously conserve ecosystem services and global biodiversity values.

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Endnotes

1 *Charmosyma meeki* has not previously been recorded in Makira. Jon Fjeldså saw five birds on 1 December 2006 (near sunset) flying towards the hilltops and wrote in his notebook, 'definitively green with yellow in tail'. On 5 December 2006, JF saw three birds flying along the top ridge – in good light – with the typical shape of small parakeets with pointed tails; they appeared all green.

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