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Effects of deforestation and forest modification on understorey birds in Central Sulawesi, Indonesia

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Summary

To estimate the potential of forest birds to persist in the increasingly deforested island of Sulawesi, we undertook a mist-net survey in the understorey of natural as well as modified forest (forest garden and heavily logged forest) at submontane elevations in Central Sulawesi. A total of forty 102 m mist-net lines were distributed over five 16 ha study sites. Two of the sites were situated in an extensively forested valley, and three in a valley with severely fragmented forest. Of 23 species captured, only seven were typical understorey dwellers of submontane forest, five of which are Sulawesi region endemics. Most were found in similar numbers in natural and modified forest, but one species was significantly more common in modified forest. Of the five endemics, two species were confined to, and one species was significantly more abundant in, the extensively forested valley compared with the severely deforested valley. Our results suggest that the conservation of the remaining submontane forest is crucial to the conservation of Central Sulawesi's understorey bird diversity, but that many Sulawesi endemics might be able to survive in modified habitats.

Introduction

The island of Sulawesi is home to *c.* 224 resident landbird species, most of which are inhabitants of rainforest. Forty-one (18%) of these are endemic to the main island and a further 56 species (25%) are confined to Sulawesi and/or its satellite islands (Coates *et al.* 1997). As many as 11 endemic genera can be found, ranking Sulawesi among the most important Endemic Bird Areas of the world (Stattersfield *et al.* 1998) and contributing to Wallacea being a global biodiversity hotspot (Myers *et al.* 2000).

Logging and land conversion have caused dramatic decreases in the forest cover of Sulawesi, mainly in lowland and submontane regions and particularly in the northern, southern and eastern peninsulas (Collins *et al.* 1991). Sulawesi's lowland forest has virtually disappeared (FWI/GFW 2002) and forest margins are progressively shifting towards higher elevations. It is very likely that this loss of habitat (Waltert *et al.* 2004b), as well as increased hunting levels (e.g. O'Brien and Kinnaird 1996, 2000, Rosenbaum *et al.* 1998), and possibly pollution (Thiollay and Rahman 2002), have caused declines in Sulawesi's terrestrial vertebrate fauna.

In the Lore Lindu area of Central Sulawesi, forest is now mainly restricted to protected areas, but according to our own unpublished observations, illegal agricultural encroachments have created forest margins characterized by habitat mosaics of secondary forest and small-scale plantations. This has limited the availability of undisturbed forest at submontane elevations.

Although deforestation and forest modification can be expected to pose severe threats to the bird fauna, few studies to date have attempted to assess the effect of human impact on Wallacean bird communities (but see Marsden 1998, Alvard and Winarni 1999, Thiollay and Rahman 2002). To our knowledge, there is no published quantitative study on the understorey birds in the area. Understorey insectivores are considered to be particularly sensitive to forest disturbance and fragmentation (Karr 1982, Wong 1985, Lambert 1992, Thiollay 1992, Johns 1996, 1997, Laurance *et al.* 2002). They can easily be sampled in a quantitative way using mist-nets (Karr 1981), which permits comparisons of data from different researchers with varying abilities and experience in detecting rainforest birds and minimizes misidentifications. Environmental stress can also be estimated using morphological measurements of the birds (Lens *et al.* 1999; Anciães and Marini 2000).

The aim of this study was to describe basic patterns of understorey bird diversity from a poorly known biogeographical region and to assess the potential of understorey bird species to persist in the modified forest habitats which remain. We compared the abundance and species richness of understorey bird assemblages between two submontane valleys with different amounts of forest cover and between natural and modified (logging and small-scale agriculture) forest within the Lore Lindu National Park, Central Sulawesi. We hypothesized that understorey bird species richness and abundance will vary according to both the overall amount of remaining forest cover in the different valleys and the types of forest modification in the different habitats studied.

Study area

The Lore Lindu National Park in Central Sulawesi is approximately 2,180 km^2 in size (TNC/BTNLL 2002). It ranges from *c.* 200 to 2,610 m above sea level (m.a.s.l.) and is largely mountainous with 64% of its area being located above 1,200 m.a.s.l. (Waltert *et al.* 2004a). Annual precipitation lies between 2,500 and 3,500 mm (Wirawan 1981, in Watling 1983). In 1999, the Park contained approximately 770 km^2 of closed canopy forest at low and moderate altitudes up to 1,200 m.a.s.l. (Waltert *et al.* 2004a; Figure 1). At that time these areas were still continuous along the northern and western Park border but were already severely fragmented along the valleys bordering the Park to the east. This study was conducted in two different valleys: the Palolo valley, which is still extensively forested and characterized by less fragmented forest at submontane elevations, and the Napu valley, where submontane forest is much more reduced in comparison with Palolo (Figure 1).

Palolo valley

The Palolo valley is located at the northern Park border. As in other valleys surrounding the Park, areas of the Palolo valley situated outside the National Park are largely deforested. At the time this study was conducted (2001/2002), the forest border was situated at altitudes between *c.* 750 and 1,000 m.a.s.l. and was largely congruent with the Park's borders. However, the marginal zone of the forest was strongly influenced by human activities including forest gardening and collection of rattan and firewood, as well as hunting and snare-trapping. Forest gardening and planting of tree crops (coffee and cocoa) were mainly found within a distance of 500 m from the Park's

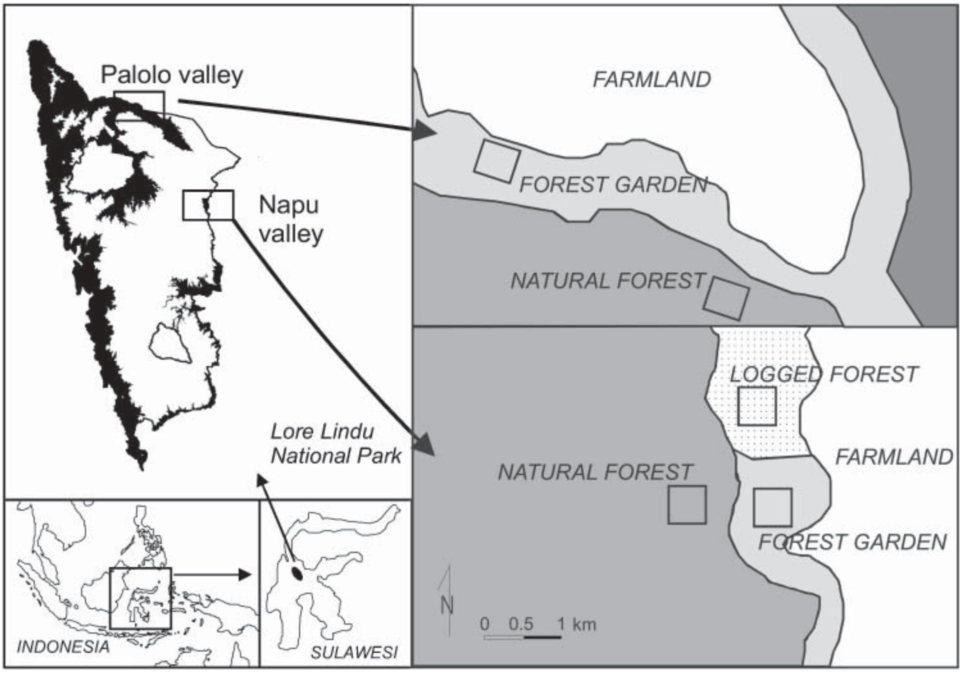

Figure 1. Location of Sulawesi within Indonesia, Lore Lindu National Park, and Park area below 1200 m a.s.l. (black; from Waltert *et al.* 2004a). The locations of the Palolo and Napu valleys and five 16 ha study sites are also shown.

boundary, and other signs of human disturbance such as rattan collection were found in more inaccessible areas above 900 m.a.s.l., at distances of more than 1 km from the forest edge. A study in 1994 indicated that forest near the Park border was undisturbed (Bynum 1999) and that human activities near the Park border had started only recently.

In the Palolo valley, two 16 ha study sites were selected: a forest garden and a natural forest site. The forest garden site was situated at *c.* 800 m.a.s.l., near Kamarora Field Station at the forest border (01°12′S, 120°08′E) (Figure 1). It included a mosaic of old small-scale subsistence farms, recently abandoned farms and regenerating secondary forest (Figure 2B). The forest structure was similar to that of the natural forest (Figure 2A) as upper and middle layers of the forest were largely intact. The understorey, however, consisted of dense thickets in abandoned areas and around active farms, but was very sparsely vegetated at active farming sites. The major crop was coffee, but bananas, chilli and other minor crops were also planted.

Because undisturbed forest was difficult to access and could only be found at higher elevations, the natural forest site selected at Palolo valley was approximately 4 km from the forest garden site at about 1,000 m.a.s.l., and *c.* 1.5 km from the forest border (01°13′S, 120°09′E). In contrast to the forest garden, there were no signs of human impact (e.g. major breaks in the canopy or manually cleared understorey) (Figure 2A). A prominent sign of (near-)natural conditions was the presence of rattan *Calamus* spp. and other palms, including screw palms (Pandanaceae) and large epiphytes at

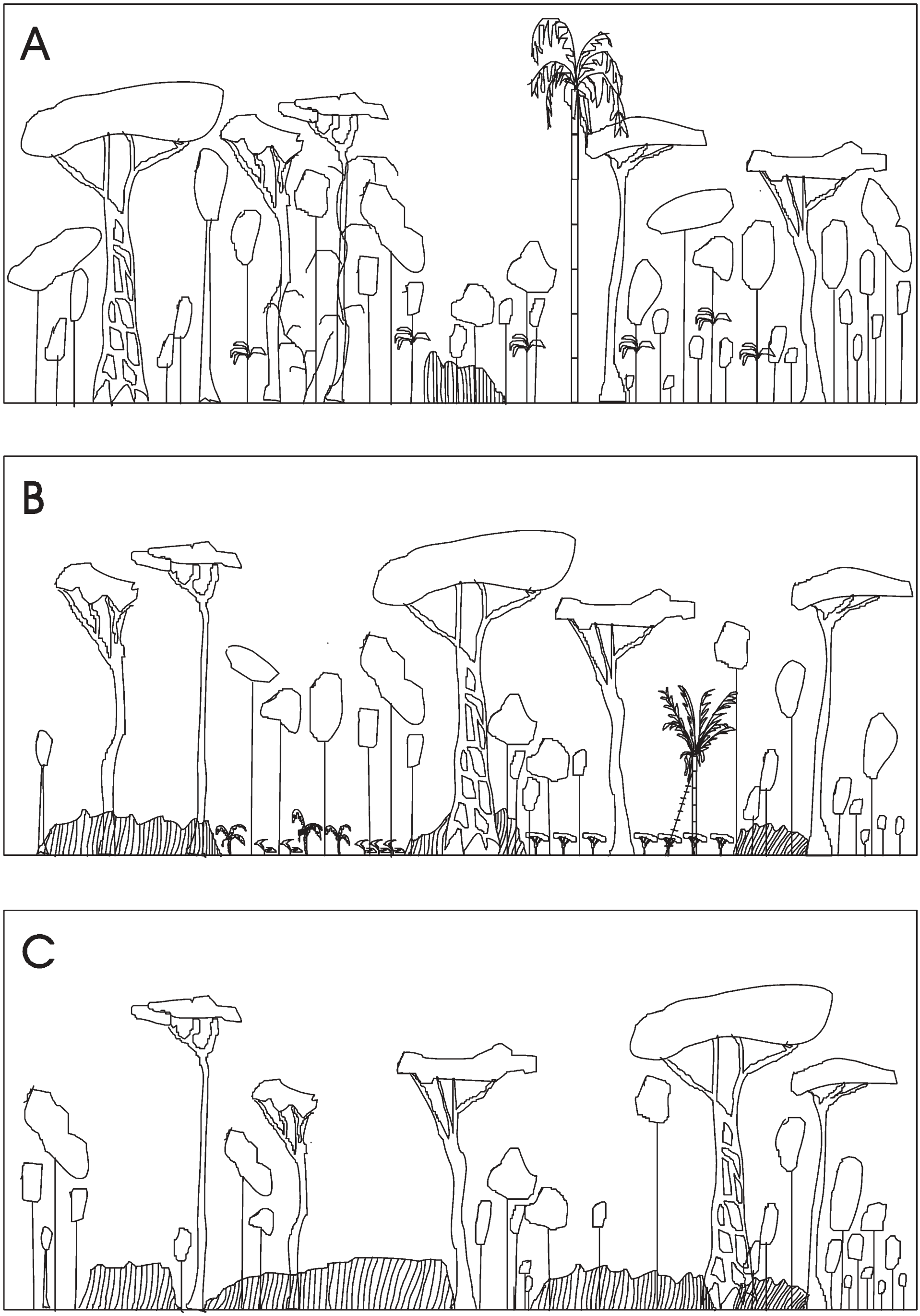

Figure 2. Vegetation profiles along a 200 m transect, based on sketches made in the field. (*A*) Natural forest; (*B*) forest garden with cacao trees, bananas, *Arenga* palm; (*C*) logged forest. Shaded areas represent the extent of thick secondary growth.

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lower understorey level. The site was, however, accessible by one or two major trails, and rattan collection as well as snare-trapping of smaller mammals were observed.

Napu valley

The Napu valley is located at the eastern border of the Park and is separated from the Palolo valley by mountain ranges reaching more than 1,700 m.a.s.l. At this valley, three 16 ha study sites were selected, one each in natural forest, forest garden and logged forest, all located at 1,050 m.a.s.l. As in the Palolo valley, the bottom of the Napu valley has been largely cleared. The Park's border in this area approaches 1,100 m.a.s.l. and submontane forest below 1,200 m.a.s.l. is now much reduced compared with Palolo, leaving only a relict patch in which our three study sites were situated (Figure 1).

The natural forest site was *c.* 500 m from the forest border (1°25′S, 120°18′E). The site was relatively undisturbed, and no major signs of logging were visible at the time of our study. Rattan palms were small in size and scarce, but the canopy was closed. The forest garden site (1°26′S, 120°18′E) was characterized by a closed canopy but the understorey was partly cleared, containing a mixture of small-scale coffee plantations and long-overgrown former plantations.

At the logged forest site (1°24′S, 120°18′S) canopy closure was estimated at *c.* 40% (Figure 2C). Timber was frequently carried out of this forest site along numerous permanent tracks with the help of buffaloes (personal observations). The extracted wood was mainly used in the construction of private homes, needed for the continuing influx of immigrants from the neighbouring Poso province. No comparable logged site could be found in the Palolo valley.

Methods

Data collection

Our research was conducted between 21 December 2000 and 21 February 2001 at Palolo and between 5 December 2001 and 18 January 2002 at Napu. Mist-netting was conducted using standard procedures described in Waltert (2000a, b). A combination of 6- and 12-m-long mist-nets, 2.7 m high with 16 mm mesh, was used to produce a single 102-m net-line for which narrow trails were cut in the understorey. Net trails were positioned on a systematic grid, using a spacing of 100 m, with trails being parallel to each other. The net line was opened for 10 hours from 15h00 until 18h00 and 6h00 until 13h00 on the following day. The whole net line was then moved to another net trail, 100 m away within each 16 ha study site, resulting in a total of eight 102-m lines per study site and 40 (8×5 study sites) in total. The sampling effort amounted to *c.* 680 net-hours for each study site (3,400 net-hours in total). Net lines were checked every 1–2 hours. Birds were identified and banded with uniquely numbered metal rings. Birds found at 18h00 in mist-nets were kept in cotton bags until 7h00 the next day to avoid possible disorientation of animals released in the dark.

Data analysis

For each study site, we counted the total number of species detected, the number of species represented by only a single individual (singletons), as well as Fisher's alpha,

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Simpson, Shannon–Weiner diversity and Shannon–Weiner Evenness indices (see Magurran 1988). In most field studies, not all species which are actually present are also recorded (see Nichols and Conroy 1996). Therefore, we also quantified 'estimated' species richness that takes into account the fact there are species which are not actually recorded but whose presence can be inferred from the pattern of observed species occurrence. To calculate estimated species richness, we used the estimator ACE, a non-parametric species richness estimator based on abundance data (Chao *et al.* 1993), as well as the Michaelis–Menten species richness estimator MME, which fits an asymptotic function to the sample-based rarefaction curve (Colwell *et al.* 2004). To calculate measures of ecological diversity for each site and to extrapolate species richness from samples, Colwell's (1997) software EstimateS version 5.0.1 was used.

We also used multidimensional scaling based on the Sörensen quantitative sample similarity index (Magurran 1988) to depict dissimilarities in species composition among the five sites. To analyse differences in mean abundance per sample (net line) between forest habitats and valleys we used a two-way ANOVA. Tukey's honest-significant-difference test (HSD test) was used for multiple comparisons of means. Only species with a minimum of nine captured individuals were tested. Only one individual was recaptured in a different net line and was excluded from the analysis to avoid pseudo-replication. All statistical analyses were performed using Statistica 5.1 (Statsoft 1995).

Results

Numbers of individuals and species; species composition

On average, 50.8 (±17.1 SD) individuals were trapped in the plots. The mean number of species per plot amounted to 9.8 (±2.8 SD) and the total numbers of species in all five plots combined was 23 (254 individuals).

Using the single 102 m mist-net lines as a sampling unit, mean numbers of individuals were higher in the extensively forested Palolo valley than in the more deforested Napu valley (ANOVA, $F_{1,35} = 9.70$, $P = 0.004$; Figure 3h). Differences were especially pronounced between Palolo forest gardens (10.0 ± 3.1 individuals per 102 m net-line) and Napu natural forest (4.75 ± 1.8; Tukey's HSD test, $P = 0.015$) or Napu logged forest (5.1 ± 2.6; Tukey's HSD test, $P = 0.029$). Mist-netting in the Palolo forest garden site also produced the highest number of species, but similarly high or higher diversity indices (Fisher's α-diversity, Simpson index and Evenness) as well as species richness estimators (ACE, MMMean) were obtained in Napu natural forest (Table 1).

There was a major difference between the species composition of the two valleys. Comparing species composition between sites within valleys, the sites at Napu were very similar, while the two Palolo sites were rather more different from each other (Figure 4).

Only seven of the 23 species present in our samples are classified as understorey dwellers for which submontane forests represents an important part of their altitudinal range (see Appendix). These same species were the most common ones: in the extensively forested Palolo valley, the understorey bird community was composed of four sallying insectivores: the Mangrove Blue Flycatcher *Cyornis rufigastra*, the Rufous-throated Flycatcher *Ficedula rufigula*, the Rusty-bellied Fantail *Rhipidura*

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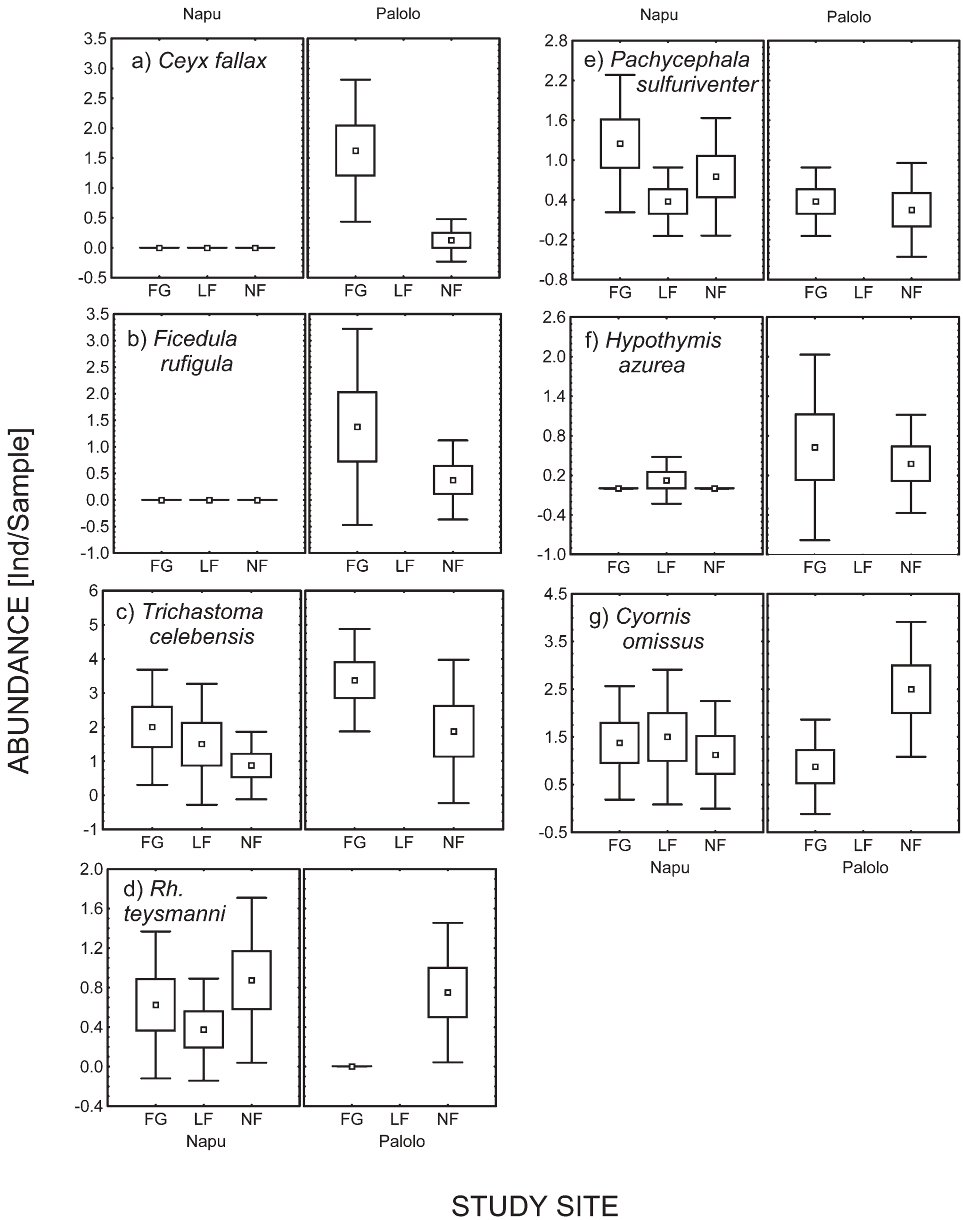

Figure 3. Mean, standard error and standard deviation for numbers of individuals trapped in 102 m mist-net lines set for 10 daylight hours in three forest habitats (NF, natural forest; FG, forest garden; LF, logged forest) of two submontane valleys (Palolo, Napu) differing in their degree of forest fragmentation (fragmented, continuous), at Lore Lindu National Park, Sulawesi.

teysmanni and the Black-naped Monarch *Hypothymis azurea*. The Sulawesi Babbler *Trichastoma celebense*, the Yellow-bellied Whistler *Pachycephala sulfuriventer* and the Sulawesi Dwarf Kingfisher *Ceyx fallax* were also frequently trapped. These species accounted for 89% of all individuals trapped in Palolo valley and all but two,

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Table 1. Number of individuals, species, diversity indices[a] and species richness estimators[b] of understorey bird communities at five sites in submontane areas of Lore Lindu National Park, Central Sulawesi.

		Palolo valley		Napu		
		Natural forest	Forest garden	Natural forest	Forest garden	Logged forest
Individuals		51	80	38	45	40
Species		8	14	11	7	9
Singletons		2	3	5	3	3
Diversity	Fisher's α (SD)	2.66 (0.63)	4.91 (0.91)	5.19 (1.33)	2.32 (0.58)	3.61 (0.92)
Diversity	Simpson (1/*D*)	4.02	6.02	7.40	4.30	5.57
Diversity	H_S	1.59	2.1	1.99	1.54	1.75
Evenness	H_S/ln S	0.80	0.77	0.83	0.79	0.79
Estimator	ACE	9.44	16.07	16.76	12.16	11.18
Estimator	MMMean	10.6	18.89	16.62	7.82	11.81

[a]Diversity (Fisher's α, Shannon H_s, Simpson) after Magurran (1988).
[b]Species richness estimators (ACE, MMMean) after Colwell (1997).

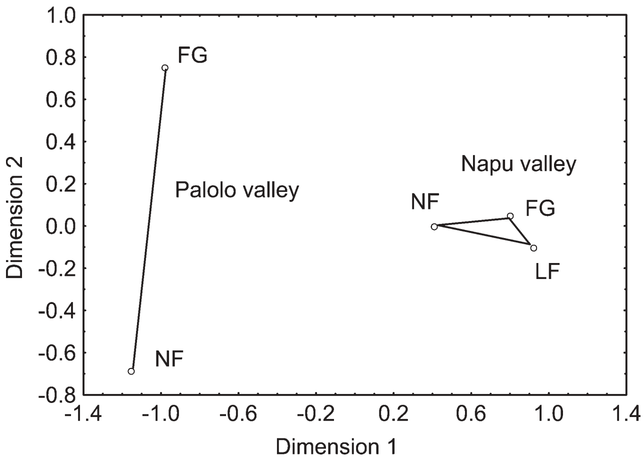

Figure 4. Multidimensional scaling of bird communities mist-netted in five study sites (NF, natural forest; FG, forest garden; LF, logged forest) and two valleys (Palolo, Napu) of Lore Lindu National Park, Sulawesi. Based on dissimilarities from the Sörensen quantitative sample similarity index (Magurran 1988).

the Black-naped Monarch and the Mangrove Blue Flycatcher, are endemic to the Sulawesi biogeographical region (White and Bruce 1986, Coates *et al.*, 1997).

In the more deforested Napu valley, the understorey bird community was dominated by fewer species than Palolo, consisting mainly of four species which were also netted at Palolo (Mangrove Blue Flycatcher, Rusty-bellied Fantail, Sulawesi Babbler and Yellow-bellied Whistler). These four species accounted for 81% of all individuals trapped. Two species found in Palolo (Sulawesi Dwarf Kingfisher and Rufous-throated Flycatcher) were not recorded in Napu valley.

The remaining species netted were mainly representatives of the lower midstorey–canopy (i.e. flowerpeckers Dicaeidae, sunbirds Nectariniidae, Australian robins

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Petroicidae, honey-eaters Meliphagidae, white-eyes Zosteropidae, and the island verditer flycatcher *Eumyias panayensis*), larger non-passerine species (i.e. hawks Accipitridae, cuckoos Cuculidae, pigeons Columbidae) or species that have their main distribution at higher altitudes than our study sites (i.e. Chestnut-backed Bush Warbler *Bradypterus castaneus*, Snowy-browed Flycatcher *Ficedula hyperythra*) (see Coates *et al.* 1997; Appendix).

Differences in abundance between valleys and habitats

For the seven commonest species (see above), the mean number of individuals trapped per 102 m mist-net line is shown in Figure 3. Comparisons of abundance data revealed significant differences between the two valleys (Palolo, Napu) in three species and between habitats in one species (Table 2). The Sulawesi Dwarf Kingfisher (Figure 3a: Tukey's HSD test, $P < 0.001$), the Rufous-throated Flycatcher (Figure 3b; Tukey's HSD test, $P < 0.005$) and the Sulawesi Babbler (Figure 3c; Tukey's HSD test, $P < 0.045$) were all significantly more abundant in the extensively forested Palolo than in the more deforested Napu valley (Table 2). Although caught more frequently in Palolo, there was no significant difference in abundance of the Black-naped Monarch between the valleys (Fig. 4f; Tukey's HSD test, $P < 0.060$). None of the species was more abundant in Napu than Palolo, although one species, the Yellow-bellied Whistler, was nearly so (Figure 3e; Tukey's HSD test, $P < 0.06$).

The Sulawesi Dwarf Kingfisher was more frequent in forest garden than in natural forest (Figure 3a; Tukey's HSD test, $P < 0.001$). However, while the Sulawesi Babbler was more common in forest gardens than natural forest, and the Rusty-bellied Fantail appeared to be more common in natural forest than forest garden, these differences were not significant (Figure 3c; Tukey's HSD test, $P < 0.078$; Figure 3d; Tukey's HSD test, $P < 0.081$).

Table 2. Effects of upland valley sampled (two valleys: Palolo, Napu) and habitat (natural forest, forest garden and logged forest) on numbers of bird individuals trapped in 102 m mist-net samples

Species		Factor	$F_{1,35}/F_{2,35}$	$P <$	Highest abundance[a]
Ceyx fallax	Sulawesi Dwarf Kingfisher	Valley	23.93	**0.001**	Palolo
		Habitat	9.32	**0.001**	Forest garden
Cyornis rufigastra	Mangrove Blue Flycatcher	Valley	0.79	0.382	
		Habitat	1.24	0.303	
Ficedula rufigula	Rufous-throated Flycatcher	Valley	9.27	**0.005**	Palolo
		Habitat	2.03	0.146	
Hypothymis azurea	Black-naped Monarch	Valley	3.79	0.060	
		Habitat	0.21	0.811	
Pachycephala sulfuriventer	Yellow-bellied Whistler	Valley	3.81	0.059	
		Habitat	1.11	0.340	
Rhipidura teysmanni	Rusty-bellied Fantail	Valley	1.49	0.231	
		Habitat	2.76	0.078	
Trichastoma celebense	Sulawesi Babbler	Valley	4.78	**0.036**	Palolo
		Habitat	2.85	0.072	

Analysis is based on two-way analysis of variance; number of mist-net samples $n = 40$. Significant results are highlighted in bold.

[a]Tukey's HSD test, $P < 0.05$.

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Discussion

Understorey bird species richness compared with areas west of Wallace's line

There are few quantitative studies on Wallacean bird communities despite their global importance for biodiversity conservation (but see Alvard and Winarni 1999, Marsden 1998). Sulawesi's avian endemism is remarkably high but its species richness (224 landbird species) is relatively low compared with the smaller island of Java which has 340 resident bird species (MacKinnon *et al.* 1997). The low diversity of understorey bird species that we found within habitats is a reflection of this general biogeographical pattern, but the disparity seems to be especially pronounced for insectivorous understorey species. In comparable studies on the lowlands of Borneo and peninsular Malaysia, the number of insectivorous understorey passerines can be up to 3 times greater (e.g. Wong 1985, Lambert 1992). This higher species richness west of Wallace's line is due to a higher number of sallying species (Muscicapidae, Monarchidae), gleaners (e.g. Timaliidae) as well as species from guilds which are not represented at all in Central Sulawesi, such as the insectivorous-frugivorous Pycnonotidae (Lambert 1992). It is unlikely that the low species number in our study reflects insufficient sampling effort, as only two additional passerine understorey species are known to occur at respective elevations in the Park (Red-backed Thrush *Zoothera erythronota* and Red-bellied Pitta *Pitta erythrogaster*; see Coates *et al.* 1997, Merker and Ebert in press.).

Shifts in vertical stratification

We found a relatively high species richness and diversity in the forest garden habitats of the Palolo valley. Higher species richness in disturbed than natural tropical forest habitats has been reported for birds and butterflies (Andrade and Rubio-Torgler 1994, Bennett and Dahaban 1995, Karim-Dakog *et al.* 1997, Alvard and Winarni 1999, Hill *et al.* 1995, Brown 1997, Wood and Gillman 1998, Fermon *et al.* 2000), but is often due to a local increase in edge species, e.g. in smaller nectarivores or frugivores (Murphy 1989, Thiollay 1995, Mason 1996, Dale *et al.*, 1999). In canopy gaps and disturbed forest, bird species shift their vertical range downwards (Terborgh and Diamond 1970, Pearson 1971, Greenberg 1981, Bell 1982, Levey 1988, Driscoll and Kikkawa 1989) as do butterflies (DeVries 1987, Wood and Gillman 1998, Fermon *et al.* 2005). Our experience confirms that understorey data from disturbed sites might be strongly biased by an increased proportion of higher-strata species. We caught several species which are typical canopy-dwellers of undisturbed forest, in particular flowerpeckers, sunbirds and white-eyes (Driscoll and Kikkawa 1989, Coates *et al.* 1997), in the understorey of one forest garden. If these species are excluded from the analysis, overall species richness and number of individuals per site are more similar between forest garden and natural forest habitats.

Differences in abundance between natural and modified forest

Our data do not show any negative impact of forest modification on the abundance of the understorey bird species studied. The Sulawesi Dwarf Kingfisher was even more abundant in the forest garden than the natural forest habitat. From our data, we can conclude that the studied species are capable of colonizing modified forests. Our results are corroborated by studies on bird diversity in different land-use systems, showing that secondary forest areas along the borders of Lore Lindu are used by many species (Schulze *et al.* 2004; Waltert *et al.* 2004b). It remains unclear, however, to what extent these secondary forests represent suitable habitats for the long-term persistence of these species. Predation on artificial nests has been found to be higher in disturbed tropical forest than in natural forest in South-east Asia (Cooper and Francis 1998, Wong *et al.* 1998) as well as in our own study sites in Sulawesi (Pangau-Adam 2003). The possibility of higher predation pressure in disturbed forest may have relevance for the species in this study. In addition, remote sensing analyses reveal that much of the forest in the Palolo and Napu valley was cleared between 1983 and 1999 (TNC/BTNLL 2002). It is therefore possible that densities of birds in remaining forest habitats might not yet be in equilibrium and that many individuals are "trapped" in suboptimal conditions. Longer-term monitoring would be necessary to substantiate these hypotheses.

Differences in species composition between valleys

Of the 23 netted bird species, seven species are typical for submontane elevations in Central Sulawesi and for three of these, deforestation has been shown to have a significantly negative impact on their abundance. Two of these species, Sulawesi Dwarf Kingfisher and Rufous-throated Flycatcher, both endemics, have a known altitudinal range below 1200 m.a.s.l. (Coates *et al.* 1997) and were completely absent from the largely deforested Napu valley. It is unknown whether these species have ever occurred in this valley; however, the Napu/Besoa valley system bordering the Lore Lindu National Park to the East, is extensive, and – at least in pre-colonial times – was covered by extensive submontane rainforest. It is therefore very likely that this area now contains only a fraction of the bird species found in valleys where forest cover is greater, less fragmented and adjacent to lower-lying areas. Similar patterns of species loss have also been reported for tree communities in submontane forests of Napu compared with Palolo (Kessler *et al.* 2005, P. J. A. Kessler, pers. comm.).

Conservation

The bird fauna of lowland and hill forest habitats in Central Sulawesi is currently under serious pressure due to rapidly increasing deforestation and other forms of human disturbance. If the Sulawesi upland form of the Mangrove Blue Flycatcher (*Cyornis rufigastra*) is upgraded to species level (Sulawesi Blue Flycatcher *Cyornis omissus*; see Monroe and Sibley 1993), there are 25 restricted-range species of the Sulawesi region which are mainly confined to lowland/hill forest habitats (Stattersfield *et al.* 1998). Six of these are understorey species present in the Lore Lindu National Park (Watling 1983, Coates *et al.* 1997).

In the Palolo valley, three of these species were recorded: the Sulawesi Dwarf Kingfisher, the Mangrove Blue Flycatcher and the Rufous-throated Flycatcher. In the less forested Napu valley, only the Mangrove Blue Flycatcher was found, the Rufous-throated Flycatcher being replaced by its mountain congener, the Snowy-browed Flycatcher. The absence of three other Sulawesi endemics (Lilac-cheeked *Cittura cyanotis* and Green-backed Kingfisher *Actenoides monachus*, as well as the above-mentioned Red-backed Thrush) in our mist-net samples could indicate that they need

Appendix. Numbers of individuals and capture rates (individuals per 12 net-hours, 12 m net) of bird species trapped in mist-nets in five 16 ha study sites at Lore Lindu National Park, Central Sulawesi, Indonesia Altitudinal range is given as lowl. (lowland)-hill (mainly below 1200 m), lowl.-mont. (montane) (sea level up to 2500 m), hill-mont. (from 500 to 2500 m), mont. (mainly above 1000 m); preferred stratum/feeding guild is given as terr. (terrestrial), und. (understorey), mid. (midstorey), can. (canopy), and C (carnivorous), I (insectivorous), N (nectarivorous), F (frugivorous), G (granivorous), respectively (all information from Coates *et al*. 1997). Species endemic to the Sulawesi subregion are marked with an asterisk.

	Altitudinal range	Stratum/ Guild	Palolo valley			Napu valley				Grand total
			Forest garden	Natural forest	Total	Forest garden	Logged forest	Natural forest	Total	
Accipitridae										
*Accipiter trinotatus**	lowl.-mont.	mid./C	2 (0.04)		2					2
Columbidae										
*Gallicolumba tristigmata**	lowl.-mont.	terr./G				1 (0.02)			1	1
Cuculidae										
Cacomantis sepulcralis	lowl.-mont.	mid./I	1 (0.02)		1					1
*Phaenicophaeus calyorhynchus**	lowl.-mont.	mid./I					1 (0.02)		1	1
Alcedinidae										
*Ceyx fallax**		und./I	13 (0.26)	1 (0.02)	14					14
Dicruridae										
*Dicrurus montanus**	mont.	und./I				1 (0.02)			1	1
Timaliidae										
*Trichastoma celebense**	lowl.-mont.	und./I	27 (0.54)	15 (0.26)	42	16 (0.29)	12 (0.22)	7 (0.12)	35	77
Sylviidae										
Bradypterus castaneus	mont.	und./I						1 (0.02)	1	1
Muscicapidae										
Eumyias panayensis	mont.	mid/I						1 (0.02)	1	1
Ficedula hyperythra	mont.	und./I						2 (0.04)	2	2
*Ficedula rufigula**	lowl.-hill	und./I	11 (0.22)	3 (0.05)	14					14
Cyornis rufigastra	hill.-mont.	und./I	7 (0.14)	20 (0.35)	27	11 (0.20)	11 (0.20)	9 (0.16)	31	58
Hypothymis azurea	lowl.-hill	und./I	5 (0.10)	3 (0.05)	8		1 (0.02)		1	9
*Rhipidura teysmanni**	hill.-mont.	mid/I		6 (0.1)	6	5 (0.09)	3 (0.05)	7 (0.12)	15	21

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Appendix. Continued

	Altitudinal range	Stratum/ Guild	Palolo valley			Napu valley				Grand total
			Forest garden	Natural forest	Total	Forest garden	Logged forest	Natural forest	Total	
Petroicidae										
Culicicapa helianthea	lowl.-hill	mid/I	2 (0.04)	1 (0.02)	3					3
Pachycephalidae										
Pachycephala sulfuriventer*	hill-mont.	und./I	3 (0.06)	2 (0.03)	5	10 (0.18)	3 (0.05)	6 (0.11)	19	24
Meliphagidae										
*Myza celebensis**	mont.	mid/N						1 (0.02)	1	1
Nectariniidae										
Anthreptes malacensis	lowl.-hill	mid/N	2 (0.04)		2					2
Aethopyga siparaja	lowl.-hill	mid/N	1 (0.02)		1		1 (0.02)		1	2
Dicaeidae										
*Dicaeum aureolimbatum**	lowl.-hill	mid/F	3 (0.06)		3		3 (0.05)	1 (0.02)	4	7
*Dicaeum celebicum**	lowl.-hill	can./F	1 (0.02)		1					1
Zosteropidae										
Zosterops atrifrons	lowl.-hill	mid/I	2 (0.04)		2	1 (0.02)	5 (0.09)	2 (0.04)	8	10
Estrildinae										
Erythrura hyperythra	hill-mont.	mid/G						1 (0.02)	1	1
Total individuals			80	51	131	45	40	38	123	254
Total species			14	8	15	7	9	11	16	23

more extensive lowland habitat below 1,000 m.a.s.l. (Watling 1983, Coates *et al.* 1997, Stattersfield *et al.* 1998) and that they now occur in very low densities in the region.

It seems obvious that a further decrease of the remaining lowland/hill forest around the Lore Lindu National Park threatens all lowland/hill forest species by reducing their habitat to fragments surrounded by either montane forest or farmland. Sixty-two (47%) of the 131 resident forest species of the Lore Lindu National Park are confined to areas below 1,200 m.a.s.l. (data from Coates *et al.* 1997, Nur Mallo and Ma'dika 1999, Waltert *et al.* 2004a). Illegal encroachments and organized timber exploitation have seriously increased since 1999 (Waltert *et al.* 2004a). It has been estimated that closed lowland and hill forest (below 1200 m.a.s.l.) within the Park has been reduced by nearly 19% between 1999 and 2001, most of it in the north-eastern part of the Park including the Palolo valley (Waltert *et al.* 2004a). This recent loss of forest habitat in the Park's hill forest zone is serious since most of the Park's area is located above 1,200 m.a.s.l. If measures are not taken immediately to stop further illegal encroachments, the Park could lose its remaining lowlands and with them up to half of its forest birds.

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