The impact of sustainable forest management on plant and bird diversity in East Kalimantan, Indonesia

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Diversity and abundance of endemic bird species in logged sites and primary rain-forest sites in East Kalimantan, Indonesia

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Abstract

The aim of our study was to analyze the impact of selective logging on Bornean endemic avian species in terms of abundance and species richness. Our study compared secondary forest sites with relatively undisturbed primary lowland dipterocarp rain forest sites of East Kalimantan. The secondary forest sites were located in the Berau district and were in the process of being FSC certified. At these sites, the forest had been selectively logged in 2003, 2007 and 2011. One additional non-certified disturbed secondary forest site was selected in the Pusrehut forest, in the Kutai Kartanegara region. The two primary forest sites were located in the Berau district and in the Sungai Wain protected forest in Balikpapan, respectively. We found a significantly higher abundance of insectivorous endemic birds in primary forests compared to the secondary forests, suggesting their vulnerability to selective logging. Selective logging did not have a clear effect on the diversity of endemic bird species in other feeding guilds.

Key words: Endemic avian Bornean species, Sustainable forest management, Selective logging, Species diversity, Southeast Asia.

Introduction

Logging activities in tropical rainforests lead to various degrees of forest destruction and subsequent habitat loss (Kartawinata, 1977; Skole & Tucker, 1993; Laurance, 1998; Parthasarathy *et al.*, 1999; Meijaard *et al.*, 2005), which in turn initiates a variety of ecosystem processes that could compromise populations of plants and animals (Meijaard *et al.*, 2005). Among the negative impacts of logging that have been reported are mortality of canopy trees due to edge effects (Laurance *et al.*, 2000; Wang *et al.*, 2006) and declines in bird abundance and/or diversity (Boulinier *et al.*, 2001; Beier *et al.*, 2002; Slik & Van Balen, 2006). Since tropical rainforests harbor most of the world's biodiversity, tropical deforestation has become a major cause of global species extinctions (Pimm & Raven, 2000). In disturbed forests, species richness may increase due to an increased number of common edge species (Johns, 1996). Species richness alone may therefore not be a good indicator for the status or recovery of forest biodiversity (Ghazoul & Hellier, 2000; De Iongh & Van Weerd, 2006; De Iongh & Persoon, 2010).

During recent years, the Indonesian government has promoted certified timber production through FSC and LEI in order to achieve Sustainable Forest Management (SFM). Although it is generally believed that such SFM practices are less harmful than conventional logging practices, van Kuijk *et al.* (2009) concluded that there are still serious knowledge gaps regarding their impact on e.g. biodiversity conservation.

The vegetation in later successional stages of forest ecosystems is usually taller and has a greater tree species richness compared to vegetation in an early successional stage (Linder *et al.*, 1997; Cochrane and Schulze, 1999; Wang *et al.*, 2006; Ding *et al.*, 2008). Vegetation in the late successional stage also tends to have higher variation in tree size, and more vertical layers (Linder *et al.*, 1997; Venier & Pearce, 2005). Such variations in habitat structure, including canopy cover, tree height and understorey regeneration, have been reported to be strongly associated with changes in avian communities (Barlow & Peres 2004; Oppel, 2006; Schieck & Song, 2006; Slik & Van Balen, 2006; Ding *et al.*, 2008; Arbainsyah *et al.*, 2015b).

One of the characteristics of avian communities in tropical areas is the high number of species classified as endemics (Anderson, 1994; Stattersfield *et al.*, 1998; Boer, 2006). Endemic avian species diversity is highly sensitive to disturbance in forests, such as logging (MacArthur & MacArthur, 1961; Henle *et al.*, 2004; Meijaard *et al.*, 2005). Meijaard *et al.* (2005) believes that there is an evolutionary explanation for the sensitivity of endemic bird species in Borneo to disturbance of forests, which have evolved in rainforest refugia during multiple ice-age cycles. Terrestrial insectivores and low to mid understorey flycatchers are for instance consistently intolerant of logging and show a greater decline than other guilds after logging (Johns, 1989; Lambert, 1992; Thiollay, 1992). Among the bird guild of understorey insectivores, both the number of bird species that are present or absent and their proportional representation within the population sample decrease following logging at moderate intensities. Lambert (1992) reported trogons *Harpactes* spp., woodpeckers (Picidae), wren babblers (*Kenopia striata* and *Napothera* spp.) and flycatchers (*Cyornis* spp. and *Ficedula* spp.) as prone to decline in logged forests. Reported declines are suggested to be a reflection of the loss of understorey vegetation, foraging substrata and the associated cryptic insect prey that understorey insectivores specialize on (Robinson, 1969). Karr and Freemark (1983) reported that physiological conditions (i.e., high temperature and water stress) have a more significant impact than local food abundance in determining the ranging of some understorey species in Panamanian forests. Microclimatic conditions are altered by loss in tree canopy cover and understorey vegetation species are often reluctant to cross open spaces or dense secondary growth that separates remaining patches of primary forest (Meijaard *et al.*, 2005).

Based on these findings, we intend to test the hypothesis that endemic bird guilds are more sensitive to logging. We present a detailed analysis of the endemic avian species in East Kalimantan in forests that were selectively logged in 2003, 2007, 2011, a primary forest site and two external sites; the Sungai Wain forest site (a primary forest) and Pusrehut forest site (a disturbed forest). Our main research question was: What are the differences in endemic avian species diversity and abundance between selectively logged forest sites in comparison to primary forests?

Materials and methods

Study area

The study area is located in tropical lowland rainforest in the Berau district, East Kalimantan province, within a forest concession which was in the process of being FSC certified, and two external sites: one primary forest site (Sungai Wain) and one disturbed non-certified forest site (Pusrehut) (Figure 5.1). In the Berau district, four FSC-candidate sites were selected to be sampled: one primary forest site and three selectively logged forest sites logged in 2003, 2007 and 2011. One site of primary forest was selected in the Sungai Wain Protected forest and one disturbed site was selected in the Pusrehut forest, in the district of Kutai

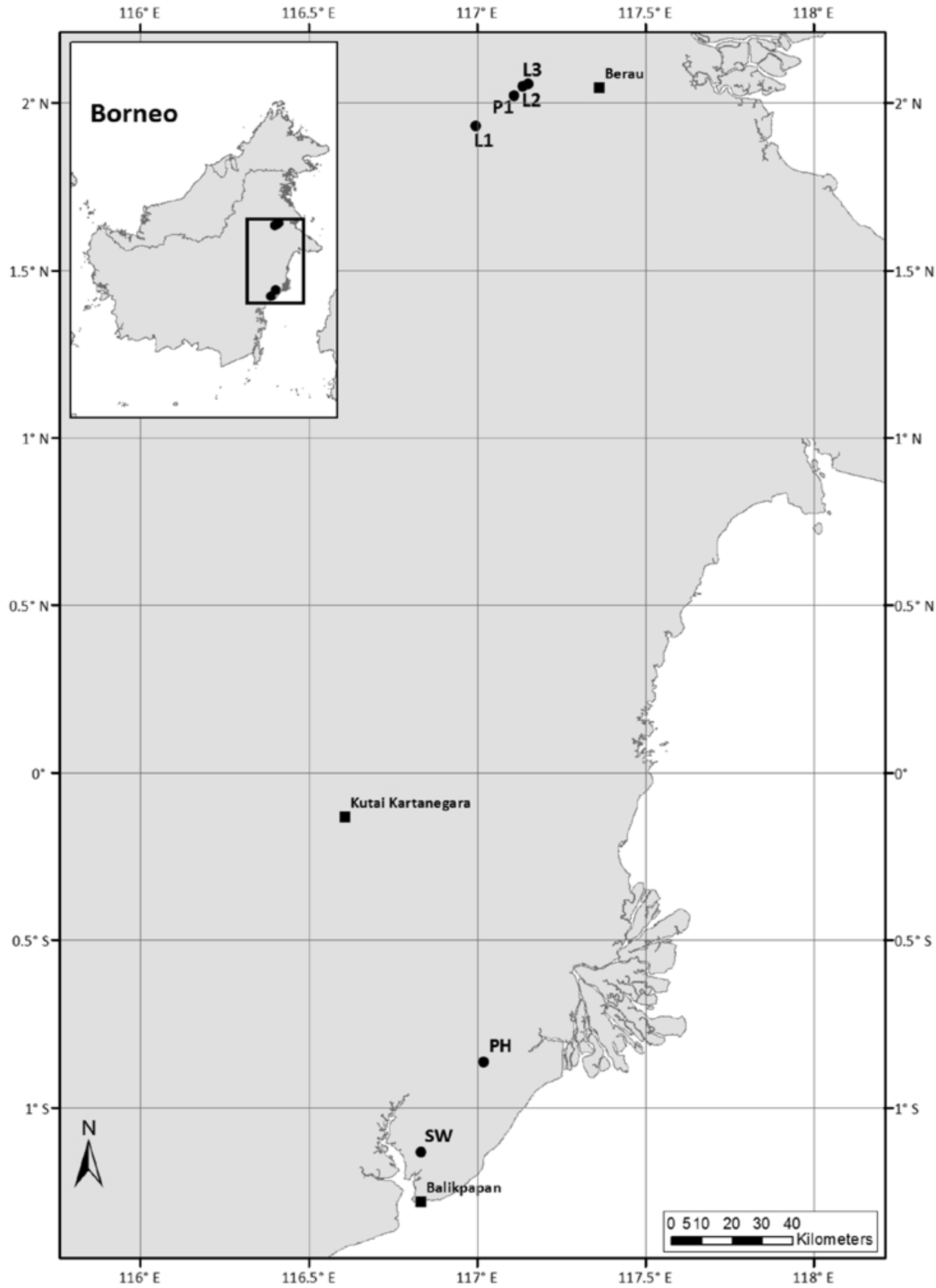

Figure 5.1
Map of East Kalimantan with the location of sampling points. P1 primary forest site, L1 logged in 2011, L2 logged in 2007, L3 logged in 2003, SW Sungai Wain forest site (primary forest), PH Pusrehut forest site (disturbed forest).

Kartanegara. This non-certified site had been logged long ago, in the 1970s, had been moderately to heavily burned in 1982/1983 and then replanted (Figure 5.1). It had been subjected to illegal logging activities in the period up to 2014. In all sites, the elevation range is between 25-140 m above sea level (Mantel *et al.*, 2002; Slik and Eichhorn, 2003). The topography of all sites consists of a rolling hilly landscape with shallow valleys and gullies.

The three forest types were adopted according to FAO (2001): 1) Primary forest is defined as a forest that has been logged more than 30 years ago or has never been logged; 2) Selectively logged forest is defined as forest with specific areas where the trees have been removed less than 30 years ago as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvicultural measures; 3) Disturbed forest is defined as forest containing significant areas which have been exposed to human disturbance, including clearing, harvesting or logging, felling for wood extraction, hunting, anthropogenic fires and road construction.

Bird surveys

Within each of the study sites five sampling points were identified at a distance of 200 m from each other and these were used for point counts to assess bird species presence (Bibby *et al.*, 2000). Observations were done in all sites between February and August 2014. In total we conducted 30 point counts, 2 × 5 in the primary forest, 15 in forest sites logged selectively and 5 in the disturbed forest site. Point counts are generally preferred as a counting method in dense forests, because they are suggested to cause less disturbance in comparison to e.g. transect counts and offer the possibility to include auditory observations (Bibby *et al.*, 2000).

Counts were repeated four times during mornings (at dawn) and late afternoons (at dusk), each on subsequent days, based on Slik & Balen (2006) (Table 5.1). The observations were made by the 1st, 4th and 5th authors of this paper and a bird expert from the University of Mulawarman, Samarinda. Morning visits usually started around 6 am and afternoon visits around 16 pm, each visit lasting approximately 2 hours. During a site visit all 5 sampling points were surveyed for 15 min each (following Pieterse & Wielstra, 2005; Slik & Van Balen, 2006). All individual birds seen and heard were recorded. No distance limitation was used, but the bias caused by this was considered similar for all sites. We also used a digital sound recorder Olympus Linear PCM recorder LS-11 placed on a tripod, to record all the bird sounds for later identification. These recorded bird sounds were used as a reference for which we asked advice from a Dutch bird expert (Bas van

Balen) and two Indonesian bird experts (Agus Prastiono & Satriyo Susito). In addition, we used bird sounds from the xeno-canto website. In order to allow any birds that might have been scared away when approaching the sampling site to return, counts started 2 min after reaching each observation point. To minimize a possible bias occurring from visiting the sampling points at the same time of day, the points were visited in a reversed order during alternating visits. Counts were not conducted during rain fall because of the decrease in bird activity during such weather conditions (Bibby *et al.*, 2000; Slik & Balen, 2006). Throughout this study, each bird species was assigned to a single bird guild, based on Wielstra *et al.* (2011) and De Iongh *et al.* (2007).

Data Analyses and Statistics

Based on literature (Smythies, 1999; Phillipps & Phillipps, 2011), we determined whether each bird species was endemic to Borneo or not. We also determined the individual body mass (grammes) based on Thiollay (1995) and Dunning (2007) (Table 5.1). For each bird species, a data set was created which contained the following dependent variables per point count location: i) 'Total species': all species encountered during the eight visits; ii) 'Mean abundance': the average number of individuals per visit; iii) 'Mean species': the average number of species per visit (Table 5.2). The six forest sites were compared with respect to the above parameters. Our forest sites were regarded as randomly selected within the lowland rainforest areas of Kalimantan. We used either a Linear Mixed Model or a Generalized Linear Mixed Model, depending on whether the transformed data showed a Poisson distribution or not, with 'Forest' as random effect variable. The transformation that was applied included a multiplication of the data with a constant and then rounding the multiplied data.

Following Wielstra *et al.* (2011), the birds were classified according to diet in so called "guilds": Nectarivore (N), Frugivore (F), Frugivore / Insectivore (FI) and Insectivore (I). For each of these guilds we calculated the average abundance per point count over the eight visits. We also calculated the ratio of endemic bird species versus all bird species per point count, for each guild. Primary forests were compared to secondary forests with respect to 'Mean abundances per guild' and 'Mean ratio per guild' using a generalized Linear Mixed Model for which 'Forest' was included as random effect variable.

For testing, we used a Likelihood-Ratio Test (LRT) and Kruskal Wallis Test. We performed the statistical analyses using R software 3.2.2 with R Development Core Team 2015. For the mixed models, we used lmer () or the glmer () of the package lme4 (Bates 2014), version 1.1-7

Results

A total of 10 endemic avian Bornean species were recorded during field work in all sites (Table 5.1), with 9 endemic species recorded in the primary forest sites (Berau and Sungai Wain) and 8 endemic species in the secondary forest sites (Berau and Pusrehut) (Table 5.1). The Bornean Barbet (*Megalaima eximia*) was more abundant in the primary forest sites compared to the secondary forest sites (Table 5.1). The Bornean Ground-cuckoo (*Carpococcyx radiatus*) and the Bornean Blue Flycatcher (*Cyornis superbus*) were absent in the secondary forest sites. The Dusky Munia (*Lonchura fuscans*) was absent in the primary forest sites.

We found that most endemic avian Bornean species had a body mass above 41g (provide statistical proof); only 2 species had a smaller body mass (i.e. one Dusky Munia (*Lonchura fuscans*) and one Yellow-rumped Flowerpecker (*Prinochilus xanthopygius*) (Table 5.1).

When comparing the primary forest site with the secondary forest sites, we did not find significant differences in 'Total species number', 'Mean abundance', or 'Mean species number' for the endemic avian Bornean species (Figure 5.2; Table 5.2). However, we did find a significant difference between the primary forest site and secondary forest sites in the ratio between the number of endemic species and all species of the insectivorous guild per visit per site ($p = 0.041$) (Table 5.3). Also, we found a significantly higher abundance of insectivores in primary forest as opposed to secondary forest ($p = 0.011$). We found no significant differences for any of the other guilds when we compared the primary forest site with secondary forest sites (Table 5.4, Figure 5.3).

Table 5.1
Comparative occurrence of endemic avian Bornean species per day per site based on weight class, feeding guild and mean abundance in primary versus secondary forest sites.

Endemic species	Body mass (g)	Feeding guild	Primary forest		Secondary forest			
			Berau	Sungai Wain	Logged 2003 (Berau)	Logged 2007 (Berau)	Logged 2011 (Berau)	Pusrehut
Bornean Ground-cuckoo *Carpococcyx radiatus*	321–640	Arboreal frugivore/ insectivore	0	0.375	0	0	0	0
Bornean Blue Flycatcher *Cyornis superbus*	11–20	Arboreal insectivore	0	0.125	0	0	0	0
Dusky Munia *Lonchura fuscans*	<10	Terrestrial frugivore	0	0	0	0.25	0.125	0.25
Bornean Barbet *Megalaima eximia*	41–80	Terrestrial frugivore	0	3.125	0	0	0	2.25
Blue-banded Pitta *Pitta arquata*	41–80	Arboreal insectivore	0	0.25	0	0	0	0.25
Blue-headed Pitta *Pitta baudii*	41–80	Arboreal insectivore	1	0	0	0	0.125	0.125
Bornean Black Magpie *Platysmurus atterimus*	161–320	Arboreal insectivore	0.25	2	0.25	0.75	1.125	0
Bornean Peacock-pheasant *Polyplectron schleiermacheri*	641–1280	Understorey frugivore	0	0.25	0	0	0	0.25
Yellow-rumped Flowerpecker *Prinochilus xanthopygius*	<10	Arboreal nectarivore	0.25	0.125	0.5	0.25	0	0
Bornean Wren-babbler *Ptilocichla leucogrammica*	21–40	Arboreal insectivore	0.125	0	0	0.125	0.125	0

Table 5.2
The difference between primary and secondary forest sites in total species, mean abundance and mean species; * = p < 0.05; NS = not significant.

Location / Forest types (sites)	Point Counts	Total Endemic Species	Mean Abundance of Endemic	Mean Endemic Species
Berau				
▪ Primary forest1	1	3	0.75	0.625
	2	1	0.125	0.125
	3	0	0	0
	4	3	0.5	0.5
	5	1	0.25	0.25
SungaiWain				
▪ Primary forest2	1	4	1.75	1.5
	2	4	1.25	0.875
	3	2	0.875	0.75
	4	2	1.5	1.125
	5	4	0.875	0.75
Berau				
▪ Logged 2003	1	0	0	0
	2	1	0.25	0.125
	3	1	0.25	0.125
	4	0	0	0
	5	1	0.25	0.125
▪ Logged 2007	1	0	0	0
	2	2	0.375	0.25
	3	3	0.625	0.5
	4	1	0.25	0.25
	5	1	0.125	0.125
▪ Logged 2011	1	1	0.125	0.125
	2	2	0.5	0.375
	3	1	0.25	0.125
	4	1	0.375	0.25
	5	2	0.25	0.25
Pusrehut				
▪ Disturbed forest	1	3	1	0.75
	2	0	0	0
	3	2	0.75	0.625
	4	3	0.875	0.75
	5	2	0.5	0.375
p-values LRT-test		0.167(NS)	0.241(NS)[a]	0.154(NS)[a]

[a] Poisson distribution of the error was assumed

Table 5.3
The difference between primary and secondary forest sites in ratio of endemic avian Bornean species vs all avian species observed per feeding guild: N, F and I, per visit per site; * = p < 0.05); NS = not significant.

Location / Forest types (sites)	Point Counts	Mean ratio Nectarivores	Mean ratio Frugivores	Mean ratio Insectivores
Berau				
▪ Primary forest1	1	0.125	0	0.105
	2	0	0	0.021
	3	0	0	0
	4	0.111	0	0.083
	5	0	0	0.057
SungaiWain				
▪ Primary forest2	1	0	0.75	0.114
	2	0	0.333	0.114
	3	0	0.455	0.024
	4	0	0.5	0.067
	5	0.25	0.4	0.083
Berau				
▪ Logged 2003	1	0	0	0
	2	0	0	0.026
	3	0.67	0	0
	4	0	0	0
	5	0.25	0	0
▪ Logged 2007	1	0	0	0
	2	0.1	0.25	0
	3	0.125	0	0.073
	4	0	0	0.067
	5	0	0	0.042
▪ Logged 2011	1	0	0.125	0
	2	0	0	0.061
	3	0	0	0.028
	4	0	0	0.1
	5	0	0	0.071
Pusrehut				
▪ Disturbed forest	1	0	0.455	0.029
	2	0	0	0
	3	0	0.455	0
	4	0	0.556	0.045
	5	0	0.2	0.036
p-value		0.553 (NS)[a]	0.900(NS)[b,c]	0.041 (*)[b,c]

[a] p-value Kruskal-test
[b] p-value LRT-test
[c] Poisson distribution of the error was assumed

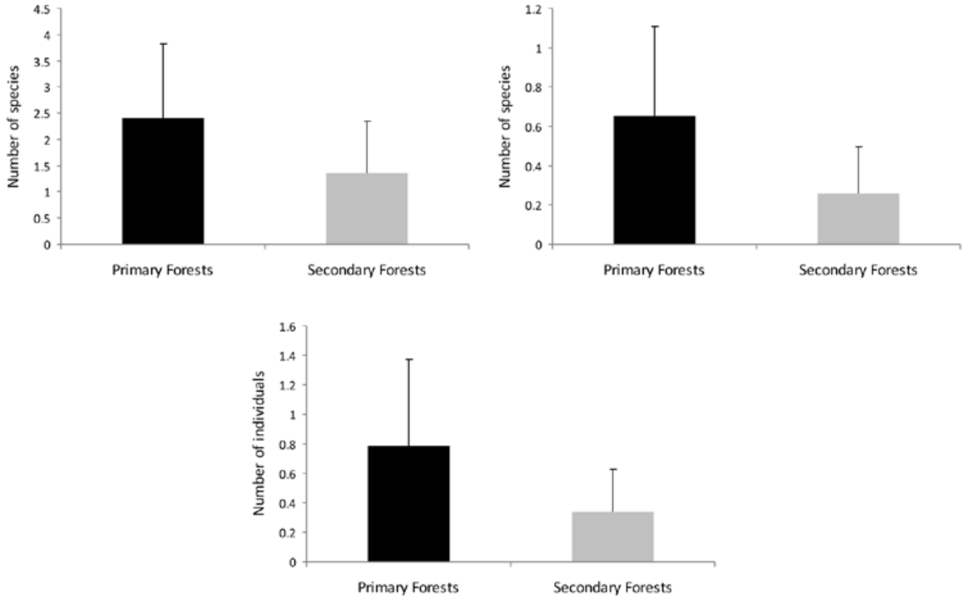

Figure 5.2
Species richness per plot (A), species richness per observation (B), abundance per observation (C) of endemic birds in the primary forest sites (black) and secondary forest sites (grey).

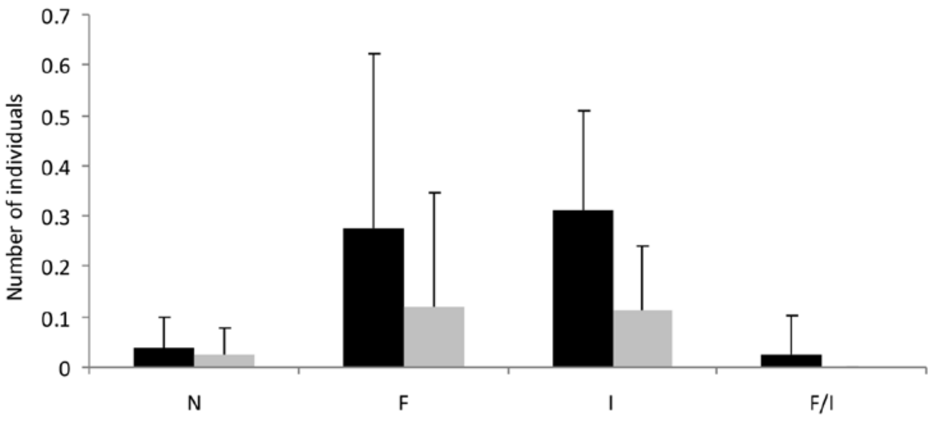

Figure 5.3
Mean abundance (plus standard deviation) endemic avian species per diet guild: Nectarivore (N), Frugivore (F), Insectivore (I), Frugivore/insectivore (F/I) in the primary forests (black) and secondary forests (grey).

Table 5.4
The difference between primary forests and secondary forests in abundance per diet guild: nectarivore, frugivore, insectivore and frugivore/insectivore birds per visit per site; * = p < 0.05); NS = not significant.

Location / Forest types (sites)	Point counts	Mean Nectarivores Endemic species	Mean Frugivores Endemic species	Mean Insectivores Endemic species
Berau				
▪ Primary forest1	1	0.125	0	0.5
	2	0	0	0.125
	3	0	0	0
	4	0.125	0	0.375
	5	0	0	0.25
SungaiWain				
▪ Primary forest2	1	0	0.75	0.5
	2	0	0.25	0.625
	3	0	0.625	0.125
	4	0	0.875	0.25
	5	0.125	0.25	0.375
Berau				
▪ Logged 2003	1	0	0	0
	2	0	0	0.125
	3	0.125	0	0
	4	0	0	0
	5	0.125	0	0
▪ Logged 2007	1	0	0	0
	2	0.125	0.125	0
	3	0.125	0	0.375
	4	0	0	0.25
	5	0	0	0.125
▪ Logged 2011	1	0	0.125	0
	2	0	0	0.375
	3	0	0	0.125
	4	0	0	0.25
	5	0	0	0.25
Pusrehut				
▪ Disturbed forest	1	0	0.625	0.125
	2	0	0	0
	3	0	0.625	0
	4	0	0.625	0.125
	5	0	0.25	0.125
p-value		0.548 (NS)[a]	0.402 (NS)[a]	0.011 (*)[b,c]

[a] p-value Kruskal-test
[b] p-value LRT-test
[c] Poisson distribution of the error was assumed

Discussion

Survival rate of endemic Bornean avian species

Eight out of ten endemic bird species observed throughout our sampling points occurred in the selectively logged sites, which is remarkable, especially in view of the reported drastic reduction in potential food trees after logging (Johns, 1987; Meijaard *et al.*, 2005). However, studies in the Philippines also found that endemic bird species may survive in forest remnants after logging (Brooks *et al.*, 2001; De Iongh & Van Weerd, 2006), and in eastern Borneo, secondary forests were found to support all avian species observed in primary forests (Wielstra *et al.*, 2011; Arbainsyah *et al.*, 2015b). Some species even appear to be unique to secondary forest habitats (Smythies, 1999; Philippe & Phillip, 2011), which is in accordance with our finding that the Dusky Munia (*Lonchura fuscans*) was observed exclusively in secondary forest sites (Table 5.1).

Since most avian species are specialized feeders, having become adapted to particular kinds of food, their abundance is determined by the availability of food sources (Meijaard *et al.*, 2005; Boer, 2006). In tropical forests, where food sources are diverse, endemic bird species are generally less dependent on a single type of food source, except for insectivorous birds, which are more specialized than other guilds and are thus more sensitive to habitat loss, caused by e.g. logging (Wong, 1985). The negative impact of logging on the terrestrial insectivorous guild reported by other authors (De Iongh & Van Weerd, 2006; De Iongh *et al.*, 2007, Mason, 1996; Pieterse & Wielstra, 2005; Slik & Balen, 2006; Arbainsyah *et al.*, 2015b) and our observation that the insectivorous guild was less abundant in logged secondary forest is in line with this and raises major concerns for the conservation of species belonging to this specialized guild.

Although tree flowering stimulation by disturbance in secondary forests (e.g. through increased sunlight due to tree canopy opening) can lead to a temporary increase in nectarivores (Ghazoul & Hellier, 2000; Lambert & Collar, 2002; Slik & Van Balen, 2006; Wielstra *et al.*, 2011), this was not evident from our findings, probably because fruit trees only occurred in limited numbers in logged sites in our study area.

In conclusion, whereas selective logging did not cause severe damage to the wider group of Bornean endemic birds in terms of their diversity, our study confirms the sensitivity of insectivorous endemic birds to the impacts of logging, which should be seriously considered for any future conservation strategy targeting this guild and its remaining habitat in Borneo.

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