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Impact of FSC-certified logging on bird communities in Berau District, East Kalimantan, Indonesia



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Abstract

Tropical forests hold a major part of the world's biodiversity and play important roles when it comes to ecosystem functions and services. However, these forests continue to be degraded worldwide and establishing protected areas does not seem to be enough to slow this process down. Hence, conservation efforts outside protected areas, in areas such as production forest, are of great importance. Nowadays there is an increase in the use of various certification schemes such as the FSC (Forest Stewardship Council), which aims at preserving biodiversity, but to date there has been little quantitative evidence to support this. This study was aimed at investigating the impact of FSC-certified logging on bird communities in Berau district, East Kalimantan, Indonesia. Birds have been shown to be one of the best and most valuable indicators for biodiversity monitoring. I conducted bird surveys in four sites; one primary site and three FSC-certified logged sites. Bird community composition differed between the sites, but when investigating difference between the sites in different diet- and feeding layer guilds, few differences were found. No differences in Shannon diversity index, overall species richness, abundance, number of genera and families were found either. However, due to illegal logging in the primary (control) site and only one replicate of this kind of site no conclusion on the impact of FSC-certified logging on bird communities can be drawn. Future studies should include several proper control sites in order to truly investigate the impact of FSC-certified logging on bird communities and biodiversity.

Key words: Birds, Sustainable forest management, FSC-certification, Selective logging, Tropical rain forest

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1. Introduction

1.1 General

Tropical forest ecosystems are known for their rich biodiversity (Jennings et al., 2001; Sheil and van Heist, 2000). They also play important roles when it comes to ecosystem services such as regional hydrology, carbon storage and global climate (Laurance, 1999). However, tropical forests continue to be destroyed worldwide and the pace does not seem to be slowing down (FAO, 2012; Laurance, 2007). Agricultural expansion is the main driving force of deforestation (Boucher et al., 2011; Geist and Lambin, 2002; Kissinger et al., 2012), industrial logging is a secondary driver (Fimbel et al., 2001).

All logging has negative effects on the function, structure and composition of the forest and it leads to fragmentation and degradation (Fimbel et al., 2001). Logging also leads to increased accessibility for local human populations through logging roads (Kartawinata and Vayda, 1984). This may in turn lead to changes in biodiversity in the remaining forests due to increased illegal logging and hunting (Curran et al., 2004; Hartshorn and Bynum, 2001; Laurance, 1998).

1.2 Sustainable forest management and forest certifications

In order to conserve biodiversity, as well as sustain important ecosystem functions and services, protected areas are established worldwide. Even though most authorities consider such areas to be the best strategy for conservation (Bruner et al., 2001; Chape et al., 2005), it is also recognized that the economic demands, social pressure on land and the high costs lead to limited size, number, distribution and protection of such areas, especially in lowland tropical forests (Joppa et al., 2009; Rodrigues et al., 2004). Hence, conservation efforts outside protected areas, in areas such as production forest, are of great importance.

In terms of conserving biodiversity, sustainable forest management (SFM) is preferable to all other forest use practices apart from complete protection (Putz et al., 2000). SFM can more specifically be defined as 'the stewardship and use of forests and forest lands in a way and at a rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, a role of ecological, economic and social functions, at local, national and global levels, and that does not cause (long term) damage to the ecosystem.' (The Ministerial Conference on the Protection of Forests in Europe 1993, as quoted in Myers 1996). Growing environmental awareness and consumer demand for more responsible and sustainable practices have also led to an increase in

the development of voluntary timber certifications such as the FSC (Forest Stewardship Council) (Upton and Bass, 1996; Viana et al., 1996; Vogt et al., 2000).

SFM and forest certifications usually involve some sort of selective logging (or low impact logging) where stems above a certain diameter in breast height (d.b.h) of specific economically valuable tree species are logged in specific areas (Fimbel et al., 2001). However, it is important to note that the standards and the outcome of these practices are not fixed. They often reflect compromises between different incompatible interests, and trade-offs between what is practically feasible and what is desired (Gullison, 2003; Rametsteiner and Simula, 2003).

Apart from tree species diversity, biodiversity is rarely determined directly during certifications audits in certification systems such as FSC. The reason for this is that monitoring biodiversity most often is costly and time-consuming (van Kuijk et al., 2009). Instead, attempts to retain biodiversity are done through measurements of management processes and protected habitats (Lindenmayer et al., 2000). Hence, whether it can be assumed that logging through FSC-certification actually is sustainable in terms of maintaining biodiversity is still a question. In fact, there is little quantitative evidence showing this to date (Van Kuijk et al., 2009).

1.3 Birds and logging

Bird community composition is strongly influenced by vegetation structure through insect diversity and preservation of fruiting and seeding trees. Hence, birds are one of the best and most valuable taxa to use when monitoring impacts of logging on biodiversity (Barlow and Peres, 2004; Mason and Thiollay, 2001; Meijaard et al., 2005). In addition, birds also have important ecological roles as pollinators, seed dispersers and seed predators (Fimbel et al., 2001; Furness and Greenwood, 1993; Ghazoul and Hellier, 2000; Gray et al., 2007; Meijaard et al., 2005).

Studies have reported a decrease in the widely used Shannon diversity index for birds following disturbance such as logging and forest fires (Posa, 2011; Slik and van Balen, 2006; Thiollay 1992). One broad explanation for such a decrease is that disturbed areas generally are considered to have less spatial variation than undisturbed areas. Hence, disturbed areas do not allow for the same amount of niches to be occupied by different bird species. However, the Shannon diversity index takes both species richness and relative abundance of species into account, and is therefore difficult to interpret (Ghazoul and Hellier, 2000). Nevertheless, it is widely used and might provide some rough information about disturbance levels.

Bird species richness has been shown to both decline (Marsden, 1998) and increase following logging (Johns, 1997). Studies have also shown that the majority of species inhabiting primary forest actually survive in logged forests as well (Danielsen and Heegaard, 1995; Johns A.D., 1986, 1989; Johns A.G, 1996, Lambert, 1992; Round and Brockelman, 1998). This is likely due to nearby intact forests which serve as sources for rapid reinvasion (Lambert and Collar, 2002). Further, even if such forests exist many studies suggest that abundances of certain species in logged areas are so low so the species can no longer fulfil their ecological roles in the forest, which cause changes in the ecosystem as a whole. This kind of pattern has been shown to often occur for specific species of birds belonging to particular feeding guilds (Gray et al., 2007; Johns A.D., 1986, 1989; Johns A.G, 1997; Lambert, 1992). Terrestrial and understorey insectivores have, for example, been found to decrease in both abundance and species richness after logging (Johns A.D., 1986, 1989, Johns A.G, 1997; Lambert, 1992). Frugivores and nectarivores, on the other hand, have been found to increase in abundance after logging (Lambert, 1992). This can be due to an increased availability of nectar and fruit arising from a decrease in canopy cover (Mason 1996; Wunderle et al., 2006). However, Gray et al. (2007) found that the abundance of frugivores, nectarivores and insectivores decrease following logging. In addition they found a decrease in species richness for insectivores, but not for frugivores.

My study aimed at investigating if sustainable forest management through FSC-certification had an effect on bird communities in Berau District, East Kalimantan. To assess this I used the Bray-Curtis distance to compare possible differences in overall bird community composition between a primary forest site and three FSC-certified logged sites logged in the year of 2003, 2007 and 2011. I also compared sites in terms of Shannon diversity index, species richness, abundance and number of genera and families, as well as species richness and abundance of specific guilds.

Since all types of logging change the structure and composition of the forest (Fimbel et al., 2001), I expected the sites to differ in community composition. I also expected to find differences between sites in abundance and species richness of certain guilds, e.g. a lower abundance and species richness of insectivores in logged areas. Further, I expected the logged areas to have a lower Shannon diversity index due to a lower spatial variation than a primary forest.

2. Materials and Methods

2.1 Research area

The research area is located in the lowland tropical forest of Berau district in East Kalimantan within the forest concession of PT. Hutansanggam Labanan Lestari (HLL) Labanan (Figure 1). Within this area, a state-owned logging company called PT Inhutani operates. This company owns the largest share of the total PT Hutansanggam area, 830 km² (Purbawiyatna, 2002), and has an FSC-certification. Within this area approximately 20 km² is transmigration forest, 70 km² community forest 160 km² protected forest while the rest of the area is used for production (Arbainsyah, personal communication). The area's topography consists of a rolling hilly landscape with shallow valleys and gullies which ranges from 25 to 140 m above sea level. Most of the soil consists of loamy clay and sand and the top soil layer is approximately 5-10 cm (Mantel et al., 2002).

Within the research area four sites were established for data collection; one primary forest site and three FSC-certified selectively logged forest sites logged in 2011, 2007 and 2003 (Figure 1). These sites are hereafter referred to as: Primary, L2003, L2007 and L2011. The overall area of logged sites is between 15 and 20 km² respectively, while the area of Primary is unknown (Arbainsyah, personal communication).

There is a lot of charcoal mining and logging occurring in the area of Berau district (personal observation; Arbainsyah, personal communication). Around the forest concession of PT. Hutansanggam Labanan Lestari (HLL) Labanan there is not much continuous primary forest left apart from in the east where the forest becomes more inaccessible due to the increase in elevation.

The primary site is dominated by the plant families *Dipterocarpaceae*, *Euphorbiaceae*, *Caesalpiniaceae*, *Burseraceae* and *Sapotaceae* while abundant species in the logged sites belong to the families of *Myrtaceae*, *Dipterocarpaceae*, *Ulmaceae*, *Sapotaceae*, *Euphorbiaceae* (Arbainsyah et al., 2014). The primary site and L2003 have a higher overall tree and sapling density than the other logged sites. The primary forest is also characterised by a higher abundance of palm lianas compared to the logged sites. However, the logged sites have a higher abundance of fern lianas and fern herbs than the primary forest site. Compared to the primary forest the logged sites have a higher abundance of species belonging to the family *Euphorbiaceae*, which include fast-growing pioneer species with little economic interest.

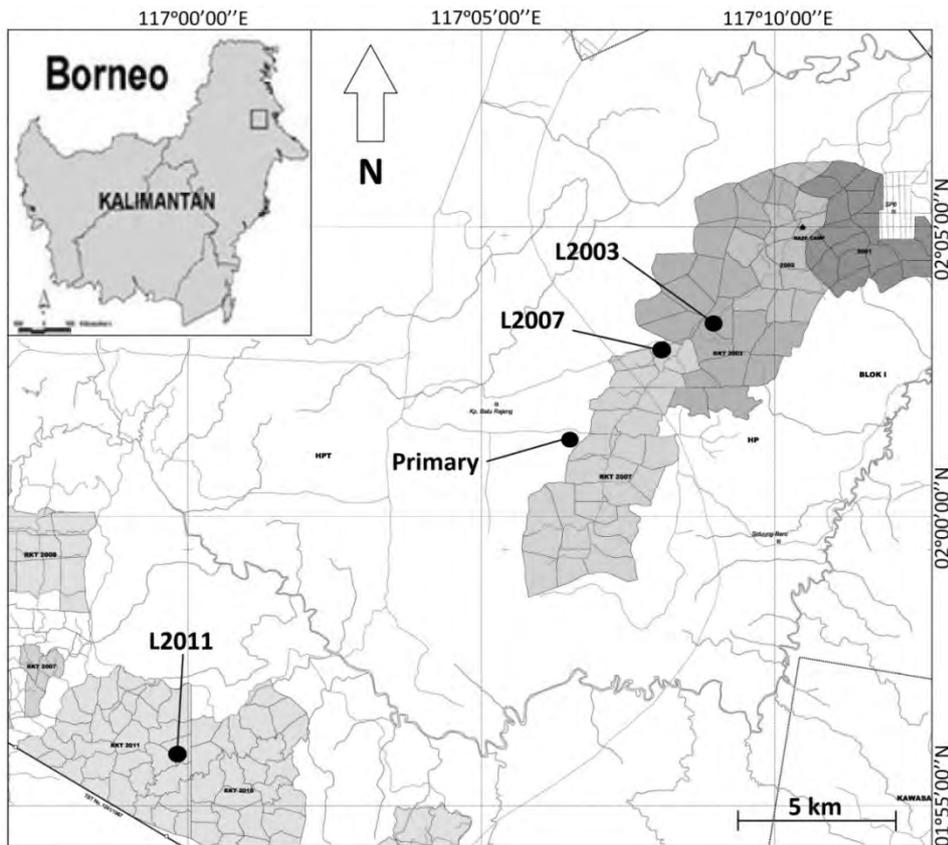


Figure 1. Map of East Kalimantan with the four study sites; primary forest (N 02°01` E 117°06`) and FSC-certified logged forest sites logged in 2003 (N 02°03` E 117°09`), 2007(N 02°02` E 117°09`)and 2011 (N 01°55` E 116°59`). The different shades of grey indicate within which areas PT. Hutansanggam Labanan Lestari (HLL) Labanan operates. Figure modified from Arbainsyah et al., 2014.

Within each of these sites, five points were established and used for point counts (Bibby et al., 2000). These points were spaced 200 meters apart (Figure 2).

The use of point counts is more often preferred in non-open terrain in opposite to line transects (Bibby et al., 2000). This because it is hard to focus on counts and follow transects at the same time. In addition, unnecessary noise may disturb and scare birds which may produce a bias towards more conspicuous birds.

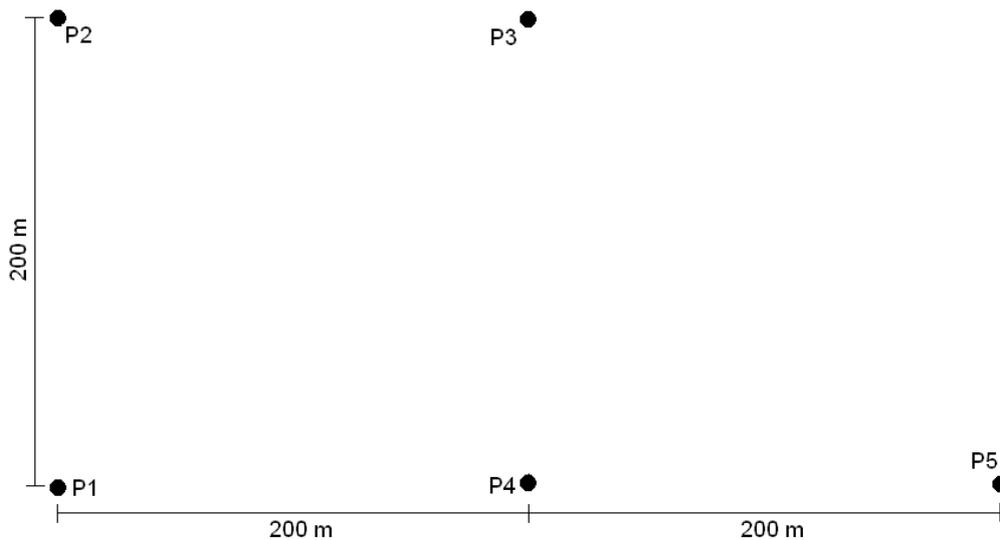


Figure 2. The five points (P1-P5) established in a site.

2.2 Data collection

Most Bornean birds breed once a year between January and July (Phillipps and Phillipps, 2011). I collected data during late February and beginning of May 2014 which are part of the breeding months and hence many birds were singing at this time. In order to familiarize with songs and appearance of the birds I, pre departure, studied literature, photographs and sound recordings (e.g. MacKinnon and Phillipps, 1993; Phillipps and Phillipps, 2011; the Xeno-canto database, <http://www.xeno-canto.org>).

Each site was visited four mornings and four afternoons rendering a total of eight visits. During all visits I was accompanied by a bird expert from the University of Mulawarman, Samarinda (Agus Prastiono). Morning visits usually started around 06:00 and afternoon visits around 16:00, each visit lasting in total approximately two hours. During a visit all five points were visited 15 minutes each (Pieterse and Wielstra, 2005). Notes of all birds seen and heard during this time were taken. No distance limitation was used and hence exact abundances were not obtained, but rather a measure which only allowed for comparison between the sites since the same method was used in all the sites. However, at each point I did take some notes of approximate distances and directions to the birds heard and observed. This allowed me to exclude loud birds that could be heard over great distance and hence heard at more than one point. In addition, some birds do move around a lot and could hence be encountered in more than one point. But since they are moving they are also likely to be missed and hence the problem with double counting an individuals is somewhat compensated. At each point I also used a microphone placed on a tripod to record all the bird songs and calls for later identification using reference sounds and help from a Dutch expert (Bas van Balen)

and an Indonesian bird expert (Agus Prastiono). In order to allow birds to return to a point that might have been scared away when approaching, counts started after two minutes of silence after reaching each point. Moreover, to minimize a possibly bias occurring from visiting the points at the same time each visit, the points were visited in a reversed order half of the morning and half of the afternoon visits. Counts were not conducted during heavy rain because of the decrease in bird activity during such weather conditions (Bibby et al., 2000).

2.3 Guilds

Previous studies have suggested that changes in vegetation structure caused by logging affect birds in different ways. The effect varies depending on the guild under consideration. Root, 1967 defines a guild as “a group of species that exploit the same class of environmental resources in the same way”. A common way to group birds into guilds is simply based on diet. Another way is to group the birds based on diet and foraging layer. These guilds represent a functional relationship with the ecosystem as a whole.

Based on literature (Myers, 2009; Phillipps and Phillipps, 2011) I determined diet (Table 1) for each bird species. Based on this I grouped the bird species into different diet guilds (Appendix I Table A1). Combining diet and foraging layer (which was also obtained from the literature) also generated a specific feeding layer guild for each species (Table 1 and Appendix I Table A1).

Nocturnal species were excluded from the analysis due to that separate systematic surveys are needed during night when these species are active. Aerial feeders and birds of prey were also excluded due to that observations are highly dependent on visibility. In addition, individuals of aerial feeders are difficult to separate from one another.

Table 1. The different guilds determined for each bird species based on literature (Myers, 2009; Phillipps and Phillipps, 2011).

Guilds
<i>Diet guilds</i>
Frugivore
Frugivore/carnivore
Frugivore/insectivore
Insectivore
Insectivore/carnivore
Nectarivore
<i>Feeding layer guilds</i>
Arboreal frugivore
Arboreal frugivore/carnivore
Arboreal frugivore/insectivore
Arboreal insectivore
Arboreal insectivore/carnivore
Arboreal nectarivore
Understorey frugivore/insectivore
Understorey insectivore
Understorey nectarivore
Terrestrial frugivore/insectivore
Terrestrial insectivore
Terrestrial insectivore/carnivore

2.4 Data analysis and statistics

All statistical analyses were done using R version 3.1.0 (R Core Team, 2014). The significance level was set to 0.05.

In order to investigate the impact of FSC-certified logging on bird communities I compared the four sites in terms of biodiversity, uniqueness, species composition, species richness, number of families, genera and abundance, as well as number of species and abundance in each guild.

Biodiversity for each site was obtained by calculating the average Shannon diversity index for each site (Equation 1). This was done using the *BiodiversityR* package in R (Kindt and Coe, 2005). Since assumptions for a parametric test was not met, I then used a Kruskal–Wallis one-way analysis of

variance to test for differences between sites. Species uniqueness (i.e. the number of species found in one site only) was manually calculated for each site, but not analysed statistically.

$$H = -\sum_{i=1}^S p_i \ln p_i \quad \text{Equation 1}$$

Where:

H = Shannon diversity index.

S = total number of species in the site.

p_i = proportional abundance of the i^{th} species calculated by dividing abundance of species i by the total abundance.

In order to investigate differences in overall bird community composition I used the *adonis* routine in the *vegan* package (Oksanen et al., 2011). *Adonis* is a non-parametric multivariate analysis of variance based on a distance matrix (Anderson, 2001). I used the Bray-Curtis distance (Equation 2), which is calculated from differences in abundance of each species present in each site. However, the final distance obtained from this is influenced more by species with larger differences in abundances and therefore I chose to transform my abundance data by a square root prior to the analysis (Kindt and Coe, 2005). *Adonis* tests for differences in mean compositions, so called centroids, between groups much like an Analysis of variance (ANOVA). It assumes that the data have the same multivariate homogeneity of group dispersions (variances). If this is not the case, a significant difference in an *adonis* analysis may be caused by differences in within group dispersion rather than mean values of composition of groups. Therefore I also tested for a dispersion effect using the *betadisper* function in the *vegan* package (Oksanen et al., 2011) when a significant effect was found in the *adonis* analysis. *Betadisper* is basically a multivariate analogue of Levene's test for homogeneity of variances. To analyse the significance of the *betadisper* model, I used an ANOVA followed by a Tukey Post Hoc test.

In order to visualize the results from the *adonis* I used a Principal Coordinate Analysis (PCoA), which is a type of unconstrained ordination method. Sites that are close to each other in an ordination graph can be interpreted as being more similar in community composition than sites further away from each other. PCoA first creates a distance matrix based on the species matrix and then creates a new matrix which includes principle coordinates for each site and species. These coordinates can

then be plotted in a graph. However, graphs can only be plotted in two dimensions (sometimes also three). The creation of the new matrix in PCoA (and other ordination methods) allows for more variance to be shown in only two dimensions rather than several dimensions without losing any of the total variance

$$D = 1 - 2 \frac{\sum_{i=1}^S \min(a_i, b_i)}{\sum_{i=1}^S (a_i + b_i)} \quad \text{Equation 2}$$

Where:

D = the Bray Curtis distance between two sites.

a and b = Two different sites that are compared.

i = abundance of the i^{th} species.

S = total number of species in the site.

$\min(a_i, b_i)$ = the lower value of the abundance of the i^{th} species that is shared between the two sites (a and b).

In order to investigate the effect of site (Primary, L2003, L2007 and L2011), and differences in species richness, abundance, and number of genera and families, I used a Kruskal–Wallis one-way analysis of variance. If a significant difference was found I used a pairwise Wilcox test with a Bonferroni correction. These tests were also done for species richness and abundance in all the guilds. The reason for choosing a Kruskal–Wallis one-way analysis of variance, which is a non-parametric test, was that my data rarely met the assumptions of a parametric test such as an ANOVA. Further, a non-parametric test is also less powerful than a parametric test and hence if a true significant effect of site was to be found it would show in a non-parametric test as well.

3. Results

A complete list of all the birds encountered during the field work, which sites they were encountered in and which guilds they belong to can be found in Appendix Table A1.

3.1 Overview

Table 2 provides a general overview of the analyses made and the outcome of them. The results shown in the table can also be found in more detail in each part of the result section.

Table 2. Overview of the analyses made and the outcome of them.

Variable tested	Test	<i>p</i>-value
Shannon diversity index	Kruskal-wallis	NS
Species richness	Kruskal-wallis	NS
Abundance	Kruskal-wallis	NS
Number of genera	Kruskal-wallis	NS
Number of families	Kruskal-wallis	NS
Bird community composition	Adonis	0.001
<i>Guilds species richness</i>		
Frugivores	Kruskal-wallis	0.023
Frugivores/carnivores		Insufficient data
Frugivores/insectivores	Kruskal-wallis	NS
Insectivores	Kruskal-wallis	NS
Insectivores/carnivores		Insufficient data
Nectarivores	Kruskal-wallis	0.020
Arboreal frugivores	Kruskal-wallis	0.023
Arboreal frugivores/carnivores		Insufficient data
Arboreal frugivores/insectivores		Insufficient data
Arboreal insectivores	Kruskal-wallis	NS
Arboreal insectivores/carnivores		Insufficient data
Arboreal nectarivores		Insufficient data
Understorey frugivores/insectivores	Kruskal-wallis	NS
Understorey insectivores	Kruskal-wallis	NS
Understorey nectarivores		Insufficient data
Terrestrial frugivores/insectivores		Insufficient data

Table 2, continued

Variable tested	Test	<i>p</i>-value
Terrestrial insectivores		Insufficient data
Terrestrial insectivores/carnivores		Insufficient data
<i>Guilds abundance</i>		
Frugivores	Kruskal-wallis	NS
Frugivores/carnivores		Insufficient data
Frugivores/insectivores	Kruskal-wallis	NS
Insectivores	Kruskal-wallis	NS
Insectivores/carnivores		Insufficient data
Nectarivores	Kruskal-wallis	NS
Arboreal frugivores	Kruskal-wallis	NS
Arboreal frugivores/carnivores		Insufficient data
Arboreal frugivores/insectivores	Kruskal-wallis	NS
Arboreal insectivores	Kruskal-wallis	NS
Terrestrial frugivores/insectivores		Insufficient data
Arboreal insectivores/carnivores		Insufficient data
Arboreal nectarivores		Insufficient data
Understorey frugivores/insectivores	Kruskal-wallis	NS
Understorey insectivores	Kruskal-wallis	NS
Understorey nectarivores	Kruskal-wallis	NS
Terrestrial frugivores/insectivores		Insufficient data
Terrestrial insectivores	Kruskal-wallis	0.004
Terrestrial insectivores		Insufficient data

3.2 Shannon diversity index and species uniqueness

There was no significant difference between sites in average Shannon diversity index (Kruskal-wallis, $\chi^2(3) = 1.776$, $p = 0.620$). The lowest species uniqueness was found in L2007 and the highest in Primary (Table 3).

Table 3. Average Shannon diversity index (\pm se) and species uniqueness and for each site.

Site	Shannon diversity index	Species uniqueness
Primary	3.27 \pm 0.18	13
L2003	3.21 \pm 0.37	10
L2007	3.16 \pm 0.16	5
L2011	3.14 \pm 0.23	9

3.3 Species richness, abundance and number of genera and families

In total I found 1832 individuals from 127 species, comprising 78 genera and 35 families (Table 4). No significant effect of site was found for species richness (Kruskal-wallis, $X^2(3) = 1.913$, $p = 0.591$), abundance (Kruskal-wallis, $X^2(3) = 5.051$, $p = 0.168$), number of genera (Kruskal-wallis, $X^2(3) = 2.251$, $p = 0.529$) or number of families (Kruskal-wallis, $X^2(3) = 2.806$, $p = 0.423$)

Table 4. Mean species richness, abundance and number of species, genera and families in each site (\pm se).

Site	Species richness	# Individuals	# Genera	# Families
Primary	31.25 \pm 2.04	66.63 \pm 4.80	24.25 \pm 1.49	17.25 \pm 0.80
L2003	31.38 \pm 3.72	58.38 \pm 8.43	26.63 \pm 2.80	18.25 \pm 1.26
L2007	23.38 \pm 1.38	47.63 \pm 3.63	22.38 \pm 1.53	15.75 \pm 1.06
L2011	29.00 \pm 2.87	56.38 \pm 7.36	23.00 \pm 2.03	16.75 \pm 1.28
Total	127	1832	78	35

3.4 Bird community composition

Overall bird community composition differed between sites (*adonis*, $R^2 = 0.231$, $p = 0.001$) and there were no differences in within site dispersion (ANOVA, $F_{(3,28)} = 2.333$, $p = 0.096$) (Figure 3). An *adonis* performed pairwise between all sites showed that all sites differed from one another (Table 5).

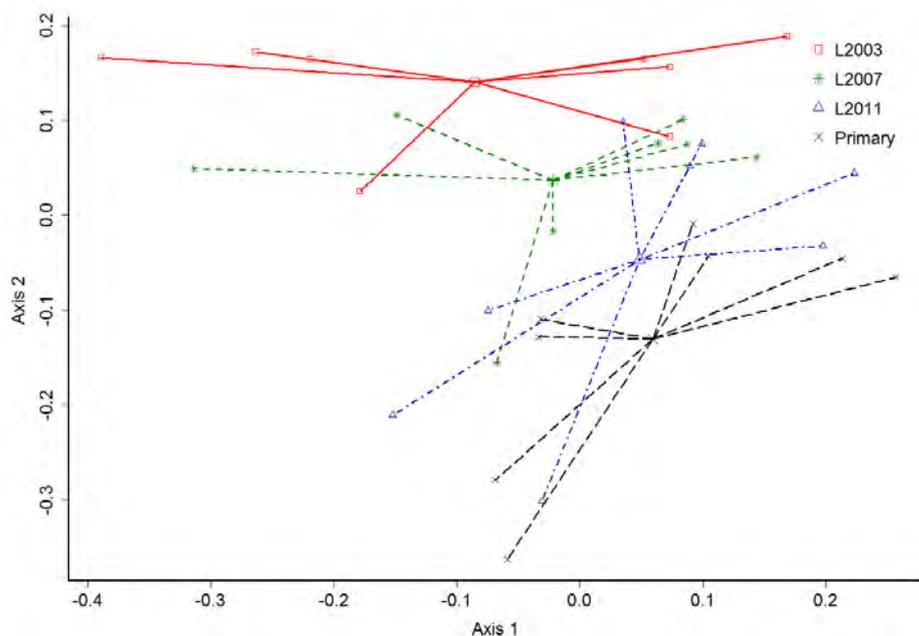


Figure 3. Centroids (centre of spiders) and within site dispersion for each site. Axis 1 and 2 are the two first principal coordinate axes, based on the Bray-Curtis distance matrix, that explain most of the variation in the dataset.

Table 5. R^2 - and p -values for all pairwise *adonis* comparisons between sites.

Sites	p -value	R^2 -value
Primary – L2003	0.001	0.187
Primary – L2007	0.002	0.189
Primary – L2011	0.002	0.171
L2003 – L2007	0.004	0.149
L2003 – L2011	0.001	0.181
L2007 – L2011	0.002	0.127

3.5 Diet guilds

3.5.1 Frugivores

There was a significant effect of site on frugivorous species richness (Kruskal-wallis, $X^2(3) = 9.533$, $p = 0.023$) (Figure 4). No significant differences between site were however found when pairwise comparisons were made, but the difference between L2003 and L2007 was close to significant ($p = 0.067$). No significant effect of site was found on the abundance of frugivores (Kruskal-wallis, $X^2(3) = 7.244$, $p = 0.065$).

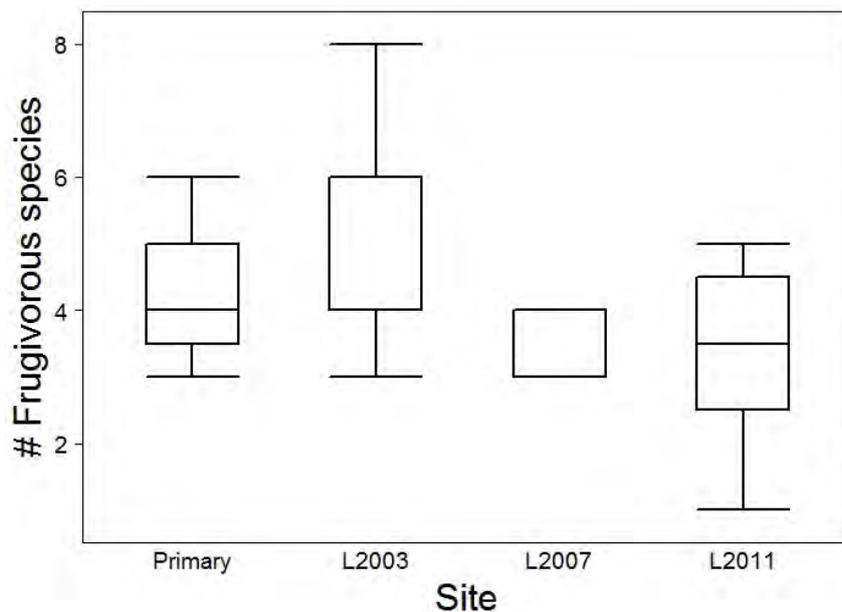


Figure 4. Number of frugivorous species (species richness) in the different sites. Wilcox test showed no significant pairwise differences.

3.5.2 Frugivores/carnivores

Only 6 species and 44 individuals belonging to the frugivorous/carnivorous guilds were encountered throughout the research (Table 6 and Appendix Table A1). These low numbers did not allow for any proper statistical analysis to be made.

Table 6. Total frugivorous/carnivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	4	14
L2003	3	14
L2007	3	10
L2011	3	6
Total	6	44

3.5.3 Frugivores/Insectivores

There were no significant differences between sites in frugivorous/insectivorous species richness (Kruskal-wallis, $X^2(3) = 2.312$, $p = 0.510$) or in abundance (Kruskal-wallis, $X^2(3) = 7.358$, $p = 0.061$).

3.5.4 Insectivores

No significant differences between sites in insectivorous species richness (Kruskal-wallis, $X^2(3) = 0.844$, $p = 0.839$) or in abundance was found (Kruskal-wallis, $X^2(3) = 1.299$, $p = 0.729$).

3.5.5 Insectivores/Carnivores

Only 7 species and 20 individuals belonging to the Insectivorous/carnivorous guild were found (Table 7 and Appendix Table A1). These numbers were too low to allow a proper statistical analysis.

Table 7. Total insectivorous/carnivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	3	6
L2003	3	5
L2007	3	2
L2011	3	7
Total	7	20

3.5.6 Nectarivores

A significant effect of site was found for nectarivorous species richness (Kruskal-wallis, $X^2(3) = 9.888$, $p = 0.020$) (Figure 5). The richness was lower in L2011 compared to L2007 ($p = 0.024$). No significant effect of site was found on abundance of nectarivores (Kruskal-wallis, $X^2(3) = 5.218$, $p = 0.157$).

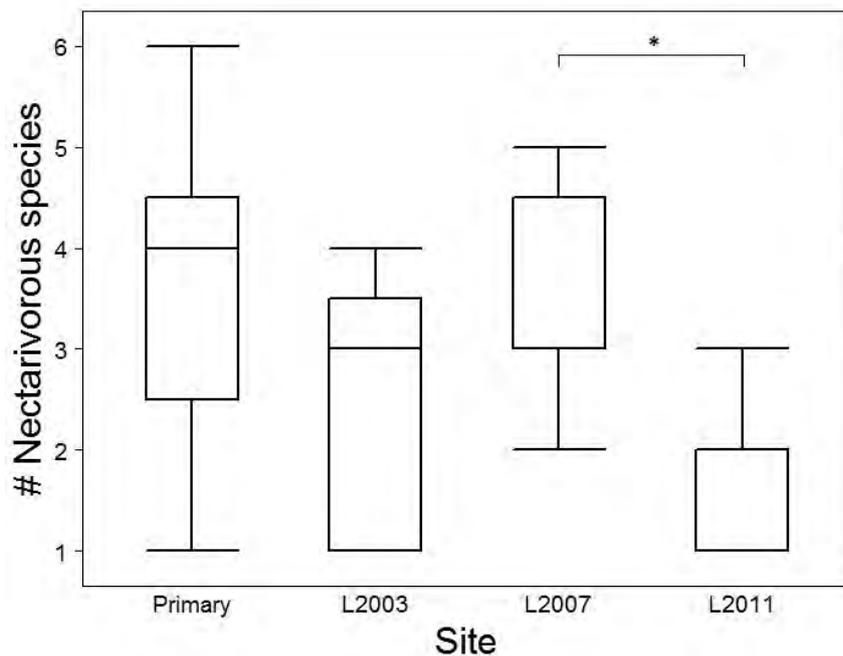


Figure 5. Number of nectarivorous species (species richness) in the different sites. The asterisk indicates significant pairwise differences when a Wilcox test was performed.

3.6 Feeding layer guilds

3.6.1 Arboreal frugivores

The results for the arboreal frugivorous guild are identical to those for the frugivorous guild since these two guilds consist of the exact same species and individuals.

3.6.2 Arboreal frugivores/carnivores

The arboreal frugivorous/carnivorous guild was identical to the frugivorous/carnivorous guild, which contained too few individuals and species to conduct a proper analysis. Hence, a proper statistical analysis could not be done for the arboreal frugivorous/carnivorous either.

3.6.3 Arboreal frugivores/insectivores

Only 8 species belonging to arboreal frugivorous/insectivorous were found throughout the research (Appendix table A1). This number was too low to allow for a proper statistical analysis to be made. Arboreal frugivorous/insectivorous abundance did however allow for a statistical analysis but it not differ significantly between sites (Kruskal-wallis, $X^2(3) = 7.678$, $p = 0.053$).

3.6.4 Arboreal insectivores

The species richness of arboreal insectivores did not differ between sites (Kruskal-wallis, $X^2(3) = 1.025$, $p = 0.795$) and neither did the abundance (Kruskal-wallis, $X^2(3) = 2.068$, $p = 0.558$).

3.6.5 Arboreal insectivores/carnivores

Only 2 species (*Phaenicophaeus curvirostris* and *Corvus enca*) and 5 individuals belonging to the guilds arboreal insectivores/carnivores were found throughout the research (Table 8 and Appendix Table A1). These numbers were too low to allow a proper statistical analysis.

Table 8. Total arboreal insectivorous/carnivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	0	0
L2003	1	2
L2007	0	0
L2011	1	3
Total	2	5

3.6.6 Arboreal nectarivores

Overall, 4 species and 31 individuals belonging to arboreal nectarivores were found (Table 9 and Appendix Table A1). These numbers were too low to allow for a proper statistical analysis.

Table 9. Total arboreal nectarivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	3	9
L2003	2	8
L2007	3	8
L2011	2	6
Total	4	31

3.6.7 Understorey frugivores /insectivores

There was no significant effect of site on frugivorous/insectivorous species richness (Kruskal-wallis, $X^2(3) = 1.927$, $p = 0.588$). Abundance did not differ significantly between sites either (Kruskal-wallis, $X^2(3) = 7.121$, $p = 0.068$).

3.6.8 Understorey insectivores

Understorey insectivorous species richness did not differ significantly between sites (Kruskal-wallis, $\chi^2(3) = 1.388$, $p = 0.708$) and neither did abundance (Kruskal-wallis, $\chi^2(3) = 2.011$, $p = 0.570$).

3.6.9 Understorey nectarivores

Only 7 species of understorey nectarivores were found throughout the research (Appendix Table A1). This number was too low for a proper statistical analysis. Site had no effect on abundance (Kruskal-wallis, $\chi^2(3) = 4.427$, $p = 0.219$).

3.6.10 Terrestrial frugivores/insectivores

Only 2 species and 4 individuals of terrestrial frugivores/insectivores were found (Table 10 and Appendix Table A1). These numbers did not allow for a proper statistical analysis to be made. Great Argus which is one of the two terrestrial frugivores/insectivores found was only encountered once during my research and that was in L2011 (Appendix table A1).

Table 10. Total terrestrial frugivorous/insectivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	0	0
L2003	0	0
L2007	1	2
L2011	2	2
Total	2	4

3.6.11 Terrestrial insectivores

Only 7 species of terrestrial insectivores were found (Appendix Table A1). This number was too low to allow for a proper statistical analysis to be made. Abundance of terrestrial insectivores did however allow for a statistical analysis and differed significantly between sites (Kruskal-wallis, $\chi^2(3) = 13.276$, $p = 0.004$) (Figure 6). Primary had a higher abundance than L2011 ($p = 0.044$). The difference between Primary and L2003 was close to significant ($p = 0.064$).

Typical terrestrial insectivores such as Black-capped babbler was only encountered once in each site except for L2003 where it was encountered twice. Garnet Pitta was encountered most times in the primary site (Table 11).

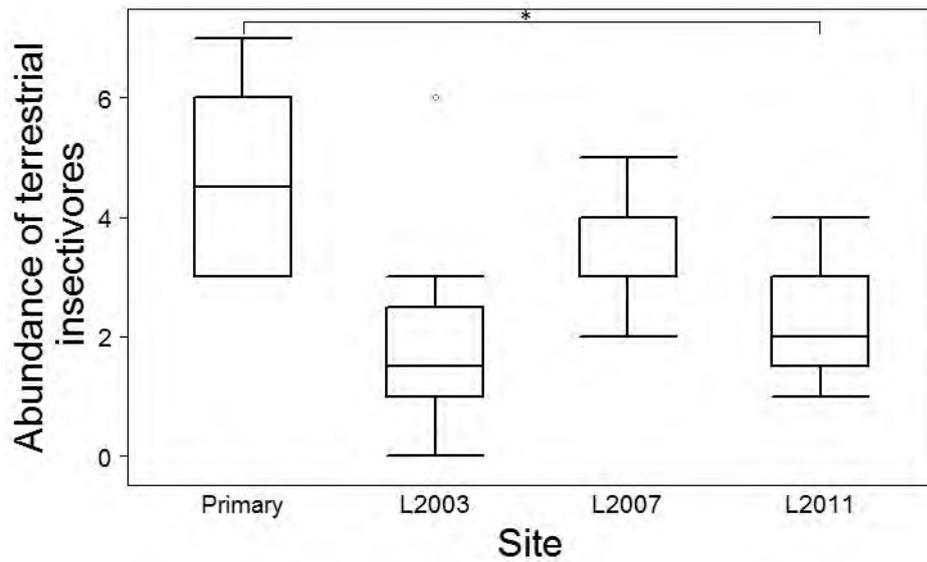


Figure 6. Abundance of terrestrial insectivores in each site. The asterisk indicates significant pairwise differences when a Wilcox test was performed.

Table 11. Abundance of Garnet Pitta encountered in each site.

Site	Total abundance
Primary	17
L2003	5
L2007	11
L2011	6
Total	39

3.6.12 Terrestrial insectivores/carnivores

Overall, 5 species and 15 individuals of terrestrial insectivores/carnivores were found (Table 12 and Appendix Table A1). These numbers did not allow a proper statistical analysis.

Table 12. Total terrestrial insectivorous/carnivorous species richness and abundance in each site and in total.

Site	Total species richness	Total abundance
Primary	3	6
L2003	2	3
L2007	2	2
L2011	3	4
Total	4	15

4. Discussion

Species richness, abundance, number of genera, number of families and Shannon diversity index did not differ significantly between sites. Bird community composition differed between the sites and this was also the case when species richness and abundance in some of the guilds were analysed. However, these significant differences were few. Further, some guilds did not have enough data to allow for statistical analyses to be done. One such example is the frugivores/carnivores which consist only of hornbills (Appendix Table A1).

Upon data collection, the primary site showed to be heavily disturbed by illegal logging (personal observation). The site was also located close to a small palm oil plantation and other logged sites. The degree of this disturbance is however not clear. Nevertheless, it means that conclusions drawn from comparing the FSC-logged sites with the primary site to investigate the impact on FSC-certified logging simply cannot be made. This also highlights the importance of having several replicates, which unfortunately was not possible in this study due to logistical problems. In order to truly measure the impact of FSC-certified logging several non-disturbed primary sites would have been needed as a control. In addition, several conventionally logged sites would have been preferable to add. That would have allowed for a proper study on the impact of FSC-certified logging in relation to conventionally logged forest and primary forest. However, some of the results can still be discussed in terms of recovery of the FSC-logged sites and speculations of the area as a whole can be done based on some of the data and personal observations.

4.1 Shannon diversity index and species uniqueness

Other studies have found a higher Shannon diversity index in primary and undisturbed sites compared to logged and disturbed sites (Posa, 2011; Slik and van Balen, 2006; Thiollay 1992). Slik and van Balen (2006) argues that such a pattern could be due to that disturbed areas provide less spatial variation than primary, undisturbed areas, which in turn do not allow for the same amount of different niches to be occupied by different bird species. I found no such pattern in my study and that would indicate that the FSC-certified logged sites do resemble that of a primary site in terms of bird diversity. However, considering that the primary site was disturbed by illegal logging it might also be an indication that the primary site is disturbed to such a degree that it resembles the disturbance of FSC-certified logged sites.

The highest uniqueness was found in the primary site. This has also shown to be the case in other studies (Danielsen and Heegaard, 1995). In that study the highest species richness was found in heavily logged forest sites, which, according to Lambert and Collar (2002), mask the important effect of uniqueness. They further argue that one reason for the higher species richness found in logged sites is a large number of so called trash species, which prefer secondary, disturbed and more open areas than primary forest species do. Even if the uniqueness was not analysed statistically in my study one might argue, based on species uniqueness, that the FSC-logged sites are more disturbed than the primary site.

4.2 Species richness, total abundance and number of genera and families

That overall species richness, total abundance and number of genera and families did not differ between the sites could be explained by the fact that all sites resemble each other in terms of level of disturbance. However, previous studies, which used proper primary sites as controls, have found similar results for species richness (Edwards et al., 2011; Lambert, 1992; Slik and Van Balen, 2006). The lack of such differences might be explained by nearby intact forest sites that serve as sources which allow for fast reinvasion after logging (Lambert and Collar, 2002). In the case of SFM through FSC-certified logging it is exactly what one wants to achieve through the logging regime where primary forest sites are kept within the logging concession, as well as that different sites are logged different years and in e.g. 30 year cycles. In addition, the intermediate disturbance hypothesis (IDH) (Connell, 1978) suggests that the highest species richness is found in areas where disturbance is neither too rare nor too frequent. This means that if the FSC-certified logged sites in this study are managed in a sustainable way the disturbance there could resemble some sort of intermediate disturbance also seen in the primary forest. But since the disturbance level of the primary site is unknown this might not be the case. Further, it is also important to bear in mind that species richness does not provide information on which species that are present/absent from the different sites and the abundance within those specific species.

4.3 Bird community composition

Bird community composition differed between all the sites. This is however not surprising considering the big data set consisting of 127 species. With large samples, small differences tend to generate significant p -values (Lin et al., 2013). Hence, it is also important to interpret the R^2 -value, which could be considered to be quite low in all instances where an *adonis* was performed in this study. I only used site as an explanatory variable in my analysis and it is likely that there are several other factors within each site that can explain my data. Further, the within site variation is quite high

(Figure 3), but it does not differ significantly between sites. In order to lower the variation more replicates might be preferable. In addition, one might expect the primary site to be most similar to the L2003 and least similar to L2011, but in fact the opposite can be seen. However, since all sites differ significantly from each other it could be considered to be a minor issue.

4.4 Diet guilds

Gray et al. (2007) found that abundance of frugivores decreases in logged areas. Findings resembling these were also reported by Felton et al. (2008). Gray et al. (2007) did not find an effect of site on frugivorous species richness, but they did highlight that such a difference was approaching significance. Lambert (1992), on the other hand reported an increase in abundance of frugivores, as well as nectarivores, in logged areas, while Gray et al. (2007) found a lower abundance of nectarivores in logged areas in Asia.

An increase in abundance of frugivores and nectarivores after logging could be linked to availability of nectar and fruit arising from a decrease in canopy cover (Mason, 1996; Wunderle et al., 2006). Costa and Magnusson (2003) show, for example, that species richness of flowering and fruiting plants, as well as abundance of flowering plants, increase shortly after logging. This then would be more in line with the pattern observed by Lambert (1992) and not in this study and by Gray et al. (2007). However, Costa and Magnusson (2003) also report that the intensity of logging affects neither the richness nor abundance of fruiting and flowering plants. Therefore, it has been argued that there are several factors in play that determines vegetation structure and hence also responses of frugivorous and nectarivorous species to logging (Gray et al., 2007).

I found a higher nectarivore species richness in L2007 than in L2011. L2011 is more recently logged than L2007 and hence L2007 might have had some time to recover and gain more nectarivorous species again. If this was the case, one would assume a similar difference to be found when L2003 and Primary was compared to L2011. But, no such difference is found and hence that conclusion cannot be drawn. Further, frugivorous species richness also differed between sites, but no difference was found when a pairwise comparison was done. L2003 did however come close to differing from L2007, but more data would be needed before any conclusions can be drawn from this. Altogether it seems like the sites do not differ that much from one another in terms of abundance and richness of these guilds. This is not in line with previous findings and the reason for that might be linked to the illegal logging in the primary forest as well as the many factors that play a role in the response of these guilds to logging.

Insectivorous bird species have been reported to be sensitive to logging (Canaday, 1996; Kattan et al., 1994; Renjifo, 1999). In my study I found no differences in species richness or abundance between different sites. This would indicate that the more recently FSC-certified logged site(s) already had recovered to resemble those that were logged longer ago. I cannot state that the FSC-certified logged sites resemble the primary forest since the primary site suffers from illegal logging. Based on the personal observation that the primary site was illegally logged one could however argue that the primary site resembles the FSC-logged sites, but based on the data no such conclusion can be made since the level of disturbance of the primary site is not known. Moreover, Cleary et al. (2007) state that solely relying on data of insectivorous species may not be a good idea when investigating impact of disturbance.

Some guilds, such as the frugivorous/carnivorous, could not be analysed statistically due to the low number of species and individuals observed. The frugivorous/carnivorous species consisted only of hornbills, which previously have been reported to be negatively affected by logging (Cleary et al., 2007). However, many hornbills are able to persist in selectively logged forest (Johns, 1987), which likely is due to the fact that they are highly mobile. Moreover, the major factor influencing breeding in hornbills is food supply (Johns, 1981) and during selective logging, cavity-bearing trees, which hornbills nest in, may only be damaged but not actively logged and removed due to their low timber value. Hence, the argument that hornbills lose breeding sites due to logging may not be valid (Johns, 1987). However, local people might illegally log and set fire to forests in order to clear land for plantations and this most likely influence the number of cavity bearing trees and hence also breeding possibilities for hornbills (personal observations, Appendix Figure A1). One might speculate on whether the number of hornbills found across all sites in this study was low and if this somehow could be related to the results obtained by Cleary et al. (2007). Is the whole research area disturbed? In order to answer that question a comparison of the area before and after FSC-certified logging took place would be needed.

4.4 Feeding layer guilds

4.4.1 Arboreal guilds

Danielsen and Heegaard (1995) found that heavily logged forest contained more arboreal frugivores than lightly logged and primary forest. I only found an effect of site on arboreal frugivorous species richness, but the pairwise comparison revealed no significant differences between sites. However,

L2003 was close to having a significantly higher species richness than L2007, but more data would be needed to investigate the significance of that possible difference. This is also the case for the abundance of arboreal frugivores, which also was close to differ significantly between sites. Zurita and Zuleta (2009) found the opposite result to that of Danielsen and Heegaard (1995). They found that arboreal frugivores were rare in more recently logged forest gaps compared to older logged forest gaps. The reason for such a pattern is believed to be linked to a scarcity in tree generation in more recently logged gaps. Further, they argue that the rarity of arboreal frugivores in more recently logged gaps will contribute to an even slower regeneration of trees since they disperse most of the seeds in tropical and subtropical areas. In my study, L2003 was logged longer ago than L2007 and they were close to differ significantly from one another in terms of species richness. Therefore, my results might be an indication of a pattern pointing towards the same findings reported by Zurita and Zuleta (2009). But, since the difference between L2003 and L2007 is non-significant and no other differences were found such a conclusion cannot be made and more data is needed to investigate this further.

Zurita and Zuleta (2009) also report that establishment of arboreal species in general in logging gaps was very slow, and they argue that this could be due to a high grass vegetation cover. In many of my arboreal guilds I do not have enough data to perform proper statistical analyses. One could therefore speculate that the whole research area consists of such logging gaps comparable to those described by Zurita and Zuleta (2009) and hence giving rise to the low overall number of species and individuals in the different arboreal guilds. However, data before and after FSC-certified logging took place is needed in order to draw any conclusions regarding this. In addition, it should be highlighted that caution in comparisons should be taken since my study was carried out in Southeast Asia whereas the study of Zurita and Zuleta (2009) was carried out in South America.

4.4.1 Understorey guilds

Understorey insectivores have been found to be negatively affected by logging (Johns A.D., 1986, 1989, Johns A.G, 1997; Lambert, 1992; Meijaard 2005; Thiollay, 1992). Based on studies like these it has been argued that the use of understorey insectivores are one of the best indicators to use when monitoring impact of disturbance such as logging (de longh and van Weerd, 2008). However, it has also been shown that understorey insectivores actually use many resources in gaps created by logging, since logging causes rapid colonization of short herbs which are consumed by arthropods which in turn are consumed by the understorey insectivorous birds (Cleary et al., 2007; Fredericksen et al., 1999). The negative effect on understorey insectivores is most likely linked to an increased predation and nest parasitism rather than changes in arthropod abundances (Burke et al., 2004).

In my study I did not have enough data to perform a proper statistical analysis for the understory nectarivore species richness. As for all the other understory analyses, no significant differences were found. The lack of such differences indicates that all the sites resemble each other. But due to the unknown level of disturbance of the primary site one cannot conclude that the logged sites resemble that of a primary forest or vice versa.

4.4.1 Terrestrial guilds

All terrestrial feeding layer guilds except one had insufficient data. I only found that the primary site had a significantly higher abundance of terrestrial insectivores than L2011. This could partly be interpreted to be in line with what have been reported earlier; that terrestrial insectivores, just as understory insectivores, are vulnerable to logging (Cleary et al., 2007; Johns A.D., 1986, 1989; Johns A.G, 1997; Lambert, 1992; Meijaard 2005; Thiollay, 1992). However, no difference between the primary site and L2007 was found. This was also the case for primary and L2003 even though that difference was close to being significant. A reason for the vulnerability of terrestrial guilds in general is argued to be that understory and forest-floor microclimates are lost, which are important as e.g. a food resources for the species within these guilds. Terrestrial guilds, as well as understory guilds, may also be physiologically intolerant to changes in heat, cold or rain levels rising from changes in vegetation structure due to logging (Lambert and Collar, 2002; Thiollay, 1997). This may contribute to poor dispersing abilities across open area gaps. Johns (1989) found a complete absence of terrestrial bird species in forest that were logged 12 years ago. In recently logged forest, terrestrial insectivores, such as Great Argus and Black-capped babbler, have been found to be absent while another terrestrial insectivore, the Garnet pitta, was present but rare (Cleary et al. 2007). The Great Argus has previously been reported to be more common in primary forests than secondary forests (Nijman, 1998). I only encountered the Great Argus once during my research and that was in L2011 (Appendix table A1). Further, I only encountered the Black-capped babbler once in each site except for L2003 where it was encountered twice. The Garnet pitta, however, was encountered more times and most of the times in the primary forest. Taking these numbers into consideration together with the low species richness and low abundances of birds in terrestrial guilds one might once again speculate around whether the whole research area is disturbed to such a degree that it has lowered the presence of terrestrial birds. But data before the FSC-certified logging took place is needed in order to make a comparison and analyse this.

5. Conclusion

Few significant differences were found between the sites. However, sites did differ in bird community composition. Whether or not FSC-certified logging has an impact on bird communities cannot be concluded due to a lack of replicates of primary sites and especially since the one replicate I had was disturbed by illegal logging. For some of the guilds a lack of data did not allow for any proper statistical analyses to be made. In order to argue that this lack of data is because the whole area is degraded, data from before the logging took place would have been needed. Future studies should include several non-disturbed primary forest sites, as well as conventionally logged sites in order to truly investigate the impact of FSC-certified logging on bird communities. Further, it might also be of interest to investigate how further precautions can be taken to stop secondary impacts such as illegal logging, which counteracts what FSC-certified logging want to achieve.

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Appendix

Table A1. List of all species encountered during the research including the guilds they belong to and total abundance in each site. (**Diet guilds:** F = Frugivore, FC = Frugivore/Carnivore, FI = Frugivore/Insectivore, I = Insectivore, IC = Insectivore/Carnivore, N = Nectarivore; **Feeding layer guilds:** AF = Arboreal Frugivore, AFC = Arboreal Frugivore/Carnivore, AFI = Arboreal Frugivore/Insectivore, AI = Arboreal Insectivore, AIC = Arboreal Insectivore/Carnivore, AN = Arboreal Nectarivore, UFI = Understorey Frugivore/Insectivore, UI = Understorey Insectivore, UN = Understorey Nectarivore, TFI = Terrestrial Frugivore/Insectivore, TI = Terrestrial Insectivore, TIC = Terrestrial Insectivore/Carnivore).

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
<i>Aegithinidae</i>							
Green lora	<i>Aegithina viridissima</i>	I	AI	0	1	0	0
<i>Alcedinidae</i>							
Banded kingfisher	<i>Lacedo pulchella</i>	IC	TIC	0	0	1	2
Blue-eared kingfisher	<i>Alcedo meninting</i>	IC	TIC	0	0	1	1
Chestnut-collared kingfisher	<i>Actenoides concretus</i>	IC	TIC	1	1	0	0
Rufous-backed kingfisher	<i>Ceyx rufidorsa rufidorsa</i>	I	UI	1	1	2	2
<i>Bucerotidae</i>							
Asian black hornbill	<i>Anthracoceros malayanus</i>	FC	AFC	4	5	3	1
Bushy-crested hornbill	<i>Anorrhinus galeritus</i>	FC	AFC	0	2	0	0
Helmeted Hornbill	<i>Buceros vigil</i>	FC	AFC	6	0	0	0
Rhinoceros hornbill	<i>Buceros rhinoceros</i>	FC	AFC	3	7	4	4

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
Wreathed hornbill	<i>Rhyticeros undulatus</i>	FC	AFC	0	0	0	1
Wrinkled hornbill	<i>Aceros corrugatus</i>	FC	AFC	1	0	3	0
Campephagidae							
Lesser cuckoo-shrike	<i>Coracina fimbriata</i>	FI	AFI	3	10	0	8
Scarlet minivet	<i>Pericrocotus flammeus</i>	I	AI	0	2	0	0
Cettiidae							
Yellow-bellied warbler	<i>Abroscopus superciliaris</i>	I	UI	0	4	0	2
Chloropseidae							
Greater green leafbird	<i>Chloropsis sonnerati</i>	F	AF	0	7	0	2
Lesser green leafbird	<i>Chloropsis cyanopogon</i>	F	AF	2	0	0	0
Cisticolidae							
Dark-necked tailorbird	<i>Orthotomus atrogularis</i>	I	UI	0	4	3	3
Red-headed tailorbird	<i>Orthotomus ruficeps</i>	I	UI	3	4	6	4
Rufous-tailed tailorbird	<i>Orthotomus sericeus</i>	I	UI	0	4	3	3
Columbidae							
Large green pigeon	<i>Treron cappellei</i>	F	AF	0	0	0	1

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
Little green pigeon	<i>Treron olax</i>	F	AF	9	7	1	0
Thick-billed green pigeon	<i>Treron curvirostris</i>	F	AF	6	5	1	3
Corvidae							
Bornean black magpie	<i>Platysmurus atterimus</i>	I	AI	2	2	6	9
Crested jay	<i>Platylophus galeritus</i>	I	UI	4	1	1	1
Slender-billed crow	<i>Corvus enca</i>	IC	AIC	0	0	0	3
Cuculidae							
Banded bay cuckoo	<i>Cacomantis sonneratii</i>	I	UI	7	4	0	2
Chestnut-breasted malkoha	<i>Phaenicophaeus curvirostris</i>	IC	AIC	0	2	0	0
Greater Coucal	<i>Centropus sinensis</i>	IC	TIC	4	2	0	1
Indian cuckoo	<i>Cuculus micropterus</i>	I	AI	9	11	7	3
Little bronze cuckoo	<i>Chrysococcyx minutillus</i>	I	AI	0	1	0	0
Moustached Hawk-cuckoo	<i>Hierococcyx vagans</i>	I	UI	1	0	0	0
Plaintive cuckoo	<i>Cacomantis merulinus</i>	I	AI	0	2	4	2
Raffles's malkoha	<i>Phaenicophaeus chlorophaeus</i>	I	AI	0	2	0	2
Short-toed coucal	<i>Centropus rectunguis</i>	IC	TIC	1	0	0	0
Square-tailed drongo-cuckoo	<i>Curniculus lugubris</i>	I	AI	1	2	0	5
Violet cuckoo	<i>Chrysococcyx xanthorhynchus</i>	I	UI	1	3	0	0

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
<i>Culicicapa</i>							
Grey-headed canary flycatcher	<i>Culicicapa ceylonensis</i>	I	UI	0	0	1	0
<i>Dicaeidae</i>							
Orange-bellied flowerpecker	<i>Dicaeum trigonostigma</i>	N	UN	4	11	2	0
Scarlet-breasted flowerpecker	<i>Prionochilus thoracicus</i>	FI	UFI	1	0	0	0
Yellow-breasted flowerpecker	<i>Prionochilus maculatus</i>	N	UN	3	1	4	3
Yellow-rumped flowerpecker	<i>Prionochilus xanthopygius</i>	N	UN	2	4	2	0
<i>Dicruridae</i>							
Bronzed drongo	<i>Dicrurus aeneus</i>	I	AI	17	2	7	7
Greater racquet-tailed drongo	<i>Dicrurus paradiseus</i>	I	AI	7	5	11	20
<i>Estrildidae</i>							
Dusky munia	<i>Lonchura fuscans</i>	FI	TFI	0	0	2	1
<i>Eurylaimidae</i>							
Banded broadbill	<i>Eurylaimus javanicus</i>	I	AI	0	2	0	3
Black-and-yellow Broadbill	<i>Eurylaimus ochromalus</i>	I	AI	24	22	18	27
Green broadbill	<i>Calyptomena viridis</i>	F	AF	5	10	11	3

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
<i>Irenidae</i>							
Asian fairy-bluebird	<i>Irena puella</i>	F	AF	18	9	1	9
<i>Meropidae</i>							
Red-bearded bee-eater	<i>Nyctornis amictus</i>	I	AI	1	0	0	0
<i>Monarchidae</i>							
Asian-paradise flycatcher	<i>Terpsiphone paradisi</i>	I	UI	11	8	3	2
Black-naped monarch	<i>Hypothymis azurea</i>	I	UI	5	11	8	7
<i>Muscicapidae</i>							
Grey-chested jungle flycatcher	<i>Rhinomyias umbratilis</i>	I	UI	0	1	2	8
Malaysian blue flycatcher	<i>Cyornis turcosus</i>	I	UI	1	0	0	0
Pale blue flycatcher	<i>Cyornis unicolor</i>	I	AI	0	1	0	0
Rufous-tailed shama	<i>Trichixos pyrropygus</i>	I	UI	17	14	3	5
White-crowned forktail	<i>Enicurus leschenaulti</i>	I	UI	1	2	0	2
White-rumped shama	<i>Copsychus malabaricus</i>	I	UI	1	1	0	6
<i>Nectariniidae</i>							
Eastern crimson sunbird	<i>Nectarinia jugularis</i>	N	UN	0	0	1	1
Grey-breasted spiderhunter	<i>Arachnothera modesta</i>	N	UN	1	0	1	0

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
Little spiderhunter	<i>Arachnothera longirostra</i>	N	UN	30	23	16	10
Long-billed spiderhunter	<i>Arachnothera robusta</i>	N	AN	1	0	0	0
Plain Sunbird	<i>Anthreptes simplex</i>	I	UI	0	0	2	0
Purple-naped sunbird	<i>Hypogramma hypogrammicum</i>	N	UN	8	5	9	5
Ruby-cheeked sunbird	<i>Chalcoparia singalensis</i>	I	AI	0	0	1	1
Spectacled spiderhunter	<i>Arachnothera flavigaster</i>	N	AN	4	0	1	1
Yellow-eared spiderhunter	<i>Arachnothera chrysogenys</i>	N	AN	0	0	1	0
<i>Orilidae</i>							
Dark-throated oriole	<i>Oriolus xanthonotus</i>	FI	AFI	0	1	0	0
<i>Pellorneidae</i>							
Black-capped babbler	<i>Pellorneum capistratum</i>	I	TI	1	2	1	1
Bornean wren-babbler	<i>Ptilocichla leucogrammica</i>	I	TI	1	0	1	1
Ferruginous babbler	<i>Trichastoma bicolor</i>	I	UI	1	0	2	5
Horsfield's babbler	<i>Trichastoma separium</i>	I	UI	4	1	0	0
Short-tailed babbler	<i>Trichastoma malaccense</i>	I	TI	9	9	16	8
<i>Phasianidae</i>							
Great argus	<i>Argusianus argus</i>	FI	TFI	0	0	0	1

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
<i>Picidae</i>							
Banded woodpecker	<i>Picus miniaceus</i>	I	AI	1	0	0	0
Buff-necked woodpecker	<i>Meiglyptes tukki</i>	I	UI	1	0	0	0
Buff-rumped woodpecker	<i>Meiglyptes tristis</i>	I	AI	1	1	1	0
Crimson-winged woodpecker	<i>Picus puniceus</i>	I	AI	0	0	1	0
Great slaty woodpecker	<i>Mulleripicus pulverulentus</i>	I	AI	0	3	1	0
Maroon woodpecker	<i>Blythipicus rubiginosus</i>	I	UI	0	0	0	4
Olive-backed woodpecker	<i>Dinopium rafflesii</i>	I	UI	0	1	0	1
Rufous woodpecker	<i>Celeus brachyurus</i>	I	UI	2	5	2	0
White-bellied woodpecker	<i>Dryocopus javensis</i>	I	AI	0	2	1	0
<i>Pittidae</i>							
Blue-headed pitta	<i>Pitta baudi</i>	I	TI	8	0	0	1
Garnet pitta	<i>Pitta granatina</i>	I	TI	17	5	11	6
Hooded pitta	<i>Pitta sordida muelleri</i>	I	TI	1	0	0	0
<i>Prinopidae</i>							
Large wood shrike	<i>Tephrodoris gularis</i>	I	AI	2	1	1	0
Rufous-winged philentoma	<i>Philentoma pyrrhopterum</i>	I	UI	0	3	0	0

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
<i>Psittacidae</i>							
Blue-crowned hanging parrot	<i>Loriculus galgulus</i>	N	AN	4	8	6	5
<i>Psittaculidae</i>							
Long-tailed parakeet	<i>Psittacula longicauda</i>	F	AF	0	1	0	0
<i>Pycnonotidae</i>							
Black-headed bulbul	<i>Pycnonotus atriceps atriceps</i>	FI	AFI	14	6	8	3
Buff-vented bulbul	<i>Iole olivacea</i>	FI	UFI	8	3	6	2
Cream-vented bulbul	<i>Pycnonotus simplex</i>	FI	AFI	16	9	17	9
Grey-bellied bulbul	<i>Pycnonotus cyaniventris</i>	FI	UFI	2	1	1	0
Grey-cheeked bulbul	<i>Criniger bres</i>	FI	UFI	3	5	0	2
Hairy-backed bulbul	<i>Tricholestes criniger</i>	FI	UFI	24	10	5	4
Olive-winged bulbul	<i>Pycnonotus plumosus</i>	FI	UFI	2	0	0	0
Puff-backed bulbul	<i>Pycnonotus eutilotus</i>	FI	UFI	0	0	0	2
Red-eyed bulbul	<i>Pycnonotus brunneus</i>	FI	UFI	42	37	26	41
Spectacled bulbul	<i>Pycnonotus erythrophthalmos</i>	FI	UFI	0	0	0	2
Straw-headed bulbul	<i>Pycnonotus zeylanicus</i>	FI	UFI	1	0	0	0
Streaked bulbul	<i>Ixos malaccensis</i>	FI	AFI	3	0	8	5
Yellow-bellied bulbul	<i>Criniger phaeocephalus</i>	I	UI	5	8	1	3
Yellow-vented bulbul	<i>Pycnonotus goavier</i>	FI	UFI	1	2	1	0

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
Ramphastidae							
Blue-eared barbet	<i>Megalaima australis</i>	F	AF	9	16	11	12
Golden-whiskered barbet	<i>Megalaima chrysopogon</i>	FI	AFI	8	0	3	16
Red-crowned barbet	<i>Megalaima rafflesii</i>	F	AF	4	13	6	0
Red-throated barbet	<i>Megalaima mystacophanos</i>	FI	AFI	24	1	0	2
Yellow-crowned barbet	<i>Megalaima henricii</i>	F	AF	7	3	9	11
Rhipiduridae							
Pied fantail	<i>Rhipidura javanica</i>	I	UI	0	1	1	0
Spotted Fantail	<i>Rhipidura perlata</i>	I	AI	0	0	1	2
Sittidae							
Velvet-fronted nuthatch	<i>Sitta frontalis</i>	I	AI	0	1	0	0
Sturnidae							
Hill Myna	<i>Gracula religiosa</i>	FI	AFI	4	20	15	6
Timaliidae							
Black-throated babbler	<i>Stachyris nigricollis</i>	I	UI	7	0	2	6
Bold-striped tit-babbler	<i>Macronous bornensis bornensis</i>	I	UI	2	2	2	5
Brown fulvetta	<i>Alcippe brunneicauda</i>	FI	UFI	2	9	3	14

Table A1, continued

Species	Scientific name	Diet guild	Feeding layer guild	Site			
				Primary	L2003	L2007	L2011
Chestnut-backed scimitar-babbler	<i>Pomatorhinus mantanus</i>	I	AI	1	1	0	0
Chestnut-rumped babbler	<i>Stachyris maculata</i>	I	UI	17	13	14	20
Chestnut-winged babbler	<i>Stachyris erythroptera</i>	I	UI	20	15	13	24
Fluffy-backed tit-babbler	<i>Macronous ptilosus</i>	I	UI	0	1	3	8
Rufous-crowned babbler	<i>Malacopteron magnum</i>	I	UI	12	6	20	22
Scaly-crowned babbler	<i>Malacopteron cinereum</i>	I	UI	3	10	5	1
Sooty-capped babbler	<i>Malacopteron affine</i>	I	UI	0	0	0	4
White-chested babbler	<i>Trichastoma rostratum</i>	I	TI	0	0	0	1
Trogonidae							
Cinnamon-rumped trogon	<i>Harpactes orrophaeus</i>	I	AI	0	0	1	0
Diard's trogon	<i>Harpactes diardii</i>	I	AI	1	1	0	2
Red-naped trogon	<i>Harpactes kasumba</i>	I	AI	1	2	1	0
Scarlet-rumped trogon	<i>Harpactes duvaucelii</i>	I	UI	6	0	1	3



Figure A1. A cavity-bearing tree illegally logged near the primary forest site in order to give room for a plantation.