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Assessing the potential for avifauna recovery in degraded forests in Indonesia

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Abstract. Continuing disappearance and degradation of primary tropical rainforests in Indonesia, and the ongoing conversion of degraded forest to monoculture plantations, threaten many bird species with local extinction. Yet, information on bird populations from the Sundaic region, which covers western Indonesia, is generally lacking, limiting our understanding of species responses to disturbance, extinction risks, and potential ways to counteract local species extinction processes. On the Indonesian island of Sumatra, bird density information is only known from two studies (on four hornbill species and one pheasant species). Here, we compare bird densities between less degraded and highly degraded forests within the Harapan Rainforest Ecosystem Restoration Concession in Sumatra. From a total of 148 bird species recorded, densities were calculated for 47 species with the highest encounter rate, 33 of which were recorded in forests of both disturbance levels, allowing comparisons to be made. We found five species with higher densities in the highly degraded forest and seven species with higher densities in the less degraded forest. While our species-specific results were generally consistent with previous biological insights, there were exceptions, such as a species previously considered to be sensitive to habitat degradation, the sooty-capped babbler *Malacopteron affine*, being more abundant in the highly degraded forest. Our study revealed that despite its condition, degraded forest retains much value for Sumatran lowland forest birds, providing a compelling argument for securing its important conservation status under improved management, rather than assigning it for clearance as typically happens.

Key words. deforestation, distance sampling, forest restoration, avian diversity, logging

INTRODUCTION

Sumatra is part of the Sundaland biodiversity hotspot (Sumatra, Peninsular Malaysia, Java, and Borneo), which has an exceptionally rich fauna including numerous endemic birds, mammals, reptiles and amphibians (Myers et al., 2000; Sodhi et al., 2004). From the 228 lowland bird specialists in Sumatra (species occurring below 200 m above sea level), eight are considered threatened and 57 (25%) are near threatened species (Wells, 1985; BirdLife International, 2015). The situation might actually be worse as undisturbed lowland forest (unlogged forest area below 200 m above sea level) has become rare in the Sundaic region (Lambert & Collar, 2002), particularly in Sumatra (Margono et al., 2012; Wilcove et al., 2013). A recent study reveals that 70% (75,400 km^2) of Sumatra's forest area was cleared from 1990 to 2010, with an additional 23,100 km^2 of primary forest being in a degraded condition mainly due to logging (Margono et al., 2012). Over those two decades, primary forest cover loss and forest degradation slowed from 7,340 km^2/year (1990 to 2000) to 2,510 km^2/year (2000 to 2010), partly owing to a greatly diminished resource base, particularly of lowland primary forest (Margono et al., 2012). It is therefore likely that many bird species considered near threatened will become threatened in the near future due to habitat loss.

A change in conservation status of many lowland bird species seems necessary as most lowland areas are outside the existing protected area network. In their evaluation of protected area networks in Sumatra, Gaveau et al. (2009) showed that allocation of forests for protected areas is skewed towards highlands, while lowland areas have been mostly left unprotected. This imbalance would also mean that, despite their poor condition, degraded forests (i.e., selectively logged primary forests) may be worth protecting because they retain a high and unique biodiversity value (e.g., Sodhi et al., 2005; Sekercioglu et al., 2007; Edwards et al., 2010). Preventing agricultural and agroforestry conversion of logged forests is an essential part of conserving biodiversity in the Sundaland hotspot (Wilcove et al., 2013).

Examining differences in animal communities across different habitat types is an important approach to improve conservation management (Peh et al., 2006; Styring et al., 2011), as it allows for assessing the relative importance of different habitat types for particular species or species groups (e.g., Barlow et al., 2007; Edwards et al., 2011) as well as

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species susceptibility to disturbance (e.g., Marsden, 1998; Waltert et al., 2004; Mallari et al., 2011). This approach is particularly important in areas with high loss and alteration of forests through logging and agriculture (Hansen et al., 2013).

Many Asian studies on tropical forest dependent birds have been conducted to examine the relative impacts of logging, e.g., on Seram Island (Marsden, 1998) and Kalimantan (Cleary et al., 2005), but little quantitative information (i.e., density estimates) is available for tropical forest birds in Sumatra's degraded forests and, more widely, for primary forest birds across the Sundaic region. For Sumatra, the few bird density estimates that are available came from primary forest: four hornbill species (Anggraini et al., 2000) and one species of pheasant (Winarni et al., 2009). In this study, we therefore aimed to extend previous work that has compared avifauna abundance between degraded and intact forest, by investigating the effect of the degree of degradation: comparing bird species density between the less degraded and the highly degraded forest types.

MATERIAL & METHODS

Study areas. The Harapan Rainforest Concession (HRF, 984.5 km^2) is the first Ecosystem Restoration Concession in Indonesia (103°22′39″E, 2°8′79″S; Harrison & Swinfield, 2015). It covers two large selectively logged primary forest estates that are located in Jambi (491.8 km^2) and South Sumatra (492.7 km^2) provinces. The concession's overall aim is to conserve and restore the forest to its former primary condition for biodiversity and ecosystem services. The HRF is a lowland site ranging from 30–120 m above sea level.

Bird surveys were conducted in the Jambi Province section. The study site is an ex-logging concession for which logging operation started in 1970. Forest management and harvesting operations used Tebang Pilih Tanam Indonesia (TPTI), a selective logging system (Armitage & Kuswanda, 1989; Sist et al., 1998) in which commercial trees with a diameter of >50 cm are allowed to be removed under a felling cycle of 35 years. Previous logging activities have left a mosaic of degraded forest habitat in different stages of regeneration (Harrison & Swinfield, 2015), which is typical in formerly logged forest in Indonesia (Putz et al., 2001). Unfortunately, information on logging intensity was not available for the study site (Harrison & Swinfield, 2015). However, based on logging schedule maps for the concession, it is assumed that the highly degraded forest is a forest area that had been logged twice (two rotations) with the first rotation in 1972 and the second rotation in 2007. The less degraded forests had only been logged once in 1992. Between 2004 and 2009 there was no active management in this area (Harrison & Swinfield, 2015).

The less degraded forest had a well-stratified structure from seedlings to trees, relatively high canopy cover (71–100%), and average tree diameter at >20 cm. The highly degraded forest was dominated by shrub layer plants, a relatively low canopy cover (<40%), with an estimated average tree diameter at <20 cm. We used 11 transects of 2 km length with 11 data collection points per transect. These transects were allocated to cover, as much as practicable, the two main degraded forest types: five transects in the less degraded forest and six transects in the highly degraded forest.

Avian sampling. Bird point-transect surveys were conducted from April to June 2011, which was during the breeding season of most birds in Sumatra (van Marle & Voous, 1988). Point count surveys are a preferred sampling method for multi-species surveys in tropical forests (Bibby et al., 1992; Lee & Marsden, 2008). Each point was spaced 200 m apart (11 points per transect) to maintain independent bird detections at consecutive points (Reynolds et al., 1980; Hutto et al., 1986), with 55 survey points in the less degraded forest and 66 points in the highly degraded forest. Surveys were conducted in the morning from 0630 to 1000 hours to coincide with the peak period of bird activity (Lee & Marsden, 2008). To reduce observer bias, all bird surveys were conducted by the same team of observers. At each point, the survey was initiated immediately after the observer arrived, without a settling down period, and any birds detected moving away from around the survey point on the observer's arrival were counted as being present during the sampling period (Lee & Marsden, 2008). During 10 minutes after arrival, all perched birds, whether single or in groups, were recorded along with the number of individuals in the group. Horizontal distance from the survey point to the bird's initial position was estimated using a digital Nikon laser rangefinder. We also recorded all birds that were heard but not seen to produce as many bird data observations per transect as possible. We first determined the location of the call and then measured the horizontal distance to that location using a digital rangefinder. We also recorded all bird calls using an Olympus VN-8100PC Digital Voice Recorder with Audio Technica ATR-55 Condenser Shotgun Microphone. Sound recordings were then identified either by comparing with known bird recordings (e.g., from http://www.xeno.canto.org) or in consultation with other bird experts. Each transect was surveyed three times during periods of no rain and no strong winds, if possible on three consecutive days, otherwise on the next possible day. We also rotated the daily order in which transects were visited.

Habitat sampling. Habitat data were collected within a 25 m radius at each of the 121 sampling points. The following physical variables were sampled: (1) altitude using a Garmin GPSMAP® 60CSx; (2) degree of slope using a Suunto Tandem Compass/Clinometer; and (3) distance to water body (m). For 10 trees nearest the center point with diameter at breast height (DBH) >20 cm, we measured the DBH (cm), and tree height (m), also we counted all dead standing trees >20 cm DBH. For 10 trees nearest the center point and >20 cm DBH, we identified the tree to genus level as *Macaranga* spp. or other. *Macaranga* spp. are easily identified in the field and are common pioneer species in degraded forests with higher proportions in highly degraded forests (Harrison & Swinfield, 2015). We estimated the proportion of leaf litter cover in four 1 m^2 quadrats positioned randomly in each quarter of the sample area and averaged over the samples. Canopy openness was estimated in each quarter of the sample using an array of 25 dots at 5 cm intervals marked on a transparent Perspex sheet (30 × 30 cm, Brown et al., 2000) and estimating the percentage of dots that overlay open sky in each quarter and then taking the average value of the samples. Understory openness was estimated in each quarter of the sample by holding a 1 × 1 m plastic sheet with 64 black dots at 10 cm intervals at 1.5 m height perpendicular to the ground, at 5 m distance from observer at the center of the plot and counting the number of visible dots, converted to percentage and averaged over the samples. To estimate density of saplings, lianas, palms, ginger, rattan and bamboo, an observer held a 1 m stick at 1 m parallel to the ground and turned slowly on the spot while counting the number of stems <5 cm DBH that the stick touched.

Data analysis. We calculated the estimated species pool for each degraded forest type using four common abundance-based species richness estimators (Chao1, Jack1, Jack2, and Bootstrap; Edwards et al., 2009). We then used the average of the four estimates as the 'true' species richness in each forest type (Posa & Sodhi, 2006). All species richness estimates were calculated using the "specpool" function in the "vegan" R package (Rossi, 2013). To compare cumulative species richness between the less and the highly degraded forest we used the "c2cv" function with n=99 randomisations in the "rich" R package (Rossi, 2013). Using this function, species richness was computed cumulatively over all samples and compared using a randomisation test. Similarities in observed bird species composition among habitat types were quantified using Sørensen's similarity index (Magurran, 2004), a commonly used and effective similarity test (e.g., Southwood & Henderson, 2000). Species accumulation curves were produced using the "specaccum" function in the "vegan" R package (Oksanen et al., 2013). All computations were conducted in R version 2.8.1.

In the bird density analysis, a transect was taken as the sampling unit, and bird records from the three survey repetitions per transect were pooled. Hence the total survey effort for each transect was 33 (11 points per transect × three survey repetitions per point-transect). In bird surveys, audio detections may account for more than 80% of the total (Scott et al., 1981), and combining data across detection types may be necessary to achieve a sufficient sample size (Anderson et al., 2015). We combined aural and visual observations following (Kinnaird et al., 1996; Marsden, 1999; Gale & Thongaree, 2006; Gale et al., 2009). We used Distance v.6.0 (Thomas et al., 2010) to calculate bird densities for bird species that were recorded ≥10 times per forest type. We calculated densities for each habitat separately. All data were right-truncated at 50 m to remove any outlying records. This truncation approach aimed to improve model fit and reduce the likelihood of recording a bird outside the intended habitat type. We evaluated the uniform, half-normal, and hazard rate functions for each species using ungrouped data and compared these to analyses using grouped data. If grouping of distance data improved the precision of the estimate (Lee & Marsden, 2008), then we used the grouping, otherwise we used ungrouped data. For grouped distances, we examined the goodness of fit with Chi-square tests, while for un-grouped distances, we assessed the model fit using the Kolmogorov-Smirnov goodness-of-fit and Cramér-von Mises goodness-of-fit statistics (Buckland et al., 2001). We selected the final model using the lowest Akaike's Information Criterion (AIC) for a given set of models (Buckland et al., 2001). If two or more models had similar AIC values, we examined histograms of the data and combined them with goodness-of-fit tests to decide the preferred model (Buckland, 2006). Densities were presented as the number of birds per km^2 ± coefficient of variation (CV, i.e. the standard error of the density expressed as a percentage) and we compared densities between the two disturbance levels using Z-tests (Plumptre, 2000). To avoid the possibility of obtaining false-positive results (Type I errors) we applied a Bonferroni correction for multiple comparisons (Napierala, 2012). The bird taxonomy in this study follows that of BirdLife International (2015).

To evaluate potential habitat structure differences, we compared the 14 habitat variables between less degraded and highly degraded forest habitat using Student's t-test in R version 2.8.1 software (R Development Core Team, 2008), and applied a Bonferroni correction for multiple comparisons.

To visualise the dependency of the bird species on environmental variables (i.e., for all bird species that showed significant differences in density between disturbance levels regardless of whether they became non-significant after applying Bonferroni correction for multiple comparisons), we conducted indirect gradient analysis using non-metric multidimensional scaling (NMDS) on the count data site-species matrix. This type of ordination can be described as unconstrained, because it is based solely on the species data and is not constrained by environmental variables. NMDS is a computational-intensive iterative optimisation method that searches for the best positions of n entities (samples) on k dimensions (axes) that minimises the departure from monotonicity in the relationship between the original dissimilarity data of the n samples and the reduced k-dimensional ordination space of these samples (McCune & Grace, 2002). NMDS is commonly regarded as the most robust, unconstrained ordination method in community ecology (Minchin, 1987). We used NMDS to ordinate plots and species in species space, and conducted separate analysis for point-species matrix and transect-species matrix. The lowest-stress ordination was selected after repeating the NMDS routine, and used the following guidelines for acceptable stress values: <0.05=excellent, <0.10=good, <0.20=usable, >0.20=not acceptable (Clarke, 1993). We then superimposed computed vectors for the environmental variables onto the ordination diagrams using the "envfit" function in the "vegan" R package (1,000 permutations) to find significant correlations. The goodness of fit statistic is the squared correlation coefficient r^2 (Oksanen et al., 2013). All analyses except for the density and Z-test were conducted in R 2.8.1 (R Development Core Team, 2008).

Table 1. Results of t-test and descriptive statistics of habitat variables measured in less degraded and highly degraded forest in The Harapan Rainforest Concession. Bold underlined t values remain significant after applying a Bonferroni correction (P <0.003).

	Less Degraded Forest			Highly Degraded Forest			95% CI for Mean Difference	t	df
	Mean	SD	N	Mean	SD	N			
Geographic									
Altitude (m)	76.18	13.8	55	75.02	14.9	66	-4.02, 6.35	0.45	117.7
Slope (degree)	14.32	12.2	55	16.77	11.7	66	-6.78, 1.88	-1.1	113.2
Distance to water body (m)	2.05	5.48	55	2.56	5.48	66	-2.52, 1.51	-0.5	116.3
Tree related variables									
Tree density (trees/ha)	195.9	86.5	55	151	80	66	14.59, 75.07	2.94*	111.4
Mean tree height (m)	23.17	3.42	55	20.34	3.45	66	1.59, 4.08	**4.52*****	115.5
Number of *Macaranga* spp.	0.16	0.86	55	0.83	1.66	66	-1.13, -0.20	-2.85*	100.7
Canopy openness	4.15	2.76	55	5.26	4.74	66	-2.48, 0.27	-1.6	107.4
Number of dead standing trees	0.67	0.86	55	1.18	1.33	66	-0.91, -0.11	-2.5*	112.4
Basal area proportion (*1000)	1.79	0.89	55	1.34	0.77	66	0.15, 0.78	3.01*	106.9
Understory related variables									
Understory openness	9.17	8.39	55	11.45	8.43	66	-5.31, 0.77	-1.5	115.3
Ginger density(1)	1.36	3.97	55	5.04	6.53	66	-5.59, -1.77	**-3.8****	109.5
Understory liana density(1)	3.51	8.39	55	2.61	2.49	66	-0.01, 1.81	1.97	114.2
Understory rattan density(1)	0.4	1.05	55	0.19	0.5	66	-0.10, 0.51	1.32	74.47
Sapling density(1)	17.53	7.43	55	10.08	6.02	66	4.98, 9.92	**5.98*****	103.5
Leaf litter cover (%)	95.68	6.77	55	78.02	22	66	11.98, 23.35	**6.18*****	79.39

Significant: *P <0.05; **P <0.001; ***P <0.0001. (1)average number of stems/m^2; SD: Standard deviation; N: number of observation point; CI: Confidence Interval; t: value from the t-test; df: degree of freedom

RESULTS

We recorded a total of 4,353 records of 148 bird species, including 2,771 bird records within 50 m of the points (see Supplementary Material 1). In the less degraded forest, we recorded 139 bird species and in the highly degraded forest, we recorded 133 species. Auditory contact accounted for 99.6% of the birds recorded. Based on the average value of estimators (see Supplementary Material 3), the average expected total bird richness was 165.5 in the less degraded forest and 158.7 in the highly degraded forest, which showed a survey completeness of approximately 84% in each habitat type. We found a significant difference in species richness between the two disturbance levels (p=0.024) but with a high similarity in species composition (Sørensen similarity index=0.90). 15 species were only recorded in the less degraded forest and nine species only in the highly degraded forest, and all these species were recorded <10 times. From the 15 species that were only recorded in the less degraded forest, two species are vulnerable in their conservation status: short-toed coucal *Centropus rectunguis* and large-billed blue-flycatcher *Cyornis caerulatus*, and four near threatened: Malaysian blue-flycatcher *Cyornis turcosus*, red-crowned barbet *Psilopogon rafflesii*, black-bellied malkoha *Phaenicophaeus diardi*, striped wren-babbler *Kenopia striata*.

We recorded 47 species more than 10 times in each habitat type, including 33 species for which we could compare densities between the two disturbance levels (Table 2). Results from Z-test revealed significant differences in densities between the less degraded and the highly degraded forest for 19 bird species, but only 12 bird species still showed a significant difference in densities after applying the Bonferroni correction for multiple comparisons. Of these 12 species, five had higher densities in the highly degraded forest (e.g., purple-naped sunbird *Hypogramma hypogrammicum*, sooty-capped babbler *Malacopteron affine*), while densities for the other seven species were higher in the less degraded forest (e.g., rufous-tailed shama *Trichixos pyrrhopygus*, greater racket-tailed drongo *Dicrurus paradiseus*, black-capped babbler *Pellorneum capistratum*).

There were 21 species that did not show any significant difference (i.e., those species that showed non-significant difference or those species that showed significant difference but becoming non-significant after the Bonferroni correction, e.g., Asian fairy-bluebird *Irena puella*, black-and-yellow broadbill *Eurylaimus ochromalus*. For 14 species (Table 2), the comparison could not be made as densities could only be calculated in one of the two habitat types (e.g., density estimate for rufous-crowned babbler *Malacopteron magnum* was only calculated in the less degraded forest, and pin-striped tit-babbler *Macronous gularis* was only in the highly degraded forest).

There were significant differences in most habitat variables measured between the less and highly degraded forest types (but not for geographic variables, Table 1). The less degraded forest had significantly higher tree density, higher average tree height, lower numbers of *Macaranga* spp. trees and

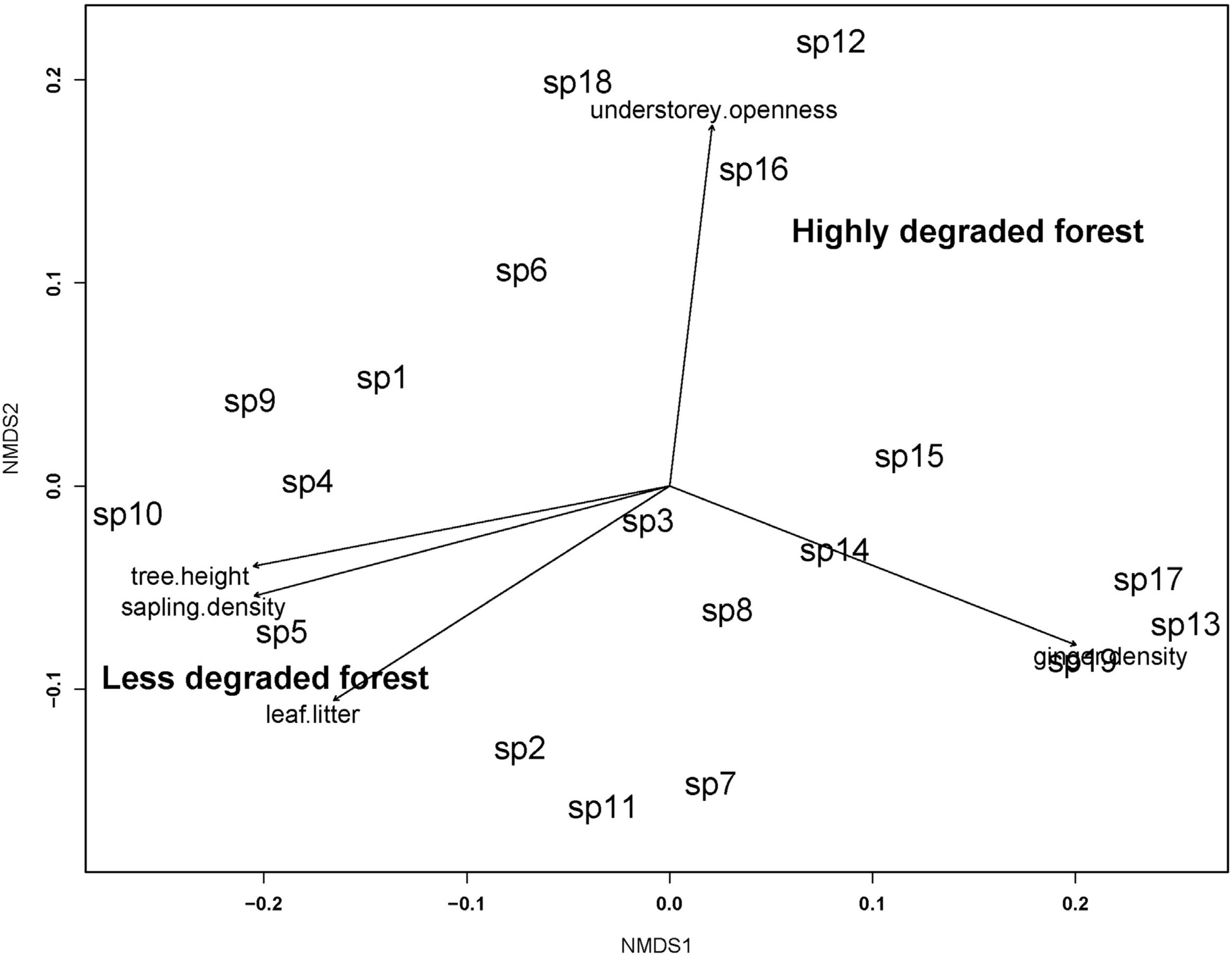

Fig. 1. NMDS ordination biplots of bird species (e.g., sp1) that show a significant difference in their densities between less and highly degraded forest with the habitat variables (text) superimposed. Bird species code: (sp1) yellow-bellied bulbul *Alophoixus phaeocephalus*; (sp2) hairy-backed bulbul *Tricholestes criniger*; (sp3) green iora *Aegithina viridissima*; (sp4) scaly-crowned babbler *Malacopteron cinereum*; (sp5) chestnut-rumped babbler *Stachyris maculata*; (sp6) rufous-tailed shama *Trichixos pyrrhopygus*; (sp7) blue-winged leafbird *Chloropsis cochinchinensis*; (sp8) greater racket-tailed drongo *Dicrurus paradiseus*; (sp9) short-tailed babbler *Malacocincla malaccensis*; (sp10) black-capped babbler *Pellorneum capistratum*; (sp11) blue-eared barbet *Psilopogon duvaucelii*; (sp12) brown barbet *Calorhamphus hayii*; (sp13) black-headed bulbul *Pycnonotus atriceps*; (sp14) spectacled bulbul *Pycnonotus erythropthalmos*; (sp15) olive-winged bulbul *Pycnonotus plumosus*; (sp16) cream-vented bulbul *Pycnonotus simplex*; (sp17) sooty-capped babbler *Malacopteron affine*; (sp18) fluffy-backed tit-babbler *Macronous ptilosus*; (sp19) purple-naped sunbird *Hypogramma hypogrammicum*.

fewer dead-standing trees. Less degraded forest also had lower values for most of the understory related variables (i.e., understory openness, ginger, liana, and rattan density).

Nineteen species that showed significant differences in their density between less and highly degraded forest (ignoring the Bonferroni correction for multiple comparisons) were used in the NMDS analysis to test whether species with a high density in the less degraded forest were also correlated with habitat variables typical of that forest type. We did not find a convergent solution when we used the point-species matrix due to the preponderance of zero counts, however, a convergent solution was achieved when we up-scaled and used the transect-species matrix (Fig. 1; convergent solution found, two dimensions, stress=0.16, a value between good and useable fit). Fitting environmental variables as vectors into this space revealed that average ginger density, average leaf litter cover, average sapling density, and average tree height were useful in explaining gradients (goodness-of-fit: ginger density, r^2=0.72, p=0.007; leaf litter cover, r^2=0.68, p=0.02; sapling density, r^2=0.71, p=0.01; tree height, r^2=0.72, p=0.008; understory openness, r^2=0.62, p=0.02). Species situated towards the lower-left part of the multidimensional scaling plot tend to occur in transects typical of the less degraded forest with high average values for tree height, sapling density, and leaf litter cover. Examples are chestnut-rumped babbler *Stachyris maculata* (sp5) and black-capped babbler *Pellorneum capistratum* (sp10; Fig. 1). On the upper-left part of the plot were species that were commonly observed in transects with high values in tree height and sapling density, but particularly in areas with low understory openness, typical for the less degraded forests. Examples are yellow-bellied bulbul *Alophoixus phaeocephalus* (sp1) and short-tailed babbler *Malacocincla malaccensis* (sp9). On the upper-right part of the plot were species that correlated with high understory openness such

Table 2. Densities (individuals/km^2 with 95% confidence intervals in brackets) for 47 lowland bird species in less degraded and highly degraded forest. Asterisks (*) indicate significance at p <0.05, bold underlined Z-test values indicate continuing significance after applying a Bonferroni correction, i.e., Z value >3.26 or <-3.26). The negative sign shows higher estimates in the highly degraded forest whereas positive signs show higher estimates in the less degraded forest. NT = Near Threatened.

Species	IUCN 2015 Conservation Status	Less Degraded Forest	Highly Degraded Forest	Z test
Yellow-bellied bulbul *Alophoixus phaeocephalus*		30.9 (24.9–38.4)	16.1 (12.2–21.1)	**<u>3.79</u>***
Hairy-backed bulbul *Tricholestes criniger*		112.4 (84.0–150.3)	59.6 (35.9–98.7)	2.41*
Green iora *Aegithina viridissima*	NT	37 (30.4–45.2)	27.6 (23.2–32.9)	2.18*
Scaly-crowned babbler *Malacopteron cinereum*		23.1 (17.9–29.9)	14.8 (11.3–19.3)	2.42*
Chestnut-rumped babbler *Stachyris maculata*	NT	35.5 (27.5–45.8)	18 (13.9–23.4)	**<u>3.48</u>***
Rufous-tailed shama *Trichixos pyrrhopygus*	NT	16.2 (13.9–18.8)	9 (7.3–11.1)	**<u>4.97</u>***
Blue-winged leafbird *Chloropsis cochincinensis*		19.3 (17.1–21.8)	11.6 (10.2–13.1)	**<u>5.91</u>***
Greater racket-tailed drongo *Dicrurus paradiseus*		23.9 (20.9–27.4)	15.4 (13.9–17.2)	**<u>4.92</u>***
Short-tailed babbler *Malacocincla malaccensis*	NT	24.7 (20.9–29.1)	14.1 (11.2–17.9)	**<u>4.19</u>***
Black-capped babbler *Pellorneum capistratum*		21.6 (17.3–27.0)	7.1 (5.4–9.3)	**<u>5.88</u>***
Blue-eared barbet *Psilopogon duvaucelii*		14.7 (12.8–16.8)	18.6 (16.1–21.6)	-2.48*
Brown barbet *Calorhamphus hayii*	NT	10.8 (9.2–12.7)	32.4 (24.1–43.4)	**<u>-4.66</u>***
Black-headed bulbul *Pycnonotus atriceps*		13.9 (11.9–16.2)	36.1 (30.4–42.7)	**<u>-7.09</u>***
Spectacled bulbul *Pycnonotus erythropthalmos*		64 (49.2–83.3)	149.6 (117.3–190.9)	**<u>-4.6</u>***
Olive-winged bulbul *Pycnonotus plumosus*		16.2 (12.7–20.7)	25.2 (18.4–34.5)	-2.07*
Cream-vented bulbul *Pycnonotus simplex*		28.5 (24.1–33.9)	75.1 (48.7–115.8)	-2.82*
Sooty-capped babbler *Malacopteron affine*	NT	21.6 (16.8–27.7)	38.6 (31.7–46.9)	**<u>-3.75</u>***
Fluffy-backed tit-babbler *Macronous ptilosus*	NT	8.5 (7.9–9.1)	14.1 (10–19.9)	-2.44*
Purple-naped sunbird *Hypogramma hypogrammicum*		10.8 (9.9–11.7)	28.6 (20.5–39.9)	**<u>-3.81</u>***
Asian fairy-bluebird *Irena puella*		14.7 (11.1–19.3)	14.1 (11.7–17.0)	0.26
Grey-cheeked bulbul *Alophoixus bres*		12.3 (9.7–15.7)	9.6 (7.6–12-2)	1.62
Moustached babbler *Malacopteron magnirostre*		18.5 (13.9–24.7)	13.5 (9.4–19.5)	1.49
Raffles's malkoha *Rhinortha chlorophaea*		13.1 (10.8–15.8)	11.6 (9.5–14.0)	0.95
Plain flowerpecker *Dicaeum concolor*		38.5 (28.1–52.8)	31.3 (23.7–41.3)	0.99
Black-and-yellow broadbill *Eurylaimus ochromalus*	NT	16.2 (13.4–19.6)	15.4 (12.3–19.3)	0.36
Buff-vented bulbul *Iole olivacea*	NT	33.9 (28.2–40.9)	34.1 (22.4–51.9)	-0.03
Dark-necked tailorbird *Orthotomus atrogularis*		29.3 (25.2–34.1)	31.2 (22.5–43.2)	-0.35
Chestnut-winged babbler *Stachyris erythroptera*		24.9 (17.3–35.9)	28.3 (23.5–34.1)	-0.66
Ferruginous babbler *Trichastoma bicolor*		30.1 (25.6–35.4)	34.7 (28.3–42.6)	-0.31
Orange-bellied flowerpecker *Dicaeum trigonostigma*		64.2 (43.7–94.3)	95.9 (61.3–149.9)	-1.30
Little spiderhunter *Arachnothera longirostra*		128.3 (83.4–197.4)	129.9 (93.2–181.2)	-0.05
Black-naped monarch *Hypothymis azurea*		27.8 (23.9–32.3)	46.4 (27.8–77.4)	-1.54
Rufous-winged philentoma *Philentoma pyrhoptera*		10.8 (8.7–13.4)	15 (8.2–27.4)	-0.97
Thick-billed green-pigeon *Treron curvirostra*			7.7 (7.4–8.1)	
Buff-rumped woodpecker *Meiglyptes grammithorax*			12.9 (11.1–14.9)	
Pin-striped tit-babbler *Macronous gularis*			17.4 (13.5–22.3)	
Rufous piculet *Sasia abnormis*			20.4 (10.9–38.4)	
White-crowned forktail *Enicurus leschenaultii*			9 (8.5–9.5)	
Brown fulvetta *Alcippe brunneicauda*	NT	18.5 (14.6–23.4)		
Red-eyed bulbul *Pycnonotus brunneus*		13.1 (12.1–14.2)		
Rufous-crowned babbler *Malacopteron magnum*	NT	16.9 (11.9–24.1)		
Rufous-tailed tailorbird *Orthotomus sericeus*		8.5 (7.9–9.1)		
Chestnut-backed scimitar-babbler *Pomatorhinusmontanus*		13.1 (9.8–17.6)		
Rufous-fronted babbler *Stachyris rufifrons*		20.8 (17.9–24.2)		
Ruby-cheeked sunbird *Anthreptes singalensis*		18.2 (3.6–92.2)		
Crimson sunbird *Aethopyga siparaja*		24.5 (16.2–37.1)		
Grey-chested jungle-flycatcher *Rhinomyias umbratilis*	NT	14.7 (12.2–17.7)		

Table 3. Bird densities (birds/km^2) between unlogged and logged forest in Kalimantan (Mead, 2008), and less degraded and highly degraded forest in Sumatra (current study). The density for fluffy-backed tit-babbler is from the periphery of unlogged and logged forest (Mead, 2008; see text for the explanation).

Species	Mead (2008)		Current Study	
	Unlogged Forest	Logged Forest	Less Degraded Forest	Highly Degraded Forest
Black-capped babbler *Pellorneum capistratum*	72	8	22	7
Short-tailed babbler *Malacocincla malaccensis*	115	73	25	14
Yellow-bellied bulbul *Alophoixus phaeocephalus*	66	29	31	16
Chestnut-rumped babbler *Stachyris maculata*	94	56	36	18
Scaly-crowned babbler *Malacopteron cinereum*	106	62	23	15
Purple-naped sunbird *Hypogramma hypogrammicum*	22	90	11	29
Fluffy-backed tit-babbler *Macronous ptilosus*	9	84	8	14
Hairy-backed bulbul *Tricholestes criniger*	212	239	112	60
Sooty-capped babbler *Malacopteron affine*	73	20	22	39

as brown barbet *Calorhamphus hayii* (sp12). Species situated towards the lower-right part of the plot were correlated with high ginger density, which is also a typical characteristic of the highly degraded forest. Examples are sooty-capped babbler *Malacopteron affine* (sp17), and purple-naped sunbird *Hypogramma hypogrammicum* (sp19).

DISCUSSION

Bird density comparisons between forests with different levels of habitat disturbance have rarely been carried out in Southeast Asia (Mead, 2008; Marsden, 1998) despite their importance for conservation managers in understanding species-specific habitat affinities. We present densities for 47 bird species, including 12 near-threatened species (BirdLife International, 2015) and 33 species that could be compared between forest disturbance levels. Seven bird species had significantly higher densities in less degraded forest and five bird species had significantly higher densities in highly degraded forest, while the other 21 species showed no significant differences. Our study is the first for the Sundaland biodiversity hotspot to compare the densities of multiple bird species between two degraded forest types, adding to the limited knowledge base of densities of forest birds on Sumatra, and providing timely insights into enhancing the management of degraded rainforest more generally. Furthermore, despite their degraded condition, our study demonstrates that forests still maintain populations of most lowland forest bird species in Sumatra (i.e., 64% of 228 lowland forest birds were found in the study area; Marthy, 2014), illustrating the important conservation value of degraded habitats (Sodhi & Brook, 2008).

Only one study in the Sundaic region (Kalimantan: Mead, 2008) compares bird densities between unlogged and logged forest and we compared our results to the latter (Table 3). The density of black-capped babbler *Pellorneum capistratum* exhibited an 89% reduction in logged forest compared to unlogged forest (Mead, 2008). We found a similar trend with the density of this bird, being 68% lower in the highly degraded forest compared to the less degraded forest. This species is commonly associated with high values for tree height, sapling density, and leaf litter cover (Mead, 2008). These habitat variables were found to be significantly different between the two habitat types in this study (Table 1) and significantly correlated with the presence of black-capped babblers (Fig. 1). The same pattern was true for the other five bird species: yellow-bellied bulbul *Alophoixus phaeocephalus* (48% less), scaly-crowned babbler *Malacopteron cinereum* (35% less), chestnut-rumped babbler *Stachyris maculata* (50% less), and short-tailed babbler *Malacocincla malaccensis* (44% less).

Two species have higher densities in logged forest than in primary forest: fluffy-backed tit-babbler and purple-naped sunbird *Hypogramma hypogrammicum* (Table 3; Mead, 2008). We also found a similar trend where densities for these species were 75% and 164% higher, respectively, in the highly degraded than the less degraded forest. These species prefer undergrowth of degraded and selectively logged forest (Collar & Robson, 2007), with a strong affinity to gaps and understory disturbance (Mead, 2008). A study by Moradi et al. (2009) in Peninsula Malaysia shows that the fluffy-backed tit-babbler has a higher density in the forest edge than in the forest interior. Similarly, in Sabah, Malaysia, this species also has lower abundance in selectively logged forest with a high richness of lower story growth compared to a primary forest (Edwards et al., 2011).

The different trends emerging from comparing densities across different levels of disturbance highlight the important need for more studies to be conducted for more bird communities in the Sundaic region. Secondary forest resulting from selective logging is characterised by a mosaic of degraded forest patches in different stages of regeneration (Cleary et al., 2005; Putz et al., 2001) and usually contains patches of unlogged forest (Mead, 2008). These conditions might favor some but not all species. We considered this heterogeneity as one plausible reason for the difference in patterns emerging from comparing the current study with the other available results. For example, in Kalimantan, Mead (2008) found a lower density of sooty-capped babbler *Malacopteron affine* in logged forest than in unlogged forest, whereas we found this species as having a 77% higher density in highly degraded over less degraded forests. This species prefers an area with high density of trees and saplings, good midstory cover, high litter abundance, and rarely occurs in areas with dense vine cover in the understory, as it avoids extensive gaps (Mead, 2008). In contrast, Lambert (1992) found no difference in abundance of sooty-capped babbler between logged and unlogged forest in Sabah, Malaysia. We predicted that the mosaic habitat condition provides relatively suitable habitat conditions for supporting this species. For the hairy-backed bulbul *Tricholestes criniger*, the trend is reversed. Mead (2008) found a higher density in logged forest, whereas we found a lower density in the highly degraded over less degraded forests. This indicates that these bulbuls can do well in logged forest, but do decline in forests that are severely degraded.

Black-headed bulbul *Pycnonotus atriceps*, spectacled bulbul *Pycnonotus erythropthalmos*, purple-naped sunbird *Hypogramma hypogrammicum*, Malay brown barbet *Caloramphus hayii* had significantly higher densities in the highly degraded forest than in the less degraded forest. Fruits are an important part of the diet for these species, particularly small fruit. A likely increase in the availability of small fruits that are associated with certain pioneer species might provide abundant food resources for these species (Meijaard et al., 2005). There is also possibility that the high density might be due to open forest conditions which make it easier to detect the bird visually, leading to detection bias. However, because detections were 99.6% aural and we restricted detection distance to 50 m or less, we do not think that the high density estimates for this species resulted from detection bias. Additionally, detection bias should show up as a wider effective strip width in the more open habitat, which we did not see in our data.

We found 15 species that were only observed in the less degraded forest, but we did not have density estimates for these based on low encounter rates. These species might be of particular concern for conservation, especially true of six species within this list that are globally threatened or near-threatened species: the short-toed coucal *Centropus rectunguis* and large-billed blue-flycatcher *Cyornis caerulatus* are considered Vulnerable, and the black-bellied malkoha *Phaenicophaeus diardi*, Malaysian blue-flycatcher *Cyornis turcosus*, red-crowned barbet *Psilopogon rafflesii* and spotted fantial *Rhipidus perlata* that are considered Near Threatened (BirdLife International, 2015). This certainly adds to the argument that avoiding further degradation or conversion of degraded forest is important if these species and other lowland species are to persist.

Logged forest might provide easier detection of canopy birds than in primary forest, but detection will be more difficult for terrestrial or understory species (Lambert, 1992). This is similar to the situation in our study area between the less and the highly degraded forest. However, we do not consider this to have exerted a significant influence on detection because aural detections (as suggested by Anderson et al., 2015) were overwhelmingly used in this study, similar to results from other studies (e.g., Scott et al., 1981). The estimation of the distance to the observer for auditory contact might pose another source of bias in the distance estimate analysis, where the observer might not able to locate a call accurately as distance increases, or differentiate distances beyond 65 m (Alldredge et al., 2007). However, we used Rangefinder to check for distance to avoid drifting in distance estimation (both for birds that were aurally or visually recorded) and we only included data within a 50 m radius (omitted all records beyond 50 m) to reduce bias that might result from over or underestimation. To further improve the detection probability, as birds tend to call more in the morning (see Material and Methods) we increased the chance to detect birds not only by repeating the survey at each transect but also when possible, rotating the daily order in which transects were visited. Despite the possibility of a detection bias, many density estimates from this study are consistent with those of other studies and that increases our confidence that the estimates contribute a valid and much needed baseline for future research.

Our study provides the first understanding of bird species composition, resilience, and the potential for recovery in successional forests in Sumatra, but has direct relevance to other lowland forests in the Sundaic region. Those results conflicting with other studies might reflect the heterogeneity of degraded forest resulting from logging. The high species diversity found in comparison to primary forest avifauna underlines the importance of ensuring that further degradation or conversion should not occur based on a mistaken belief that degraded forests have a low biodiversity value (Edwards et al., 2011; Peh et al., 2006). In addition, each species responds differently to habitat degradation, thus, for the purposes of forest restoration which aim to return the forest condition (including its biodiversity) to its previous condition, species specific actions may be required but might generally focus on species that specialise on lowland forest as the first main target. Our study provides not only a baseline for future studies in the current study area to assess the effectiveness of the forest restoration approach, but also a point of comparison for future studies in the Sundaic region.

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SUPPLEMENTARY MATERIAL

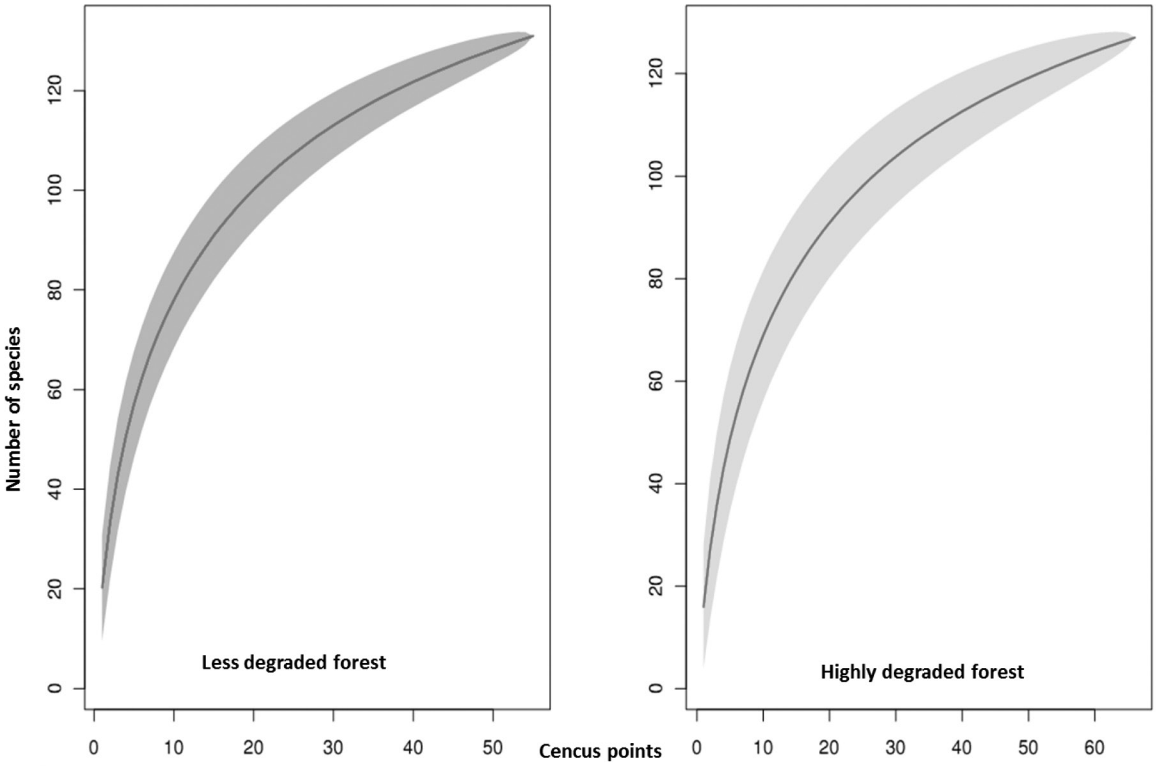
Supplementary Material 1. Abundance of all birds (from point count survey) sampled in the less and the highly degraded forest in Harapan Rainforest Ecosystem Restoration Concession (April–June 2011).

No.	Family	Common Name	Scientific Name	Less Degraded Forest	Highly Degraded Forest
1	Aegithinidae	Green Iora	*Aegithina viridissima*	68	58
2	Alcedinidae	Blue-eared Kingfisher	*Alcedo meninting*	1	6
3	Alcedinidae	Rufous-collared Kingfisher	*Actenoides concretus*	4	3
4	Alcedinidae	Black-backed Kingfisher	*Ceyx erithaca*	7	1
5	Alcedinidae	Banded Kingfisher	*Lacedo pulchella*	15	6
6	Bucerotidae	Wrinkled Hornbill	*Rhabdotorrhinus corrugatus*	4	2
7	Bucerotidae	Wreathed Hornbill	*Rhyticeros undulatus*	1	4
8	Bucerotidae	Black Hornbill	*Anthracoceros malayanus*	13	10
9	Bucerotidae	Rhinoceros Hornbill	*Buceros rhinoceros*	4	7
10	Bucerotidae	Helmeted Hornbill	*Rhinoplax vigil*		5
11	Bucerotidae	Bushy-crested Hornbill	*Anorrhinus galeritus*	3	7
12	Campephagidae	Lesser Cuckooshrike	*Coracina fimbriata*	7	2
13	Campephagidae	Black-winged Flycatcher-shrike	*Hemipus hirundinaceus*	10	13
14	Campephagidae	Scarlet Minivet	*Pericrocotus flammeus*	12	9
15	Chloropseidae	Blue-winged Leafbird	*Chloropsis cochinchinensis*	34	20
16	Chloropseidae	Lesser Green Leafbird	*Chloropsis cyanopogon*	4	11
17	Chloropseidae	Greater Green Leafbird	*Chloropsis sonneratii*	11	6
18	Columbidae	Mountain Imperial-pigeon	*Ducula badia*	1	
19	Columbidae		Ducula sp.	1	3
20	Columbidae	Thick-billed Green-pigeon	*Treron curvirostra*	25	20
21	Columbidae	Emerald Dove	*Chalcophaps indica*	12	11
22	Columbidae	Green Imperial-pigeon	*Ducula aenea*	1	2
23	Coraciidae	Asian Dollarbird	*Eurystomus orientalis*	1	1
24	Corvidae	Crested Jay	*Platylophus galericulatus*	11	4
25	Corvidae	Black Magpie	*Platysmurus leucopterus*	9	3
26	Corvidae	Slender-billed Crow	*Corvus enca*	4	8
27	Cuculidae	Rusty-breasted Cuckoo	*Cacomantis sepulcralis*	1	1
28	Cuculidae	Banded Bay Cuckoo	*Cacomantis sonneratii*	4	3
29	Cuculidae	Violet Cuckoo	*Chrysococcyx xanthorhynchus*		1
30	Cuculidae	Hodgson's Hawk-cuckoo	*Cuculus fugax*	4	3
31	Cuculidae	Oriental Cuckoo	*Cuculus saturatus*	1	
32	Cuculidae	Drongo Cuckoo	*Surniculus lugubris*	9	
33	Cuculidae	Raffles's Malkoha	*Rhinortha chlorophaea*	20	19
34	Cuculidae	Chestnut-breasted Malkoha	*Phaenicophaeus curvirostris*	2	1
35	Cuculidae	Black-bellied Malkoha	*Phaenicophaeus diardi*	4	
36	Cuculidae	Green-billed Malkoha	*Phaenicophaeus tristis*	1	4
37	Cuculidae	Short-toed Coucal	*Centropus rectunguis*	7	
38	Cuculidae	Plaintive Cuckoo	*Cacomantis merulinus*	8	7
39	Cuculidae	Indian Cuckoo	*Cuculus micropterus*	1	1
40	Cuculidae	Greater Coucal	*Centropus sinensis*	1	1
41	Dicaeidae	Yellow-vented Flowerpecker	*Dicaeum chryssorheum*		1
42	Dicaeidae	Plain Flowerpecker	*Dicaeum concolor*	29	15
43	Dicaeidae	Scarlet-backed Flowerpecker	*Dicaeum cruentatum*	2	1
44	Dicaeidae		Dicaeum sp.	9	5
45	Dicaeidae	Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	55	26
46	Dicaeidae	Yellow-breasted Flowerpecker	*Prionochilus maculatus*	6	
47	Dicaeidae	Crimson-breasted Flowerpecker	*Prionochilus percussus*		1
48	Dicaeidae	Scarlet-breasted Flowerpecker	*Prionochilus thoracicus*	1	1
49	Dicruridae	Greater Racket-tailed Drongo	*Dicrurus paradiseus*	70	48
50	Eupetidae	Rail-babbler	*Eupetes macrocerus*	16	5
51	Eurylaimidae	Dusky Broadbill	*Corydon sumatranus*	2	1
52	Eurylaimidae	Banded Broadbill	*Eurylaimus javanicus*	8	10

No.	Family	Common Name	Scientific Name	Less Degraded Forest	Highly Degraded Forest
53	Eurylaimidae	Black-and-yellow Broadbill	*Eurylaimus ochromalus*	55	29
54	Eurylaimidae	Asian Green Broadbill	*Calyptomena viridis*	18	4
55	Falconidae	Black-thighed Falconet	*Microhierax fringillarius*		1
56	Irenidae	Asian Fairy-bluebird	*Irena puella*	19	24
57	Meropidae	Red-bearded Bee-eater	*Nyctyornis amictus*	17	3
58	Monarchidae	Black-naped Monarch	*Hypothymis azurea*	40	40
59	Muscicapidae	Malaysian Blue-flycatcher	*Cyornis turcosus*	2	
60	Muscicapidae	Pale Blue-flycatcher	*Cyornis unicolor*	3	7
61	Muscicapidae	White-rumped Shama	*Copsychus malabaricus*	1	3
62	Muscicapidae	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*	1	1
63	Muscicapidae	Large-billed Blue-flycatcher	*Cyornis caerulatus*	2	
64	Muscicapidae	Rufous-winged Philentoma	*Philentoma phyrrhoptera*	13	11
65	Muscicapidae	Grey-chested Jungle-flycatcher	*Rhinomyias umbratilis*	32	4
66	Muscicapidae	Rufous-tailed Shama	*Trichixos pyrrhopygus*	57	23
67	Muscicapidae	White-crowned Forktail	*Enicurus leschenaultii*	16	16
68	Muscicapidae	Oriental Magpie-robin	*Copsychus saularis*	5	
69	Nectariniidae	Ruby-cheeked Sunbird	*Anthreptes singalensis*	13	5
70	Nectariniidae	Plain Sunbird	*Anthreptes simplex*	6	6
71	Nectariniidae	Grey-breasted Spiderhunter	*Arachnothera affinis*	5	3
72	Nectariniidae	Spectacled Spiderhunter	*Arachnothera flavigaster*	1	1
73	Nectariniidae	Long-billed Spiderhunter	*Arachnothera robusta*	9	1
74	Nectariniidae	Purple-naped Sunbird	*Hypogramma hypogrammicum*	14	25
75	Nectariniidae	Crimson Sunbird	*Aethopyga siparaja*	10	4
76	Nectariniidae	Little Spiderhunter	*Arachnothera longirostra*	122	115
77	Nectariniidae		Arachnothera sp.	1	
78	Nectariniidae	Plain-throated Sunbird	*Anthreptes malacensis*	4	10
79	Nectariniidae	Olive-backed Sunbird	*Nectarinia jugularis*	1	4
80	Oriolidae	Black-hooded Oriole	*Oriolus xanthonotus*	31	21
81	Phasianidae	Great Argus	*Argusianus argus*	3	4
82	Picidae	Maroon Woodpecker	*Blythipicus rubiginosus*	8	3
83	Picidae	Rufous Woodpecker	*Celeus brachyurus*	1	2
84	Picidae	White-bellied Woodpecker	*Dryocopus javensis*	8	7
85	Picidae	Grey-and-buff Woodpecker	*Hemicircus concretus*	3	3
86	Picidae	Buff-rumped Woodpecker	*Meiglyptes grammithorax*	8	25
87	Picidae	Buff-necked Woodpecker	*Meiglyptes tukki*	5	7
88	Picidae	Checker-throated Woodpecker	*Picus mentalis*	7	6
89	Picidae		Picus sp.	5	5
90	Picidae	Crimson-winged Woodpecker	*Picus puniceus*	6	18
91	Picidae	Rufous Piculet	*Sasia abnormis*	7	12
92	Picidae	Olive-backed Woodpecker	*Dinopium rafflesii*	1	1
93	Picidae	Orange-backed Woodpecker	*Reinwardtipicus validus*	4	7
94	Pittidae	Garnet Pitta	*Pitta granatina*	2	4
95	Pittidae	Javan Banded Pitta	*Pitta guajana*	2	2
96	Pittidae	Hooded Pitta	*Pitta sordida*		3
97	Psittacidae	Blue-rumped Parrot	*Psittinus cyanurus*	3	10
98	Pycnonotidae	Buff-vented Bulbul	*Iole olivacea*	41	42
99	Pycnonotidae	Black-crested Bulbul	*Pycnonotus melanicterus*		1
100	Pycnonotidae	Red-eyed Bulbul	*Pycnonotus brunneus*	18	9
101	Pycnonotidae	Olive-winged Bulbul	*Pycnonotus plumosus*	20	27
102	Pycnonotidae	Cream-vented Bulbul	*Pycnonotus simplex*	41	46
103	Pycnonotidae	Streaked Bulbul	*Ixos malaccensis*	10	2
104	Pycnonotidae	Spectacled Bulbul	*Pycnonotus erythropthalmos*	99	128
105	Pycnonotidae	Yellow-bellied Bulbul	*Alophoixus phaeocephalus*	41	29
106	Pycnonotidae	Black-headed Bulbul	*Pycnonotus atriceps*	5	57
107	Pycnonotidae	Puff-backed Bulbul	*Pycnonotus eutilotus*	3	3
108	Pycnonotidae	Hairy-backed Bulbul	*Tricholestes criniger*	67	46
109	Pycnonotidae	Grey-cheeked Bulbul	*Alophoixus bres*	19	17

No.	Family	Common Name	Scientific Name	Less Degraded Forest	Highly Degraded Forest
110	Pycnonotidae	Yellow-vented Bulbul	*Pycnonotus goavier*		1
111	Ramphastidae	Gold-whiskered Barbet	*Psilopogon chrysopogon*	8	20
112	Ramphastidae	Yellow-crowned Barbet	*Psilopogon henricii*	24	15
113	Ramphastidae	Red-crowned Barbet	*Psilopogon rafflesii*	3	
114	Ramphastidae		Psilopogon sp.	4	
115	Ramphastidae	Brown Barbet	*Calorhamphus hayii*	27	16
116	Ramphastidae	Blue-eared Barbet	*Psilopogon duvaucelii*	83	71
117	Rhipiduridae	Pied Fantail	*Rhipidura javanica*		1
118	Rhipiduridae	Spotted Fantail	*Rhipidura perlata*	6	
119	Sittidae	Velvet-fronted Nuthatch	*Sitta frontalis*	3	
120	Sturnidae	Hill Myna	*Gracula religiosa*	28	24
121	Sylviidae	Dark-necked Tailorbird	*Orthotomus atrogularis*	57	27
122	Sylviidae	Ashy Tailorbird	*Orthotomus ruficeps*	1	3
123	Sylviidae	Rufous-tailed Tailorbird	*Orthotomus sericeus*	17	13
124	Sylviidae	Yellow-bellied Warbler	*Abroscopus superciliaris*	1	
125	Timaliidae	White-chested Babbler	*Trichastoma rostratum*	4	6
126	Timaliidae	Short-tailed Babbler	*Malacocincla malaccensis*	46	23
127	Timaliidae	Black-capped Babbler	*Pellorneum capistratum*	21	19
128	Timaliidae	Sooty-capped Babbler	*Malacopteron affine*	34	53
129	Timaliidae	Moustached Babbler	*Malacopteron magnirostre*	28	20
130	Timaliidae	Chestnut-winged Babbler	*Stachyris erythroptera*	33	56
131	Timaliidae	Chestnut-rumped Babbler	*Stachyris maculata*	69	35
132	Timaliidae	Black-throated Babbler	*Stachyris nigricollis*	11	5
133	Timaliidae	Rufous-fronted Babbler	*Stachyris rufifrons*	26	4
134	Timaliidae	Pin-striped Tit-babbler	*Macronous gularis*	34	47
135	Timaliidae	Fluffy-backed Tit-babbler	*Macronous ptilosus*	16	24
136	Timaliidae	Striped Wren-babbler	*Kenopia striata*	6	
137	Timaliidae	Large Wren-babbler	*Turdinus macrodactylus*	1	2
138	Timaliidae	Abbott's Babbler	*Malacocincla abboti*	1	
139	Timaliidae	Scaly-crowned Babbler	*Malacopteron cinereum*	37	22
140	Timaliidae	Rufous-crowned Babbler	*Malacopteron magnum*	28	10
141	Timaliidae	Chestnut-backed Scimitar-babbler	*Pomatorhinus montanus*	52	24
142	Timaliidae	Brown Fulvetta	*Alcippe brunneicauda*	41	13
143	Timaliidae	White-necked Babbler	*Stachyris leucotis*	1	1
144	Timaliidae	Grey-headed Babbler	*Stachyris poliocephala*	7	6
145	Timaliidae	Ferruginous Babbler	*Trichastoma bicolor*	65	76
146	Trogonidae	Diard's Trogon	*Harpactes diardi*	14	3
147	Trogonidae	Scarlet-rumped Trogon	*Harpactes duvaucelli*	30	18
148	Trogonidae	Red-naped Trogon	*Harpactes kasumba*	12	7

Supplementary Material 2. Species accumulation curves (± 95% confidence intervals) for bird assemblages in the less degraded and the highly degraded forest.



Supplementary Material 3. Non-parametric species richness estimators and curve models for asymptotic species richness for each habitat type (mean value is given with the standard error).

Estimators	**Less Degraded Forest (± Standard Error)**	**Highly Degraded Forest (± Standard Error)**
Chao	176.09 + 21.75	165.56 + 18.69
Jack 1	161.58 + 6.15	155.65 + 5.49
Jack 2	177.12	170.32
Bootstrap	149.02 + 3.28	143.29 + 3.1
Observed	139	133
Averaged estimators	165.95	158.71