Birds as provider of ecosystem services at Bukit Barisan Selatan National Park, Indonesia

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Abstrak

Burung-burung frugivora dan nektarivora dikenal sebagai penyedia jasa ekosistem dalam bentuk polinasi dan penyebaran biji. Struktur dan komposisi burung di tepi hutan kawasan Taman Nasional Bukit Barisan Selatan dievaluasi. Transek disiapkan pada tiga lokasi berbeda di areal Pemerihan yang melalui tepi hutan dan kebun pertanian. Survei burung dilakukan dengan metode titik hitung, yang dilaksanakan pada bulan Juli-September 2012 di daerah Sumberejo-Pemerihan. Survei vegetasi juga dilakukan pada setiap titik. Hasil penelitian memerlihatkan batas yang jelas pada struktur habitat antara tepi hutan dan kebun pertanian meskipun terdapat perambahan di tepi hutan. Keanekaragaman burung serupa antara kedua tipe habitat. Terdapat tiga jenis burung cucak-cucakan (Pycnonotidae) umum yang mengkarakterisasi komposisi burung sepanjang tepi hutan. Kehadiran burung cucak-cucakan sebagai penyebar biji mengindikasikan terakselerasinya regenerasi alami dalam kawasan tersebut.

Abstract

Frugivores and nectarivores birds are known to provide ecosystem services in the form of pollination and seed dispersal. In the forest edge of Bukit Barisan Selatan National Park the structure and species composition of birds was evaluated. Transects were set up at three different locations in the Pemerihan area, traversing both forest edge and agricultural gardens. Birds were surveyed using point counts, which were carried out during July-September 2012 in the Sumberejo-Pemerihan area of the national park. Vegetation surveys were also undertaken at each point. The results suggest a clear demarcation of habitat structure between forest edges and agricultural gardens, although encroachment was present in the forest edge. Bird diversity was similar between the two habitat types. Three common bulbul species characterized the bird composition along the forest edge. The presence of bulbuls as seed dispersers may indicate that natural regeneration is accelerated within the area.

Keywords: birds, bulbuls, ecosystem service, forest edge, vegetation structure

Introduction

Ecosystem services are the processes and the conditions of natural ecosystems that support human activity and sustain human life (Chapin III et al., 2000). In line with this, forests provide ecosystem service such as controlling local and global climate, soil erosion, maintenance of other ecosystem processes (seed dispersal, pollination), as well as carbon storage (Böhning-Gaese, 2012; Locatelli et al., 2008; Wenny et al., 2011). Important ecological processes such as pollination and seed dispersal are carried out by birds, insects and mammals, for example, bats, large mammals and primates (Bodmer, 1991; Campos-Arceiz et al., 2011, 2008; Culot et al., 2010; de Marco and Coelho, 2004; Giombini et al., 2009; Kremen, 2005; Wotton and Kelly, 2011). Pollination and seed dispersal services contribute to human well-being by improving production of agricultural, fibre, timber and non timber forest products commdities (Hougner et al. 2006; Kremen et al. 2007; Traveset et al., 2012; Whelan et al., 2008). The ongoing deforestation influences

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pollination and seed dispersal processes negatively and has serious impact on forest regeneration.

Successful natural reforestation of native plant species in degraded areas from seeds dispersed by animals depends on distance from the nearest source forest, seed rain, plant species composition in the source forest and the rate of seed predation (Cole et al., 2010; Guevara et al., 2004; Harvey, 2000; Shono et al., 2006; Teegalapalli et al., 2009; Wotton and Kelly, 2011). Ricketts (2004) suggested that the distance between forest fragments will increase the activity of coffee pollinating agents. For this to take place, however, pollination agents and agents of seed dispersers must be present.

Birds are known as important pollinators and seed dispersers and play an important role in facilitating the recolonization of natural vegetation in degraded areas (Borges, 2007; Caves et al, 2013; Clout and Hay, 1989; Duncan and Chapman, 1999; Padilla et al, 2012; Sekercioglu, 2006), as long as perching sites, the complexity of vegetation structure and suitable food sources are available (Duncan, 2006 ; Holl, 1999; Sekercioglu et al. 2002; Wunderle, 1997).

Bukit Barisan Selatan National Park (BBSNP) in Southern Sumatra contains important populations of endangered wildlife species, including Sumatran rhinoceros, *Dicerorhinus sumatrensis*, Sumatran tiger, *Panthera tigris sumatrae*, elephant, *Elephas maximus sumatrensis* and over 300 bird species. Surrounded by human settlements, BBSNP is also important to the livelihood of the surrounding community, being the source of many types of non-timber forest products. Unfortunately, the human activities have lead to continuous deforestation at a rate of 1.69% per year between 1972-2002 (Gaveau et al., 2007). In the last three decades, forest cover has been reduced by 50% (3,470 km^2) in West Lampung and South Bengkulu, the districts in which the park lies, and by 17% (520 km^2) in the park (Gaveau et al., 2007). Although forest regrowth occur, illegal agricultural encroachment continues at an unabated rate, resulting in a net forest loss. The development of lowland coffee (*Coffea robusta*) plantations within park boundaries constitutes one of the major challenges, as deforestation rates appear to be linked to Global *robusta* prices (O'Brien and Kinnaird, 2003). Rice, coconut, damar, and pepper are other popular crops produced at the expense of BBSNP's forest habitat (Gaveau et al., 2007). Due to its elongated shape BBSNP has over 700 km of boundaries and is particularly vulnerable to fragmentation by encroachment from human settlements surrounding it. Roads bisect the park in two areas, one in the north and one in the south. As humans settle along these roads, villages are formed and residents begin to plant and expand their gardens and fields, which have create in gaps that exceed 3 km at certain places.

The lowland dipterocarp forest of BBSNP is a key habitat for animal pollinators and seed dispersers. Several hornbill species are wide-ranging species and are described as effective seed dispersers (Holbrook and Smith, 2000; Holbrook et al, 2002; Kinnaird and O'Brien, 2007; Kitamura, 2011; Lenz et al., 2010; Whitney et al., 1998). Biodiversity is an integral part of ecosystem services, and by preserving the integrity of forest edge of the park, pollination and seed dispersal agents are maintained. Deforestation may decrease the diversity of pollinating and seed dispersing agents and with a significant negative effect to agricultural crop production (de Marco and Coelho, 2004).

There remain limited information about pollinators and seed dispersers associated with forest edge, and to what degree they support the integrity of the forest edge, as well as agricultural production adjacent to the park boundary. This study aims at evaluating the community composition of bird species as provider of ecosystem services along the edge of Bukit Barisan Selatan National Park.

Methods

Study Area

This study took place in Bukit Barisan Selatan National Park (BBSNP), Sumatra, from July-September, 2012. This park is the third largest protected area (3,568 km^2) in Sumatra and located in the southwestern part of Sumatra, spanning the two provinces of Lampung and Bengkulu (O'Brien and Kinnaird, 1996). BBSNP contains the largest tracts of lowland rain forest remaining in Sumatra, with an incredible high species diversity that includes the critically endangered Sumatran tiger (*Panthera tigris sumatrae*) and Sumatran rhino (*Dicerorhinus sumatrensis*) along with an abundance of primates and more than 200 species of birds. BBSNP is the primary watershed for southwest Sumatra (O'Brien and Kinnaird, 1996).

The fieldwork was carried out along the Pemerihan River at the boundary of Bukit Barisan Selatan National Park (Lat -5.61527045, Lon 104.39306726), with

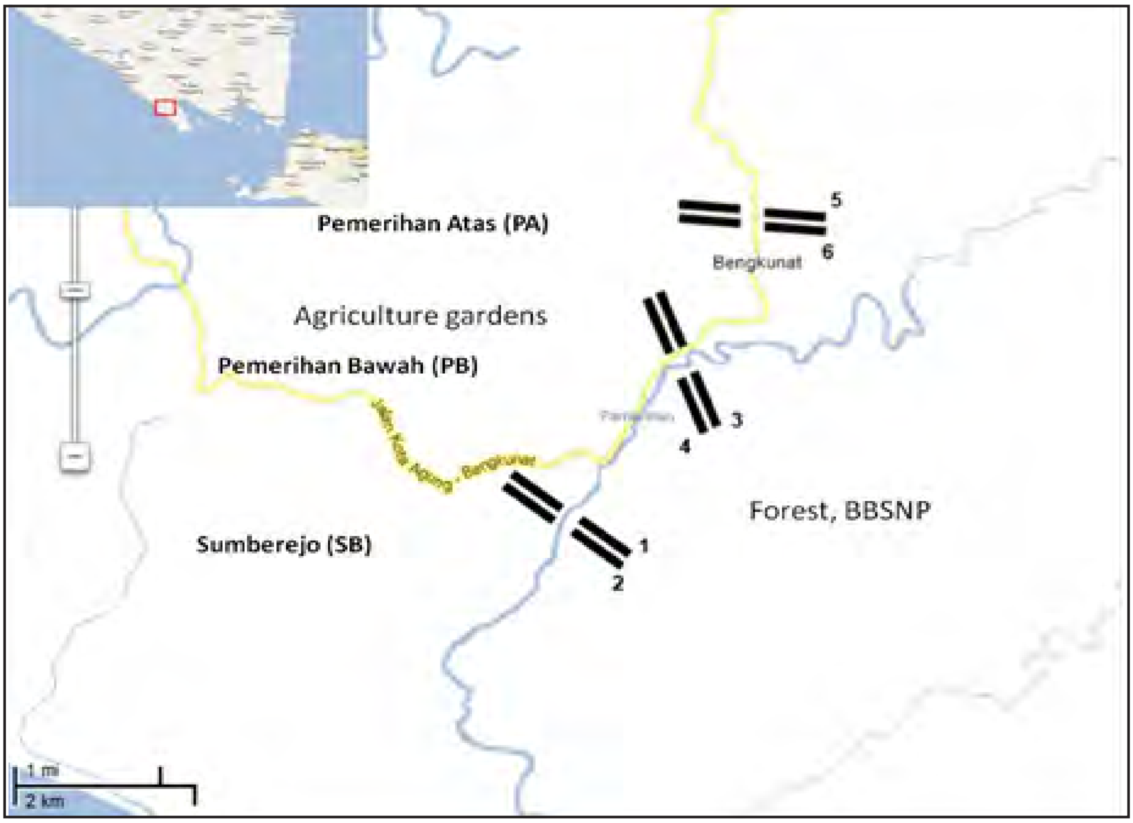

Figure 1. Study area in Pemerihan area of the Bukit Barisan Selatan National Park (BBSNP) with position of transects along forest within the park and agricultural gardens

serious encroachment (Suyadi and Gaveau, 2007). The three study sites were at Sumberejo, Pemerihan Atas and Pemerihan Bawah, with study plots setup in the ecotone between forest edge and agricultural fields.

Bird Survey

Bird surveys were conducted using point counts (Bibby et al., 2000). We selected three sites (Pemerihan bawah, Pemerihan atas, and Sumberejo) and setup monitoring plots (transects) along the forest edge of Bukit Barisan Selatan National Park around the Pemerihan area. Two transects of 2km at each site were set up at both side of the edge at positions parallel to each other (Fig.1). Points were set up on the bird survey transects at 200m interval. Bird point counts were carried out for 10 minutes at each point. Surveys were carried out for during July-September 2012.

Vegetation survey

Concurrently with the bird surveys, we set up 72 Point-Centered Quartered (PCQ) plots with 20m radius following Shukla and Chandel (1996). PCQs were divided into four quadrants and habitat variables were identified and quantified within these. At each PCQ we identified the four nearest trees to the centre and recorded the species, diameter at breast height (DBH), distance from the central point, canopy openness and the under-storey vegetation density. At the four nearest trees, we conducted phenology observation during three months of survey (July-September 2013) by estimating the proportion of flowering and fruiting in the canopy. This was estimated using four categories (1 = 0 – 25%; 2 = 26 – 50%; 3 = 51 – 75%; 4 = 76 – 100%) following Kinnaird et al. (1999).

Vegetation analysis

Principal Component Analysis (PCA) was used to determine the main characteristics of vegetation structures and habitat types. Vegetation structures used for the analysis were canopy openness, under-story density, mean girth of large trees, number of cultivated trees, and flower and fruit phenology during July – September 2012. The

Table 1. Habitat structure at the border of BBSNP

Location	Forest PA	Forest PB	Forest SR	Agri PA	Agri PB	Agri SR
Tree girth (m) (average)	16.31	15.16	16.75	17.73	16.99	15.63
Distance of trees (m)	2.46	2.76	3.00	2.38	2.68	1.97
Canopy openness	0.09	0.36	0.06	0.34	0.44	0.59
Understorey	0.59	0.66	0.61	0.12	0.10	0.12
Count of % Flower 1	0.00	2	1	9	21	16
Count of % Fruit 1	1	13	0.00	9	22	19
Count of % Flower 2	4	5	7	17	28	5
Count of % Fruit 2	10	14	4	12	26	12
Count of % Flower 3	7	10	10	14	24	10
Count of % Fruit 3	3	7	8	17	26	14
Total plant species	29	26	32	9	10	7
Coffea robusta	0	0.00%	0	10.83%	4.17%	18.33%
Erythrina - pepper	0	0.83%	0	10.83%	5.00%	12.50%
Cacao	0	2.50%	0	10.00%	23.33%	1.67%

PA = Pemerihan Atas, PB = Pemerihan Bawah, SR = Sumberejo

Table 2. Principal component of vegetation structure in the two habitats with factor loadings > 0.40

	PC1	PC2	PC3
Eigen Value	4.09	3.00	1.63
% of Variance	31.45	23.08	12.52
Cumulative %	31.45	54.53	67.05
Average of % Fruit (Sep)	0.82		
Average of % Flower (Sep)	0.79		
Average of % Fruit (Aug)	0.74		
Cacao (count)	0.74		
Average of % Fruit (Jul)	0.72		0.45
Average of % Flower (Aug)	0.68		
Average of % Flower (Jul)	0.59	0.49	
Cultivated plants (count)		0.86	
Erythrina - pepper (count)		0.81	
Average of understory plants (%)		-0.77	
Coffea Arabica (count)		0.63	0.52
Average of DBH (cm)			-0.77
Average of Canopy openness (count)		0.40	0.55

first and second Principal Component (PC) scores were plotted graphically. We used Discriminant Function Analysis (DFA) to determine the rate of vegetation structure misclassification between habitat types to identify the degree of overlap between the forest and agricultural gardens.

Bird Analysis

The bird communities from the different habitat types were compared using Shannon-Wiener and Simpson Indices (Magurran, 2004). We used t-test to test for any differences in abundance of the three bird guilds at two habitat types. Bird assemblages within the two habitat types were categorised by guild abundance (1 = frugivores, 2 = partial frugivores/insectivores, 3 = nectarivores) at the inner forest, the middle and edge of the forest, the edge of agriculture/forest, the middle of agricultural fields, the outer of agriculture fields, strata (1 = terrestrial and under-storey, 2 = mid-canopy, 3 = canopy) and morphological cue (1 = indistinct, 2 = intermediate, 3 = distinct). The data were then clustered using hierarchical clustering and tested by DFA. Results from these analyses were tested using binary logistic regression to evaluate, if the presence-absence of a particular species was correlated to habitat structures such as DBH of four nearest trees, average distance of four nearest trees, canopy openness, under-storey, and presence of cultivated trees in the study plots. The occurrence of bird species was calculated using Indicator Value (IV) following Dufrene and Legendre (1997).

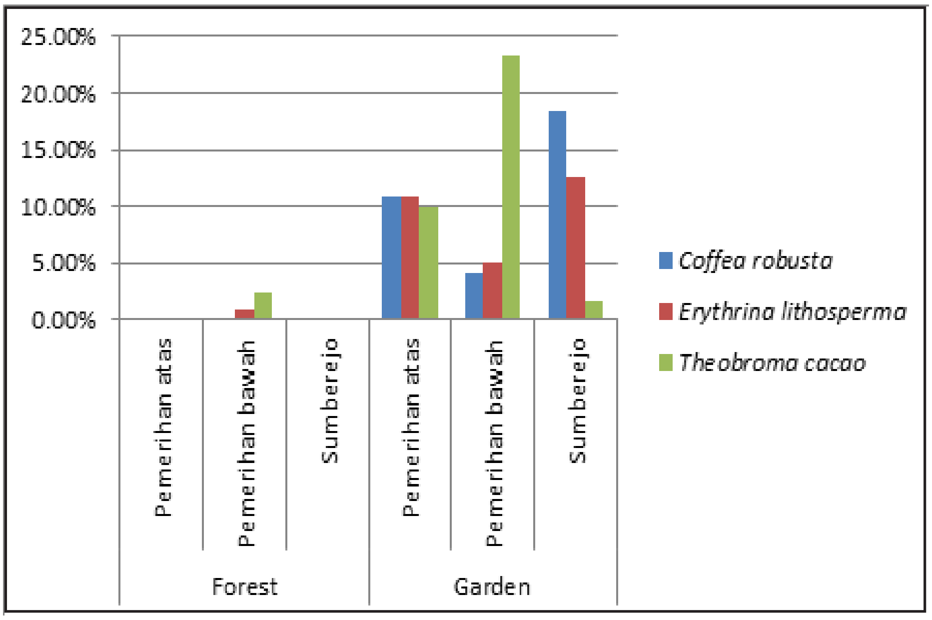

Figure 2. Percentage of dominant cultivated plants in the forest edge and agriculture gardens

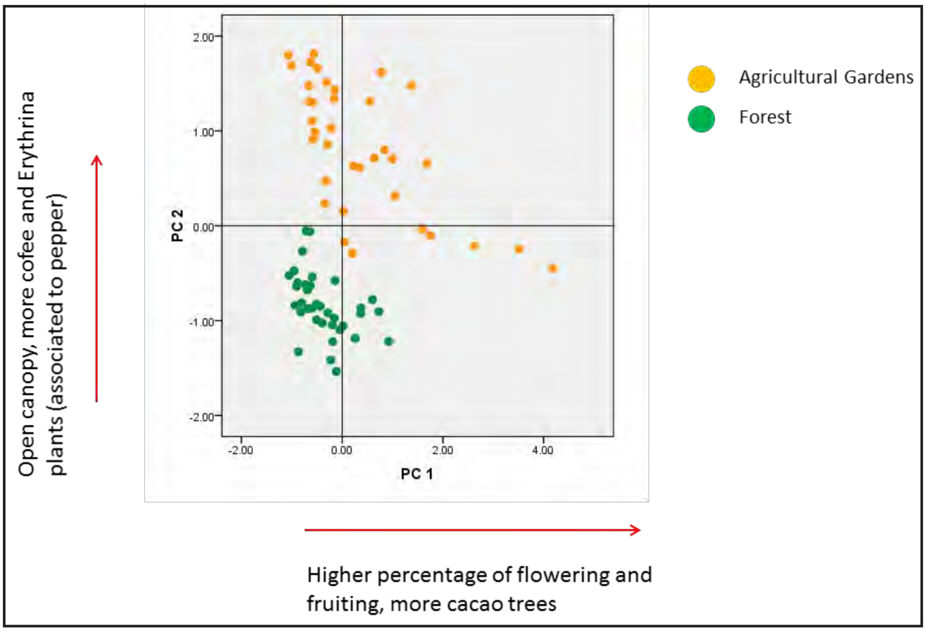

Figure 3. Distribution of vegetation plots along PC1 and PC2 of the Principal Component Analysis

Results

Habitat structure on forest edge

We recorded 69 species of tree species in the forest transects and 13 tree species in agricultural garden transects. All trees in the agricultural plots were cultivated trees (Appendix 1). Three cultivated plants, coffee, *Coffea robusta* (83.3%), *Erythrina lithosperma* (70.8%), and cacao, *Theobroma cacao* (87.5%) were the most common tree species in the agricultural gardens

(Fig. 2; Tab. 1). Cultivated plants such as *E. lithosperma* (31.2%) and cacao (6.25%) were also recorded in the forest area. The *Erythrina* trees were used to support pepper plants (*Piper aduncum*).

Although cultivated trees were recorded in the forest plots, the PCA analysis suggested that there was clear demarcation between forest and agriculture fields. Flowering and fruiting were mostly recorded in the agriculture fields (Table 1). Principal Component Analysis (PCA) showed that each component explains only a small percentage of the original variation and that the four together explain less than 69% of the variation and that the three together explain 67% of the variation (Table 2; Figure 3). The first component was characterized by higher flowering and fruiting and higher percentage of cacao. The second component represented the open areas dominated by cultivated trees (Coffee and Erythrina trees). The distinct separation between forest and agriculture fields was also supported by the Discriminant Function Analysis that suggested 98.6% of point count sites were correctly assigned to their habitat types. The classification success ranged between 97.2 – 100%.

Bird structure and composition

We recorded 47 bird species (frugivores, partial frugivores-insectivores, nectarivores) (Appendix 2) of which most were considered to be generalist. Rhinoceros hornbill (*Buceros rhinoceros*) and helmeted hornbill (*Buceros vigil*) were recorded in the forest edge, but not observed in agriculture gardens. Bird diversity in the forest sites and agriculture gardens were similar (Fig. 4; Shannon diversity index t = - 0.643, df = 4, P > 0.05; Simpson diversity index t = -0.194, df = 4, P > 0.05). The number of partial frugivores-insectivores was higher than frugivores and nectarivores. Black-capped bulbuls (*Pycnonotus melanicterus*) were recorded mostly in the forest, while the agricultural gardens was dominated by Sooty-headed bulbuls (*Pycnonotus aurigaster*) and Yellow-vented bulbuls (*Pycnonotus goiavier*).

The cluster analysis put the bird assemblage into two separate groups (Fig. 5). The first group contained the most species recorded in the survey without specific characteristics. The second group was mostly Pycnonotidae, which was abundant around the edge and agriculture, such as *P. aurigaster*, *P. goiavier* and *P. melanicterus* (Fig. 5). The results from testing the three species using binary logistic regressions showed that both *P. goiavier* (66.7% correctly classified, P = 0.011) and *P. aurigaster* (70.8% correctly classified, P = 0.041) were correlated to the average distance to the nearest trees, while *P. melanicterus* was not significantly correlated to habitat structures (P = 0.117).

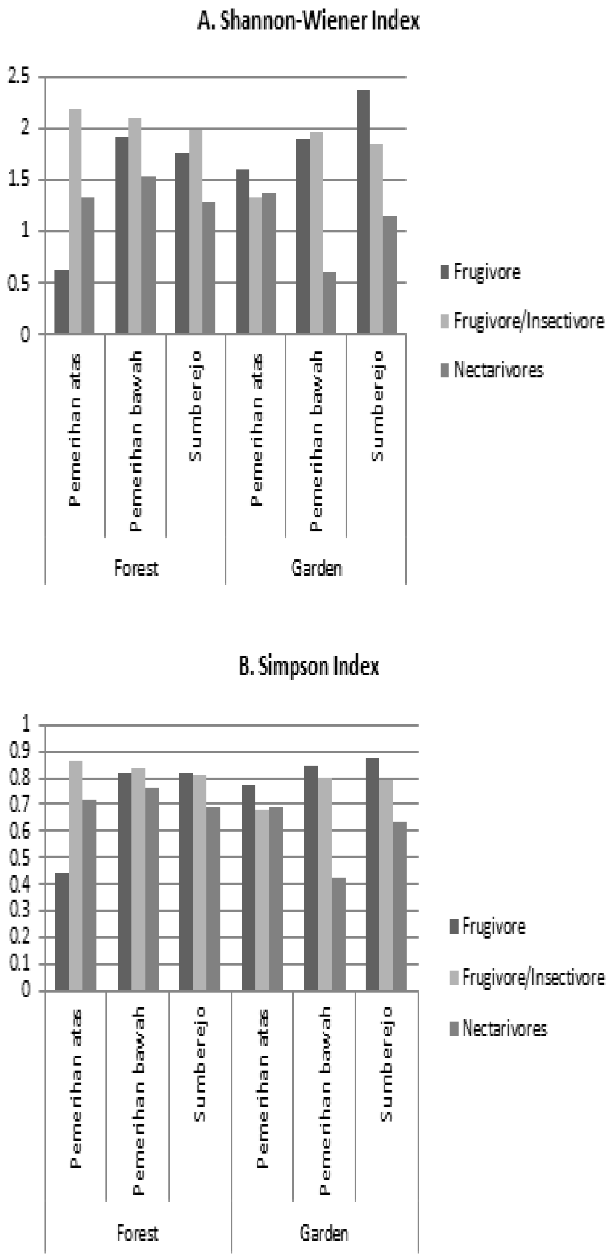

Figure 4. Diversity indices (Shannon-Wiener's and Simpson's) of birds within forest edge of BBSNP

Similar results were evident from the Indicator Value. Sooty-headed bulbuls were present at 75% of all plots indicating the high IV, while in the forest the IV for all species was less than 50% in all plots. Black-capped bulbuls were more common in forest plots. A complete list of birds including the Indicator Value (IV) is presented in Appendix 2.

Discussion

Bird structure on forest edge

Birds often have very specific habitat preferences (Cody, 1985) and changes to the tree density, and floristic composition will affect the composition of the bird community and the predominance of different bird guilds (Barlow et al, 2006; Duncan, 2006 ; Holl, 1999; Raman et al., 1998; Sekercioglu et al. 2002; Traveset et al., 2012). The forest edge, however, was not attractive to nectarivores bird species, but to "partial frugivores" species that also consume insects (Corlett and Hau, 2000). Plants within the agriculture sites seemed to offer a higher volume of nectar producing flowers than the forest (Table 1), although this did not affect the number of nectarivores species present in our study sites.

Several species of bulbuls (Pycnonotidae sp.) are known for their tolerance for human-disturbed areas and secondary forest (Corlett and Hau, 2000). As facultative frugivore consumers, bulbuls are important seed dispersers and colonists (Corlett, 1988) as they eat the small fruits of pioneer trees (Thornton, 1997). Their high abundance in the forest edge may be an indicator that regeneration of the forest edge is slowly taking place. Thornton (1997) described that two bulbul species, the Sooty-headed bulbul (*P. aurigaster*) and the Yellow-vented bulbul (*P. goiavier*) were the first to colonise Krakatau island within the first 25 years after eruption, they may be able to carry seeds long-distance. In our study, the tree bulbul species, including the Black-capped bulbul (*P. melanicterus*), were the most common species along the edge of the national park.

The high abundance of Black-capped bulbuls at the forest edge suggests that the species could play an important role in restoration of secondary forest (Wunderle, 1997). Forest edge may be able to attract seed dispersing birds depended on agricultural gardens, where food availability remains high (Parrotta et al., 1997). Corlett and Hau (2000) added that proximity of fruiting trees is important to attract seed dispersers, although this study suggested that many species made use of resources available in agricultural gardens.

The presence at high abundance in the forest edge may be an indicator of regeneration function of forest edge. This is supported by the highest IV. Structural complexity which depicted by the closed canopy, dense under-story, no or less agricultural plants were important forest characteristics that attract bird species (Wunderle, 1997). The forest may also attract frugivory (Janzen, 1988), although this should be further studied as this is related to the presence of wind-dispersed versus animal-dispersed trees.

Implication to forest edge of national park

Seed dispersing birds constitute one of the important factors that can help accelerate the natural regeneration of a forest (Caves et al, 2013; Clout and Hay, 1989; Duncan and Chapman, 1999; Hardwick et al., 2004; Padilla et al, 2012; Sekercioglu, 2006). Sooty-headed and Yellow-vented bulbuls are known to prefer habitat with close spacing of trees with an abundance of perching sites (Gorchov et al., 1993; Medellin and Gaona, 1999). The presence of known seed dispersing bird species suggests that the habitat at our forest study site is attractive to these species, and that regeneration may take place in the area.

The area around Pemerihan at the boundary of Bukit Barisan Selatan National Park has been subject to illegal logging since 1998 (Suyadi and Gaveau, 2007). The presence of cultivated plants within the forest at the edge suggests that, while deforestation is a threat to the Pemerihan area, according to Hardwick et al. (2004) the presence of seed-dispersing birds is accelerating the natural regeneration process within the area.

The lowland habitats of BBSNP have been subjected to deforestation at a higher rate than hilly areas (Kinnaird et al., 2003), and the clear demarcation between the forest and agricultural plots can be considered positive. Cultivated trees were mostly confined to agricultural gardens, although some pepper trees have invaded the forest at the boundary. Canopy openness and under-story density were reciprocal between forest and agricultural gardens. Forests around the edge of BBSNP have more structural complexity with dense under-story, offering more ecological appeal to seed dispersers. In addition, this separation seemed to support habitat segregation among the three bulbuls, in which the Black-capped bulbuls were more confined to forest edge, while the other two species were more abundant in agricultural gardens. The Black-capped bulbul is probably the first species to colonize degraded forest (Corlett and Hau, 2000). Therefore the fate of the remaining forest may be depended on the presence of seed dispersal agents.

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