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

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Avian community responses to selective logging in FSC-candidate tropical rain forests

Journal of Oryx (submitted)

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Abstract

The aim of our study was to analyze the impact of selective logging on bird communities in East Kalimantan. Our study compared secondary with primary lowland dipterocarp rainforest sites. The secondary forest sites were selectively logged in 2003, 2007 and 2011, in a forest concession which was in the process of FSC certification, in the Berau district. An additional non-certified disturbed forest site was included, the Pusrehut forest, which was situated in the Kutai Kartanegara region. The two primary forest sites were selected in the Berau district, and in the Sungai Wain protected forest in Balikpapan. We found no significant differences in species richness or Shannon diversity of bird communities between the different types of forests. However, we found a significantly higher abundance of birds in primary forests compared to non-primary forest sites. In particular, we found a higher abundance of birds classified as feeding on the ground in the terrestrial foraging layer in primary forests as compared to secondary forests. We also found a significantly higher abundance of birds of the frugivorous / insectivorous guild in the primary forest. Our results indicate that primary forests more effectively support the existing bird populations than forests that are selectively or non-selectively logged. Our results also show that selective logging practices, as implemented according to the certification process, are unlikely to be harmful to bird diversity and could thus be implemented alongside proper bird conservation measures.

Key words: Bird guilds, Sustainable forest management, Selective logging, Species composition, Species diversity, Southeast Asia.

Introduction

Logging and forest transformation forms a major threat to the biodiversity of the last remaining areas of undisturbed lowland tropical rainforest in Kalimantan (Eichhorn *et al.*, 2006; Laurance, 2004; Meijaard *et al.*, 2005; Wielstra *et al.*, 2011). As a result of logging, oil palm development, and transformation of forests into agricultural fields, large areas of natural forest in Kalimantan have been destroyed (Eichhorn *et al.*, 2006; Meijaard *et al.*, 2005; Slik *et al.*, 2002; Van Nieuwstadt, 2002). During recent years, the Indonesian government has promoted certified timber production, following the international Forest Stewardship Council (FSC) and the national Lembaga Ekolabel Indonesia (LEI), in order to achieve Sustainable Forest Management (SFM). The impact of commercial FSC-certified logging on tree diversity and forest structure has been well studied (Arbainsyah *et al.*, 2014, 2015).

A number of studies have thoroughly investigated the impact of logging on tropical lowland forest bird communities (Felton *et al.*, 2008; Haugaasen *et al.*, 2003; Johns, 1996; Kinnaird & O'Brien, 1998; Pieterse & Wielstra, 2011; Slik & Van Balen, 2006), although a review by Van Kuijk *et al.* (2009) identified major knowledge gaps with respect to the effects of reduced impact logging (RIL) – as occurs under FSC certification – on biodiversity conservation. It is unclear whether short-term effects as identified in most of the studies mentioned above also apply during longer time scales. The degree by which FSC logging possibly supports higher tree and animal diversity compared to conventional logging at different time scales remains unknown or poorly quantified. Similarly, the possible reduction in different measures of biodiversity relative to protected primary rainforest remains poorly studied. Our current understanding of the impact of FSC certification, and especially of the long-term recovery processes in FSC-certified forests on bird communities, is severely limited. Therefore, more information regarding such impacts on bird communities in tropical lowland rainforests is urgently needed, especially in Southeast Asia (De Jongh *et al.*, 2005; De Jongh & Persoon, 2010; Ghazoul & Hellier, 2000; Slik & Balen, 2006;).

The Intermediate Disturbance Hypothesis (IDH) is one of the most frequently suggested non-equilibrium explanations for the maintenance of species diversity in ecosystems (Connell, 1978; Wilson, 1990; Roxburgh *et al.*, 2004). Gaps formed by selective logging under FSC certification or other forms of RIL are generally intermediate in terms of disturbance intensity, when compared to conventional logging (Roxburgh *et al.*, 2004). However, RIL may possibly still benefit early and mid-successional bird species more than that part of the avian community that relies on a well-developed and undisturbed litter layer of suf-

ficient spatial extent, as only occurs in undisturbed primary forest (Van Kuijk *et al.*, 2009). Bird biodiversity does not only respond to mild disturbance, it is most likely also critically dependent on large and diverse natural habitats (Slik & Balen, 2006).

Avian communities have important ecosystem functions in tropical rainforests, such as pollination, seed dispersal and predation (Bibby *et al.*, 2000; De longh & Persoon, 2010; De longh & Van Weerd, 2006; Furness & Greenwood, 1993; Gray *et al.*, 2007; Stiles, 1983) and they could potentially be a suitable taxonomic group for assessing and monitoring the impact of logging on biodiversity in tropical lowland rainforests (Edwards *et al.*, 2009; Johns, 1991; Van der Hoeven *et al.*, 2000; Wielstra *et al.*, 2011). Avian community composition can be strongly influenced by logging disturbance of forest vegetation structure (Barlow & Peres, 2004b; Felton *et al.*, 2008; Mason & Thiollay, 2001; Slik & Balen, 2006; Wiens, 1992;) and bird species richness has been found to decline in response to logging (Felton *et al.*, 2008; Johns, 1991; Marsden, 1998; Thiollay, 1997), although some cases reported an increase (Johns, 1996; Kofron & Chapman, 1995). In some studies, avian communities became increasingly dissimilar from those in primary forest after logging and contained a higher abundance of avian species associated with secondary growth habitats (Barlow & Peres, 2004a; Slik & Balen, 2006). These changes in avifaunal assemblages were strongly associated with changes in the vegetation structure, such as canopy cover, undergrowth, and plant regeneration (Johns, 1991; Barlow & Peres, 2004b; Slik & Balen, 2006).

Differences in avian species composition between non-primary forests and primary forests are often more pronounced when individual guilds are examined (Bibby *et al.*, 2000; Ghazoul & Hellier, 2000). The abundance of insectivorous birds, for example, generally declines in secondary habitats, whereas nectarivore abundance and species richness may increase (Mason, 1996; Canaday, 1997; Pieterse & Wielstra, 2005). There is overwhelming evidence that logging primarily affects the understorey insectivorous guild (Johns, 1991; Van der Hoeven *et al.*, 2000).

Here we present an analysis of avian communities in East Kalimantan in forests that were selectively logged in 2003, 2007, 2011 versus a primary forest site and two external sites: the Sungai Wain forest site (a primary forest) and the Pusrehut forest site (a disturbed forest). Our main research question was: How do avian communities respond to disturbance by logging?

Materials and methods

Study area

The study area is located in tropical lowland forest within a forest concession which was in the process of being FSC certified, in the Berau district and two external sites: one primary forest site (Sungai Wain protected forest) and one disturbed non-FSC-certified forest site (Pusrehut). All sites are located in the province of East Kalimantan, Indonesia (Figure 4.1). In the Berau district, four sites were selected for data collection: one primary forest site and three selectively logged forest sites logged in 2003, 2007 and 2011. Near the city of Balikpapan a site of primary forest was selected in the Sungai Wain Protected forest. In the district of Kutai Kartanegara a disturbed site was selected in the Pusrehut forest. This site had been logged in the 1970s, suffered moderate to heavy burning in 1982/1983 and was then replanted with indigenous tree species. It was logged in 1996 and heavily disturbed by fires again in 1997 and 1998. This site had been exposed to considerable illegal logging activities in the period from 1998 to 2014 (Table 4.1).

In the Berau district, the altitude range at the study area is 25-140 m above sea level (Mantel *et al.*, 2002). The topography of all sites consists of a rolling hilly landscape with shallow valleys and gullies. In the Sungai Wain protected forest, the altitude range at the study area is 40-90 m asl (Slik & Eichhorn 2003). In the Pusrehut forest, the altitude range at the study area is 85-140 m asl (Slik & Eichhorn, 2003).

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 forests 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 the presence of individuals of different bird species (Bibby *et al.*, 2000). Point counts are

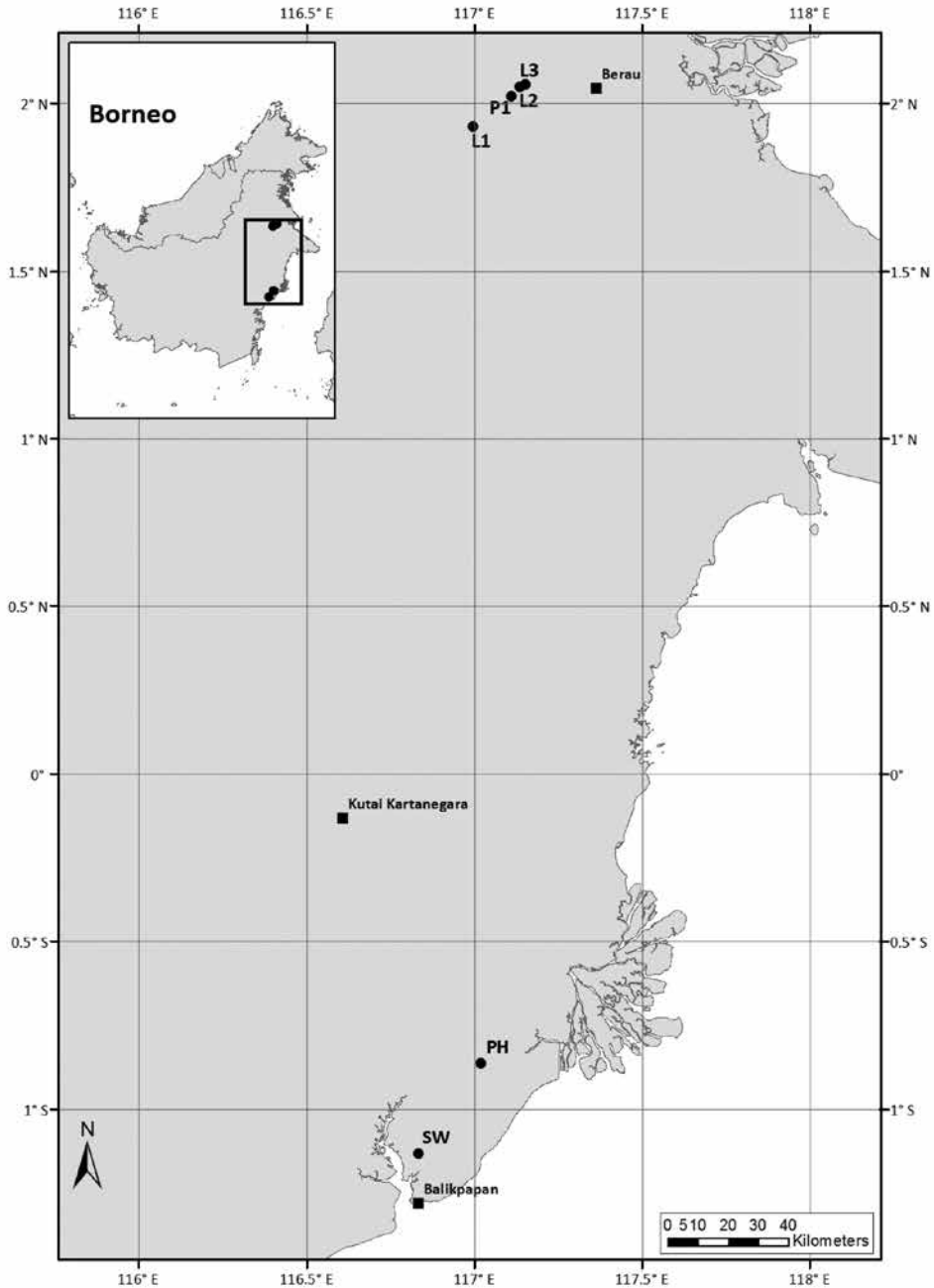


Figure 4.1

Map of East Kalimantan with the location of study areas P1 point counts: primary forest site, L1 point counts: logged in 2011, L2 point counts: logged in 2007, L3 point counts: logged in 2003, SW point counts: Sungai Wain forest site (primary forest), PH point counts: Pusrehut forest site (disturbed forest).

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). Observations were done in all sites between February and August 2014, at 30 locations in total: 2×5 in primary forest, 15 in FSC-candidate, selectively logged forest sites, and 5 in the disturbed non-FSC-certified forest site (Table 4.1).

Counts were repeated four times during mornings (at dawn) and late afternoons (at dusk), each on subsequent days, based on Slik and Balen (2006) (Table 4.1). 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 06h and afternoon visits around 16h, each visit lasting approximately 2 hours. During a site visit all five sampling points were surveyed for 15 min each (following Pieterse & Wielstra, 2005) and 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 microphone placed on a tripod to record all the bird sounds for later identification using reference bird sounds and help from a Dutch birds expert (Dr. Bas van Balen) and two Indonesian bird experts (Agus Prastiono and Satriyo Susito). In order to allow birds to return after being scared away when approaching, counts started 2 min after reaching each observation point. To minimize a possible bias occurring from visiting the points at the same time of day, the points were visited in a reversed order during alternating visits. Counts were not conducted during rainfall because of the inactivity of birds during such weather conditions (Bibby *et al.*, 2000; Slik & Van Balen, 2006). Throughout this study, each bird species was assigned to one of the bird guilds based on Wielstra *et al.* (2011).

Data analyses and statistics

For analysis, a data set was created that contained the following dependent variables per point count location: 1) 'Total species': all species encountered during the eight visits; 2) 'Mean abundance': the average number of individuals per visit; 3) 'Mean species': the average number of species per visit; 4) 'Shannon index': the Shannon diversity index over all eight visits; 5) 'Evenness index': the Pielou evenness index over all eight visits (Table 4.2). The 'Shannon index' was exponentially transformed before analysis, following Jost (2006). The six forest sites were compared with respect to the above parameters. As our point counts were regarded as randomly selected within the forest sites, forest sites were randomly selected from within the regions, and the regions were a random selection from all possible regions in East Kalimantan, the use of a mixed linear model in which

the region is the random effect variable was justified. For all parameters, residuals were checked, except for 'Total species' for which we had to apply a generalized linear mixed model with Poisson residual distribution. All our models were maximum random effect models, i.e. including the effects on both the intercept and the regression coefficient (Barr *et al.*, 2013).

Secondly, we analyzed whether primary forests were different from non-primary forests for all of the dependent variables. In this case, we assumed that all our forests were a random selection out of all possible forests. Again, we applied a linear mixed model, but now with 'Forest' as the random effect variable. Again, residuals were checked and only in case of 'Total species' we needed to assume a Poisson distribution of the residuals.

Next, based on Wielstra *et al.* (2011), the birds were classified into two feeding classes: 1) foraging layer (T = terrestrial; U = understorey; A = arboreal) and 2) diet (N = nectarivore ; F = frugivore ; FI = frugivore / insectivore ; FC = frugivore / carnivore ; I = insectivore ; IC = insectivore / carnivore). For each of these guilds the average over the eight visits of the abundance per point count was calculated. The difference between primary and non-primary forests between these 'Mean abundances per guild' were again analyzed with a linear mixed model for which 'Forest' was included as random effect variable.

For testing, we applied in all cases a Likelihood-Ratio Test (LRT). We performed the statistical analyses using R software (version 3.1.1, R Development Core Team 2014). For the mixed models, we used `lmer()` of the package `lme4` (Bates 2014), version 1.1-7. We constructed species rarefaction curves (`nrandom = 499`) using the package `rich` in R (Rossi 2011).

Results

General findings

A total of 154 species were observed during the field work covering all 6 forest sites, with 84 species in the Berau primary forest site, 84 species in the Berau forest site that was selectively logged in 2003, 76 species in the Berau forest site that was selectively logged in 2007 and 80 species in the Berau forest site selectively logged in 2011, 76 species in the Sungai Wain primary forest and 76 species in the disturbed Pusrehut forest site (Table 4.1).

Table 4.1

Number of point counts, point count visits and total number of species per forest type per location (see also figure 4.1).

Location	Forest types	Point counts	Point count visits	Total species
Berau	Primary forest1	5	8	84
Sungai Wain	Primary forest2	5	8	76
Berau	Selectively logged in 2003	5	8	84
	Selectively logged in 2007	5	8	76
	Selectively logged in 2011	5	8	80
Pusrehut	Disturbed forest	5	8	76

Table 4.2

The difference between primary forests and non-primary forests; * = $p < 0.05$; NS = not significant.

Location / Forest types (sites)	Point Counts	Total Species	Mean Abundance	Mean Species	Shannon Index	Evenness Index
Berau						
■ Primary forest1	1	45	13.88	11.63	3.57	0.94
	2	50	16.63	12.25	3.61	0.92
	3	34	11.50	9.75	3.26	0.92
	4	39	11.63	9.88	3.38	0.92
	5	45	13.00	10.00	3.59	0.94
SungaiWain						
■ Primary forest2	1	38	9.88	8.63	3.46	0.95
	2	43	12.88	10.13	3.41	0.91
	3	37	15.00	10.13	3.19	0.88
	4	34	13.13	9.13	3.16	0.90
	5	43	12.88	10.00	3.46	0.92
Berau						
■ Logged 2003	1	39	10.25	8.25	3.51	0.96
	2	45	13.00	10.63	3.54	0.93
	3	43	14.00	10.25	3.54	0.94
	4	31	9.50	7.63	3.12	0.91
	5	40	11.63	9.38	3.45	0.94
■ Logged 2007	1	35	10.13	8.38	3.30	0.93
	2	34	10.25	7.88	3.20	0.91
	3	39	10.63	9.13	3.50	0.95
	4	32	8.38	7.00	3.28	0.95
	5	32	8.25	7.00	3.28	0.95
■ Logged 2011	1	34	9.38	7.63	3.29	0.93
	2	36	11.63	9.25	3.32	0.93
	3	35	8.50	7.25	3.35	0.94
	4	44	14.50	10.50	3.49	0.92
	5	40	12.38	9.50	3.33	0.90

Table 4.2 (continued)

Pusrehut						
■ Disturbed forest	1	37	11.50	9.50	3.33	0.92
	2	42	10.75	9.00	3.59	0.96
	3	32	11.25	9.75	3.17	0.91
	4	31	7.13	6.50	3.29	0.96
	5	37	8.88	8.00	3.47	0.96
p-values LRT-test		0.1136 (NS) ^a	0.01483 (*)	0.0393 (*)	0.4692 (NS) ^b	0.1291 (NS)
p-values LRT-test with correction for ln (Mean Abundance)				0.2862 (NS)		

^a: assumed poisson distribution

^b: after exponential transformation

We did not find a significant difference between the six forest sites for ‘Total species’, ‘Mean abundance’, ‘Mean species’, ‘Shannon index’ or ‘Evenness’ (results not presented). When comparing the primary forests with the non-primary forests, we did not find significant differences in ‘Total species’ or the two diversity indices (Shannon and Evenness indices) (Table 4.2). However, we found a significantly higher mean abundance per visit per site ($P = 0.015$) and mean species richness per visit ($P = 0.040$) in the primary forests than in the non-primary forests (Table 4.2, Figure 4.2). As the higher mean species numbers in primary forests could possibly result from a higher mean abundance in the primary forests, we checked the influence of abundance on species richness by executing a rarefaction analysis (Figure 4.3). The result shows that the rarefaction curve for the primary forests was below that of the curve for secondary forests.

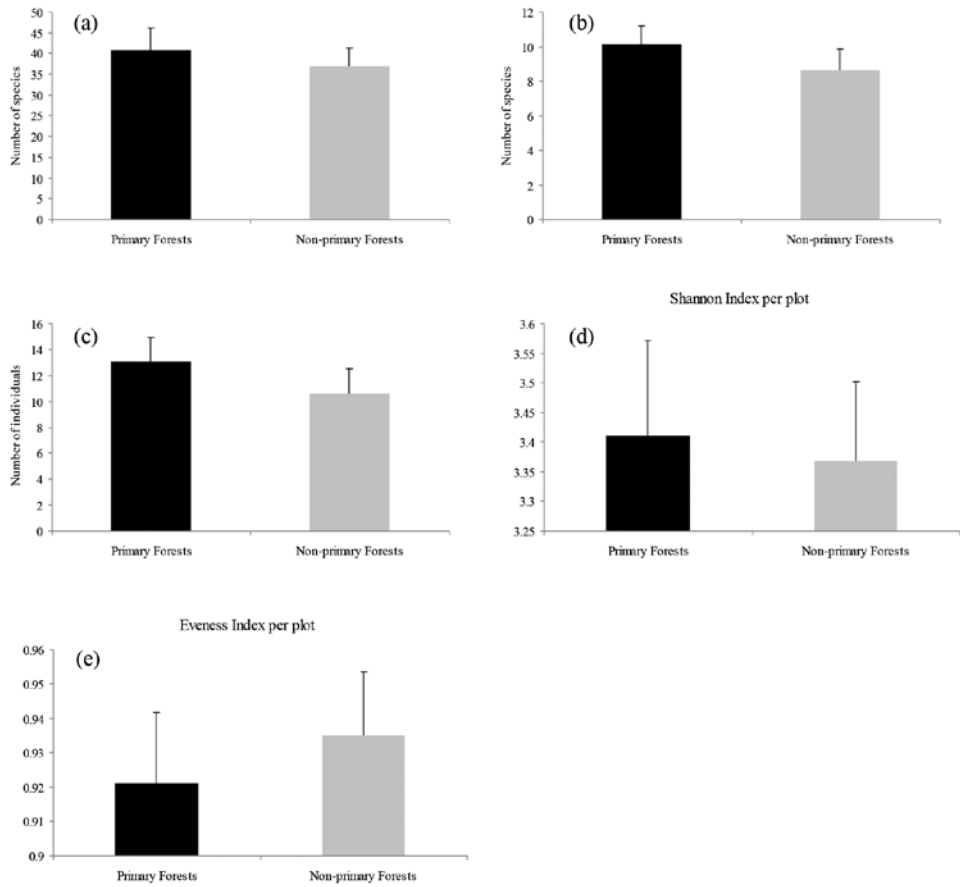


Figure 4.2
Species richness per plot (a), species richness per observation (b), abundance per observation (c), Shannon index per plot (d) and evenness index per plot (e) of birds in the primary forests (black) and non-primary forests (grey).

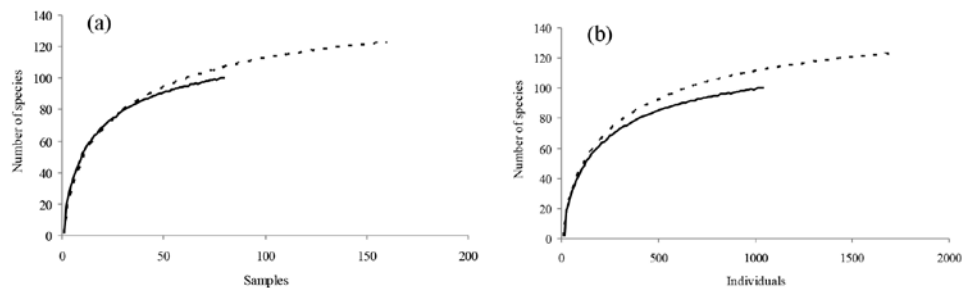


Figure 4.3
The rarefaction curves of the sample of bird species (a) and number of bird individuals (b) in the primary forest sites (line) and non-primary forest sites (dashed line).

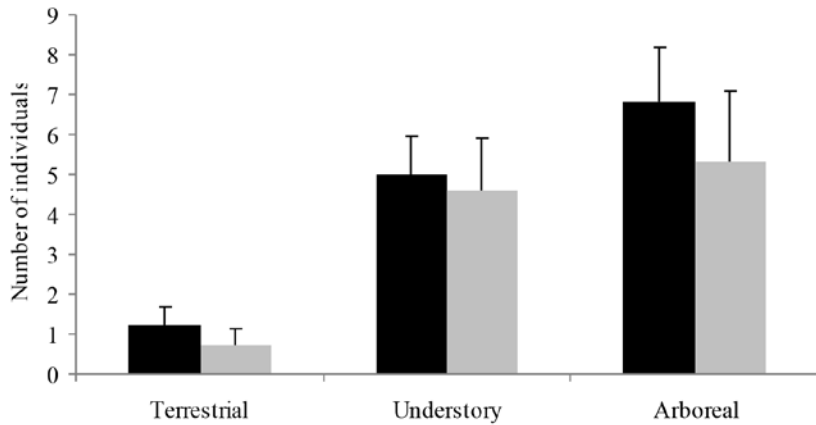


Figure 4.4

Mean abundance (plus standard deviation) per foraging layer guild in the primary forest sites (black) and non-primary forest sites (grey).

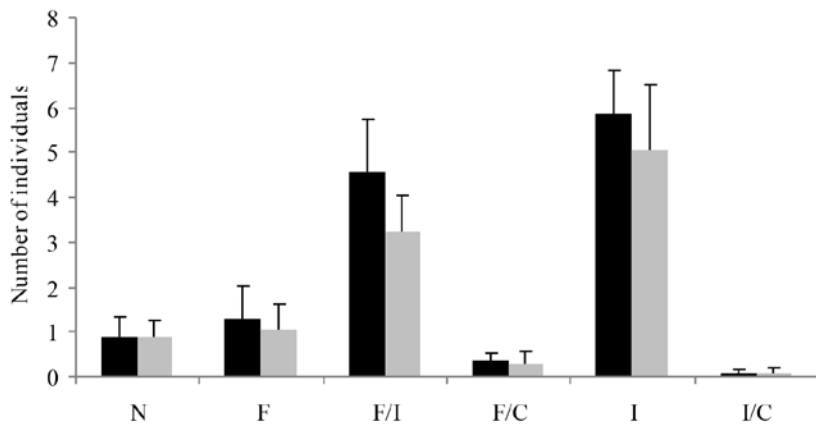


Figure 4.5

Mean abundance (plus standard deviation) per diet guild: Nectarivore (N), Frugivore (F), Frugivore/insectivore (F/I), Frugivore/carnivore (F/C), Insectivore (I), Insectivore/carnivore (I/C) in primary (black) and non-primary forest sites (grey).

Table 4.3

The difference between primary and non-primary forest sites in abundance per foraging layer guild: terrestrial, understorey and arboreal birds per visit per site; * = $p < 0.05$; . = $p < 0.1$; NS = not significant.

Location / Forest types (sites)	Point counts	Mean Terrestrial	Mean Understorey	Mean Arboreal
Berau				
■ Primary forest1	1	1.875	4.5	7.5
	2	0.75	6.375	9.5
	3	0.5	4.875	6.125
	4	1.375	4.75	5.5
	5	1.125	5.875	6
SungaiWain				
■ Primary forest2	1	1.375	4	4.5
	2	1.875	3.75	7.25
	3	1	6.5	7.5
	4	1.25	4.375	7.5
	5	1.125	5.125	6.625
Berau				
■ Logged 2003	1	0.75	3.25	6.25
	2	1	5.125	6.875
	3	0.25	5.5	8.25
	4	0.25	6.625	2.625
	5	0.25	4.25	7.125
■ Logged 2007	1	0.125	2.375	7.625
	2	0.875	5.25	4.125
	3	1	4.125	5.5
	4	1.125	2.5	4.75
	5	0.5	3.625	4.125
■ Logged 2011	1	0.125	2.25	7
	2	0.875	4.75	6
	3	0.25	4.125	4.125
	4	0.625	6.25	7.625
	5	0.625	5.75	6
Pusrehut				
■ Disturbed forest	1	1.25	5.625	4.625
	2	1.5	4.875	4.375
	3	1.375	6.75	3.125
	4	0.875	3.875	2.375
	5	0.5	4.75	3.625
p-values LRT-test		0.01894(*)	0.3721	0.05428(.)

Table 4.4

The difference between primary and non-primary forest sites in abundance per diet guild: nectarivore, frugivore, frugivore/insectivore, frugivore/carnivore, insectivore and mean insectivore/carnivore birds per visit per site; ** = $p < 0.01$); NS = not significant.

Location / Forest types (sites)	Point counts	Mean Nectarivore	Mean Frugivore	Mean Frugivore/insectivore	Mean Frugivore/carnivore	Mean Insectivore	Mean Insectivore/carnivore
Berau							
■ Primary forest1	1	1.125	0.5	6.125	0.25	5.625	0.25
	2	1.25	2.75	4.875	0.25	7.5	0
	3	1.125	0.75	4.625	0.25	4.625	0.125
	4	1.25	1.5	3.25	0.375	5.25	0
	5	1.375	0.875	3.75	0.625	6.125	0.25
SungaiWain							
■ Primary forest2	1	0.375	1	3.125	0.25	5.125	0
	2	0.75	0.75	4	0.25	7.125	0
	3	0.125	1.5	6.5	0.125	6.75	0
	4	1.125	2.375	4.125	0.375	5.125	0
	5	0.5	0.75	5.375	0.75	5.5	0
Berau							
■ Logged 2003	1	1.125	1.375	2.625	0.5	4.5	0.125
	2	0.75	0.875	3.875	0.25	7.125	0.125
	3	0.875	1.5	4.375	0.375	6.625	0.25
	4	1.625	1	4	0.125	2.75	0
	5	0.75	1.875	4.375	0.5	4.125	0
■ Logged 2007	1	0.625	1.5	3.875	0.125	4	0
	2	1.25	0.625	3	0.375	5	0
	3	1	0.375	2.625	0.375	6.25	0
	4	1	0.25	2.25	0.25	4.5	0.125
	5	1.125	0.625	2.625	0.125	3.75	0
■ Logged 2011	1	0.25	1.5	2.75	0.375	4.25	0.25
	2	1	0.25	3.75	0	6.5	0.125
	3	0.75	0.25	2.25	0	5.25	0
	4	0.5	0.875	4.75	0.25	7.875	0.25
	5	0.5	0.875	3.5	0.125	7.375	0
Pusrehut							
■ Disturbed forest	1	0.5	1.75	3	1.125	4.75	0.375
	2	0.75	1.375	2.875	0.5	5.125	0.125
	3	1.75	1.75	3.5	0	4.25	0
	4	0.75	1.375	1.625	0	3.125	0.25
	5	0.5	1.375	2.625	0.5	3.875	0
p-value LRT-test		0.8986	0.4208	0.00991(**)	0.5418	0.1378	0.4753

Table 4.5

List of feeding guild of bird species that are abundant in at least one of the forest sites. Abundant was defined as represented by at least 10 individual birds in the point counts; present (+) and not present (–).

Feeding guild	Species name	Berau (primary forest1)	Sungai Wain (primary forest2)	Berau, Selectively logged forest			Pusrehut (disturbed forest)
				in 2003	in 2007	in 2011	
Arboreal frugivore / insectivore	Alcippe brunneicauda	–	–	–	–	+	–
	Gracula religiosa	–	+	+	+	–	–
	Irena puella	+	–	–	–	–	–
	Megalaima australis	–	–	+	+	+	+
	Megalaima chrysopogon	–	–	–	–	+	–
	Megalaima henrici	–	–	–	–	+	–
	Megalaima mystacophanos	+	–	–	–	–	–
	Megalaima rafflesii	–	+	+	–	–	–
	Pycnonotus atriceps atriceps	–	+	–	–	–	+
	Pycnonotus simplex	–	–	–	+	–	–
Arboreal insectivore	Calorhampus fuliginosus	–	+	–	–	–	–
	Dicrurus aeneus	+	–	–	–	–	–
	Dicrurus paradiseus	–	–	–	–	+	–
	Eurylaimus ochromalus	+	+	+	+	+	+
	Hypothymis azurea	–	–	+	–	–	–
	Malacopteron magnum	–	–	–	+	+	–
	Platysmurus atterimus	–	+	–	–	–	–
	Trichixos pyrropygus	–	–	+	–	–	–
Terrestrial frugivore / insectivore	Megalaima eximia	–	+	–	–	–	+

Table 4.5 (continued)

Terrestrial insectivore	<i>Pitta granatina</i>	+	-	-	-	-	-	-	-
	<i>Stachyris maculata</i>	+	+	+	+	+	+	+	-
	<i>Trichastoma malaccense</i>	-	+	+	-	-	+	+	+
Understorey frugivore / insectivore	<i>Dicaeum trigonostigma</i>	-	-	-	-	-	-	-	+
	<i>Pycnonotus brunneus</i>	+	+	+	+	+	+	+	+
	<i>Tricholestes criniger</i>	+	-	-	-	-	-	-	-
Understorey insectivore	<i>Macronous ptilosus</i>	-	-	-	-	-	-	-	+
	<i>Orthotomus atrogularis</i>	-	-	-	-	-	-	-	+
	<i>Stachyris erythroptera</i>	+	-	-	+	+	+	+	-
Understorey nectarivore	<i>Arachnothera longirostra</i>	+	-	-	+	+	+	-	+

When correcting the mean species number for abundance by including the log transformed mean abundance in our model for mean species numbers, the mean species number was no longer significantly different between primary and secondary forests (Table 4.2).

We found a significant difference in the number of individual birds that are feeding on the ground in the terrestrial foraging layer between primary forests and non-primary forests. This guild showed a significantly higher mean abundance in the primary forest sites ($P = 0.019$) (Table 4.3, Figure 4.4). We also found a near significant difference in the arboreal guild between primary forests and non-primary forests. This guild also showed a (marginally) higher number of birds in the primary forests ($P = 0.054$) (Table 4.3).

With respect to guilds based on diet, we found that the frugivorous / insectivorous guild was significantly more abundant in the primary forest site ($P = 0.010$) as compared to secondary forest sites. None of the other guilds showed a significant difference in abundance between these two forest types (Table 4.4, Figure 4.5).

In the Berau primary forest, the bird species Asian fairy-bluebird (*Irena puella*), Red-throated barbet (*Megalaima mystacophanos*), Bronzed drongo (*Dicrurus aeneus*), Garnet Pitta (*Pitta granatina*) and Hairy-backed bulbul (*Tricholestes criniger*) dominated. In the Sungai Wain primary forest, the Bornean black magpie (*Platysmurus atterimus*) was the dominant bird species. These bird species were absent in the secondary forests (Table 4.5).

Discussion

Our study shows a significant difference in the mean abundance of birds observed per visit per site between two groups of forest plots: the primary forest sites had a higher number of individual birds than the secondary forest sites. This difference in abundance is probably related to the fact that the primary forest sites provide more food resources than the non-primary forest (Slik & Van Balen, 2006). Especially the reduction of trees in the secondary forest sites as a result of selective logging reduces the vertical resource availability for birds (Slik & Van Balen, 2006). Reduction in plant diversity and the strong dominance among small plants of only a few species through the growth of pioneer herbs, shrubs, lianas and trees also strongly reduces the availability of suitable habitat and may reduce resource availability through a change in the quality of vegetation structure (Arbainsyah *et al.*, 2014, 2015).

The number of individual birds per guild, when comparing the primary forests and secondary forest sites, showed some significant differences in terms of the abundance of guilds based on diet and preferred forest layer for foraging (Table 4.3 & 4.4). Our finding that the frugivorous / insectivorous guild was more abundant in the primary forest sites compared to secondary forest sites contradicts earlier studies in Borneo, where frugivorous / insectivorous guilds were more abundant in the secondary forest sites (Johns, 1996; Van Hoesen *et al.*, 2000; Pieterse & Wielstra, 2005; Wielstra *et al.*, 2011).

In the secondary forest sites the reduced availability of a foraging layer may result in a loss of food sources for certain bird guilds (Karr & Brawn, 1990; Mason, 1996; Pieterse & Wielstra, 2005; Slik & Balen, 2006). For example, birds that prefer foraging on the ground (terrestrial layer) were less abundant in secondary forests in the sites we studied (Table 4.4 & 4.5). This finding is similar to the finding of Gray *et al.* (2007) who also found a loss of terrestrial species. Some bird species may need a well-developed litter layer which has established over a long period and covers a sufficiently large spatial area (Van Kuijk *et al.*, 2009).

Illegal logging remains a serious concern that could seriously affect biodiversity in all remaining forest sites, including FSC-certified sites and protected primary rainforest sites. Local observations by the authors indicate that more effective measures need to be implemented to safeguard both protected and FSC-certified forests in Indonesia.

In conclusion, the differences we found between primary forests and secondary forests, particularly with respect to bird abundance, but also in feeding guild composition indicate that primary forests more effectively support the existing bird populations than forests that are selectively or non-selectively logged. It shows that a sustainable selective logging regime could be implemented alongside bird conservation measures in protected forests, without any major impacts on bird diversity.

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