Assessment of Surrogate of Ecosystem Health Using Indicator Species and Mixed-Species Bird Flock

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ABSTRACT

Investigation of the use of indicator species as a surrogate for ecosystem health was conducted during 2014 in the periphery of the Bukit Barisan Selatan National Park, Lampung, Indonesia. The survey area composed of forest, edge, and agricultural areas in three sites at the Pemerihan village. We used point count for bird surveys within 1 km transect to obtain the data and ad-libitum observation for mixed-species bird flock. The analysis was made by using Indicator Value (IV) to select the potential indicator species which complemented how mixed-flock groups formed at the sites and further analyzed by using principal component analysis. Among 127 species recorded, one species has been identified with high IV (IV>60) and 15 species have intermediate IV (30<IV<60). Our results suggested that Sooty-headed Bulbuls *Pycnonotus aurigaster* are the species with the highest IV which are exploiter species and indicator for agricultural gardens. Moreover, none of the birds with highest IV overlap among habitats, which indicate that proportions are very specific in terms of habitat types. Based on principal component analysis, mixed-flocks tend to comprise of edge-to-forest species and formed at edge which may indicate food availability in the area.

1. INTRODUCTION

Bukit Barisan Selatan National Park (BBSNP) is the third largest National Park in Sumatra containing the largest intact lowland forest in Sumatra with 365,800 ha in extent (O'Brien and Kinnaird, 1996). Although being the home of many large threatened wildlife species including Sumatran elephant (*Elephas maximus*), Sumatran tiger (*Panthera tigris*), and Helmeted hornbill (*Rhinoplax vigil*), the park suffers from illegal logging especially at forest edges (Gaveau, 2007). The elongated park has created more forest area adjacent to community through agricultural gardens which intensify habitat changes along the edge and therefore affected the bird communities.

Because of the responses of birds to habitat change, birds have been widely used as surrogate or represent environmental condition or ecosystem health. A healthy ecosystem suggests the absence of signs of ecosystem distress which is stable and sustainable in terms of maintaining the structure and function (Rapport et al., 1998). Selecting an appropriate indicator in a monitoring program is useful as an early warning system when the ecosystem is altered, and may help understanding of the cause of the alteration, and a continuous assessment over a wide range of pressures (Noss, 1990; Carignan and Villard, 2002). The basic requirement to meet Indicator Species is that the indicator should be able to reflect the environmental changes directly and should be linked to management purposes (Gardner, 2010). While there are many different methods, such as ordination methods (Kremen, 1992; Chase et al., 2000), to select indicator species, Dufrene and Legendre (1997) suggested a simple approach by combining species relative abundances and frequency of occurrences at various sites. By combining these two features, species selected as indicators would be able to avoid the three principal elements of indicators such as poor ecological knowledge, difficulty in linking changes in biodiversity to management impacts and technical difficulties of sampling biodiversity (Gardner, 2010).

Insectivorous birds are commonly used as indicators as they are more sensitive to land conversion and forest ecological changes (Laurance, 2004). In the tropical rainforests, many insectivores

join the mixed-species flocks in which the formation is to enhance foraging to find rich-food areas or predator avoidance (Powell, 1985). The unique behavior of the flocks includes formation of the mixed-flock, membership as well as interaction among member species. Insectivorous birds are usually the main component of mixed-species flocks which are usually more stable than frugivorous birds (Powell, 1985; Stutchbury and Morton, 2001).

While there are more studies on the sociobiology of mix-species flocks including the flock characteristics and composition, territoriality, etc., there is limited information on where the mix-species flock form in terms of habitat condition. Previous studies in Sumatra on mixed-species bird flocks described the interspecific interaction (Thiollay, 1999) and mixed-flock composition (Marthy, 1998; Marthy, 2005). There are tendencies that flock formation occurred in degraded forest which caused by low resource availability (Develey and Peres, 2000; Lee et al., 2005). Maldonado-Coelho and Marini (2000) suggested that flock species richness and size are affected by age of forest fragments. However, there is a little evidence on specific cases of the formation of mix-species flocking caused by habitat condition. Therefore, in this study we evaluated the use of indicator species as a surrogate for ecosystem health and investigate the use of indicator value (IV) to assess mixed-species bird flock as an indicator of habitat disturbance.

2. METHODOLOGY

Research was conducted in Bukit Barisan Selatan National Park (BBSNP), Sumatra during June-September 2012. BBSNP is the third largest conservation area (3.568 km^2) in Sumatra and located in the southwest of Sumatra that includes two provinces, Lampung and Bengkulu (O'Brien and Kinnaird, 1996). As the largest remaining lowland rainforest in Sumatra, BBSNP contains a high diversity of wildlife including some endangered mammals, such as the Sumatran tiger (*Panthera tigris*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*), primates and more than 200 species of birds. BBSNP contains some of the largest remaining lowland rainforest channels in Sumatra and functions as the main watershed for Sumatra power (O'Brien and Kinnaird, 1996).

Research was carried out around the Pemerihan river around the border of BBSNP (Lat: -5,61527045; Lon: 104,3930,6726) where encroachment occurs (Gaveau, 2007). The study sites are located in three locations, Sumberejo, Pemerihan Atas and Pemerihan Bawah. The plot is in the ecotone area between the edge of the forest and other ecosystems such as plantation land. In each location, two transects are provided with a length of 2 km each, divided into 1 km in the agricultural area and 1 km on the edge of the forest (Figure 1).

2.1 Bird survey

We conducted bird survey by using point counts (Bibby et al., 2000). We selected 3 sites (Pemerihan bawah, Pemerihan atas and Sumberejo) and set up monitoring plots (transects) along the forest edge of BBSNP particularly in the Pemerihan area. The plots were on the ecotone between forest edge and other ecosystem type such as agricultural fields. Two transects of 2 km at each site were set up at both side of the edge at positions parallel to each other. Points were set up at 200 m intervals on the transects for bird surveys. Bird point counts were carried out for 10 minutes at each point. Surveys were carried out during July-September 2013. For subsequent analysis, data were divided into forest (forest transects 400, 600, 800 and 1000 m), edge (forest transects 0 and 200 m; agriculture transects 0 and 200 m) and agriculture sites (agriculture transects from 400, 600, 800 and 1000 m).

In addition, we used ad-libitum to observe the composition of birds that may interact in the mixed-flock (Martin and Bateson, 1986). Observations were made by exploring transects and surroundings. Whenever groups of birds were detected, observer will follow the group up to 15 minutes. Observers recorded the data using voice recorder to focus on the object (Morse, 1970). Data collected included time of observation, bird species, number of individuals, the distance of bird from observer, location, stratum and tree species when the birds perched.

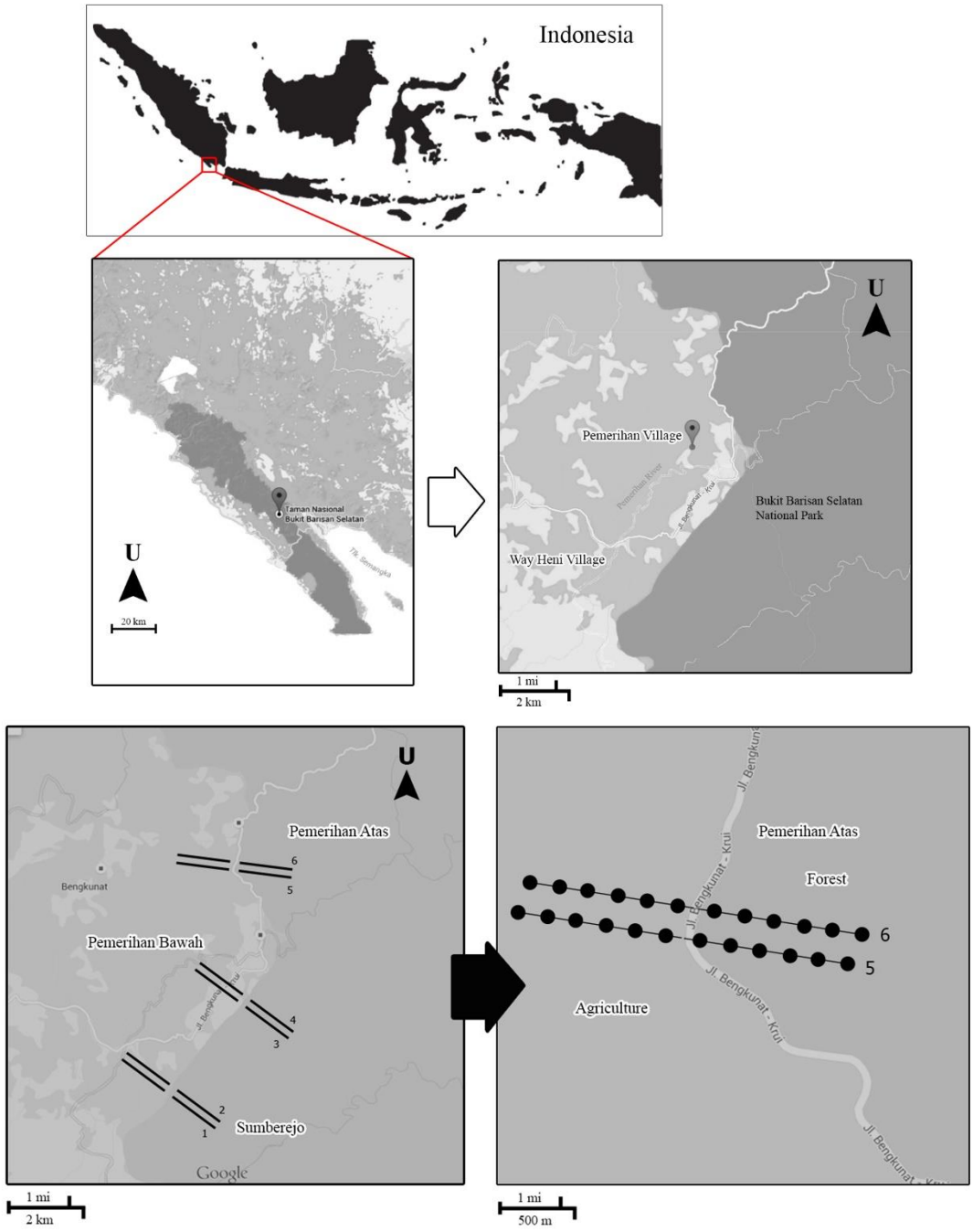

Figure 1. Map of study area and transects arrangement

2.2 Analysis

We used Indicator Value methods to select indicator species (Dufrene and Legendre, 1997) which combines relative abundance and relative frequency, therefore combining both abundance and occupancy. Indicator Value has been applied to various taxa such as plants, butterflies and birds (Slik et al., 2003; Kati et al., 2004; Venier and Pearce, 2005). We calculated IV for each species for the three sites, forest, edge and agriculture.

$$IV_{ij} = A_{ij} \times B_{ij} \times 100$$

IV_{ij} = Indicator value of species i in habitat j
A_{ij} = Relative abundance of species i in habitat j
B_{ij} = Relative frequency i in habitat j

Birds were then categorized into mixed-flock member, encounter rates, presence at forest, edge and agriculture as well as species categories. Species categories were based on hierarchical

clustering of encounter rates (ER) at forest, edge and agriculture which are divided into 6 categories: 1) Forest interior specialist or avoider (the species which are more abundant in the forest); 2) Agriculture interior specialist or avoider (the species which are more abundant in the agriculture area); 3) Edge specialist or exploiter (the species which are more abundant in the edge); 4) Well-adapted at forest (the species which are evenly abundant in the forest and the edge); 5) Well-adapted at agriculture (the species which are evenly abundant in the agriculture area and the edge); 6) Generalists (the species which are evenly abundant in three areas: forest, edge and agriculture area) (Nuruliawati and Winarni, 2014). Then we used principal component analysis (PCA) as it has been used in investigating species community arrangement (Holmes et al., 1979; Holmes and Recher, 1986) to see how the bird communities assemble into mixed-flocks based on encounter rates and IVs. We also presented the PCA graphically based on whether they are mixed-species flocks or not, as well as the species categories. The whole analysis was conducted using SPSS.

3. RESULTS AND DISCUSSION

3.1 Overall community and indicator value

In total, we have recorded 127 bird species (Appendix 1) which included some forest interior birds such as Great argus pheasant (*Argusianus argus*), Helmeted hornbills (*Rhinoplax vigil*) and banded pitta (*Pitta guajana*), to urban birds such as Sooty-headed Bulbul (*Pycnonotus aurigaster*). By looking at the highest IV, the bird composition among the three areas are quite different. The forest area has four species with high (>60) to intermediate IV (30<IV<60) whereas the agriculture area composed of nine species. In the other sides, the edge has the lowest number of species with only three species which has high to intermediate IV (Table 1). Among all recorded species, only one species Sooty-headed Bulbul has high IV and another 15 species have intermediate IV (Table 1). Little Spiderhunter (*Arachnothera longirostra)* is identified as the species which has the highest IV in the forest area, while in the edge is Black-capped Bulbul (*Pycnonotus melanicterus)* and Sooty-headed Bulbul in the agriculture area.

3.2 Principal component analysis of mixed-species flocks

Among all the species recorded, 72.44% are non-mixed flock species and 27.56% are among the mixed-flock members. From 16 species with the highest IV, 11 species were mixed-flock members and only Raffles' Malkoha (*Phaenicophaeus chlorophaeus*) listed as core species (Table 1).

Composition of birds joined the flocks includes edge species (39%), forest species (33%) and agriculture-associated species (27%). Principal component analysis (PCA) showed the components altogether explain 62% of the variation. This is confirmed with the PCA with the first component characterized by mixed species composition which include species with higher encounter rate (ER) at agriculture and edge, higher IV at agriculture and mixed-species member at agriculture. Second component characterized by species with high ER and high IV of forest species. A plot of the sampling points using PC1 and PC2 as the axis showed a clear separation of the mixed-flock species and non-flock species (Figure 2).

Mixed-flocks tended to form at edges particularly in agriculture area. Mixed-flock species mostly composed of edge avoider i.e., forest interior specialist (14.3%) or agriculture interior specialist (25.7%) and edge specialists (exploiter) (52.4%), but never a generalist. Only a few forest interior specialists such as Little Spiderhunter (*Arachnothera longirostra*), Red-throated Barbet (*Megalaima mystacophanos*), Raffles's Malkoha (*Phaenicophaeus chlorophaeus*), Yellow-breasted Flowerpecker (*Prionochilus maculatus*) and Large Woodshrike (*Tephrodornis gularis*) joined the flocks.

3.3 Evaluation of indicator value

The Indicator Value method seemed suitable to evaluate ecosystem health in the forest edge of BBSNP. Birds with the highest IV were never overlapped among habitats. This result is confirmed by Ramadhan and Winarni (2015) which suggested that forest and agriculture habitat in Pemerihan area (BBSNP) are significantly different in their habitat structure (canopy openness and understory density). This indicated that proportions of bird's abundance are very specific in terms of habitat types and that

they can serve as surrogate for each habitat. Winarni and Wijoyo (2014) suggested that three bulbul species, the Black-capped Bulbul (*P. melanicterus*), Sooty-headed Bulbul (*P. aurigaster*) and Asian Red-eyed Bulbul (*Pycnonotus brunneus*) dominated the bird species composition along the forest edge.

Sooty-headed Bulbul is considered an agricultural interior specialist living in agricultural gardens with human disturbance proximity (Winarni and Wijoyo, 2014) whereas Little Spiderhunter usually avoid disturbance which was more observable in the forest area which may be associated to higher breeding success (Sodhi, 2002). Although some coffee plants were found within the forest (Ramadhan and Winarni, 2015), the clear demarcation between forest and agriculture may suggested that the forest is much preserved. However, edge effect as a result of human disturbance may occur up to 500 m (Dale et al., 2000). Species such as Great argus pheasant (*Argusianus argus*) may avoid forest edge as it prefers intact forest (Winarni et al., 2009). Further anthropogenic influence however, should be controlled over forest edges to avoid habitat alteration because different forms of habitat alteration lowering bird abundance (Raman and Sukumar, 2002). By monitoring the selected indicator species, that habitat alteration can be detected.

3.4 Mixed-species bird flock as an indicator of habitat disturbance

Besides Indicator Value, the evidence of mixed-species flocks strengthened the evaluation of ecosystem health. In BBSNP, without differentiating forest-edge-agriculture, mixed-species flocks tend to form at agriculture area rather than forest (Afifah, 2014). In more detail, mixed-species flock in Pemerihan of BBSNP tended to form at edge particularly next to agriculture area. This means the food resource may be scarce due to microclimatic changes (Ford et al., 2001). At the edge, a wall of vegetation composed of tree saplings is usually formed. Tree mortality was usually increased due to changes in micro-climate (Williams-Linera, 1990). In the forest edge of BBSNP, forest is denser with closed canopy than agricultural gardens (Ramadhan and Winarni, 2015). Marthy (1998) also found that mixed-species flocks were observed more when insect abundance was low in the forest. Thus, joining mixed-species flocks will increase foraging efficiency. Lee et al. (2005) suggested that flocking species sensitive to disturbance were composed of Corvidae, Nectarinidae and Sylviidae. While these groups also joined mixed-flocks in this study, species composition may vary from the previous study (Lee et al., 2005). Variation of land conversion adjacent to forest may have an impact on flock formation due to the composition of vegetation. Thiollay (1999) found that mixed-flock formation occurred in plantation composed of rubber (*Hevea brasiliensis*) and *Shorea javanica* (Thiollay, 1999) while in Pemerihan, the agriculture area composed of mix vegetations such as maize (*Zea mays*), cacao (*Theobroma cacao*), coffee (*Coffea* sp.) and *Erythrina lithospermum* (Afifah, 2014).

The Indicator Value, which composed of proportions and abundance, however, did not seem to provide important value to PCA of mixed-flock species as flock members are usually composed of interactions of variety of species. This suggested that mixed flock may be composed of abundant to low abundant species. Greig-Smith (1978) suggested that the abundance of a species has no correlation with number of flocks joined. A combination of Encounter Rate at different habitat may better describe the member of mixed flocks.

Table 1. List of selected species with the highest indicator value (IV>30) at forest, agriculture and edge (highest IVs are indicated in bold), as well as their membership in flock (1=mixed-flock species, 0=non mixed-flock species).

Species	IV forest	IV agriculture	IV edge	Mixed flock
Arachnothera longirostra	**46.26**	1.36	14.56	1
Cacomantis merulinus	1.39	**36.11**	11.46	1
Dicaeum trigonostigma	0.42	**50.72**	29.62	1
Eurylaimus ochromalus	**41.67**	0.16	4.01	0
Lonchura leucogastroides	0.00	**36.04**	2.25	0
Megalaima mystacophanos	**30.17**	6.54	15.88	1

Table 1. List of selected species with the highest indicator value (IV>30) at forest, agriculture and edge (highest IVs are indicated in bold), as well as their membership in flock (1=mixed-flock species, 0=non mixed-flock species) (cont.).

Species	IV forest	IV agriculture	IV edge	Mixed flock
Nectarinia jugularis	2.75	**55.83**	8.25	1
Orthotomus ruficeps	1.45	**46.50**	28.74	1
Phaenicophaeus chlorophaeus	**43.33**	0.00	3.33	1
Picoides moluccensis	0.00	**55.74**	1.35	1
Platysmurus leucopterus	12.21	0.19	**39.24**	1
Prinia familiaris	0.10	**30.56**	7.74	0
Pycnonotus aurigaster	0.13	**65.92**	17.28	0
Pycnonotus brunneus	4.97	3.08	**38.35**	1
Pycnonotus goiavier	0.60	**40.86**	36.70	0
Pycnonotus melanicterus	18.25	16.58	**43.06**	1

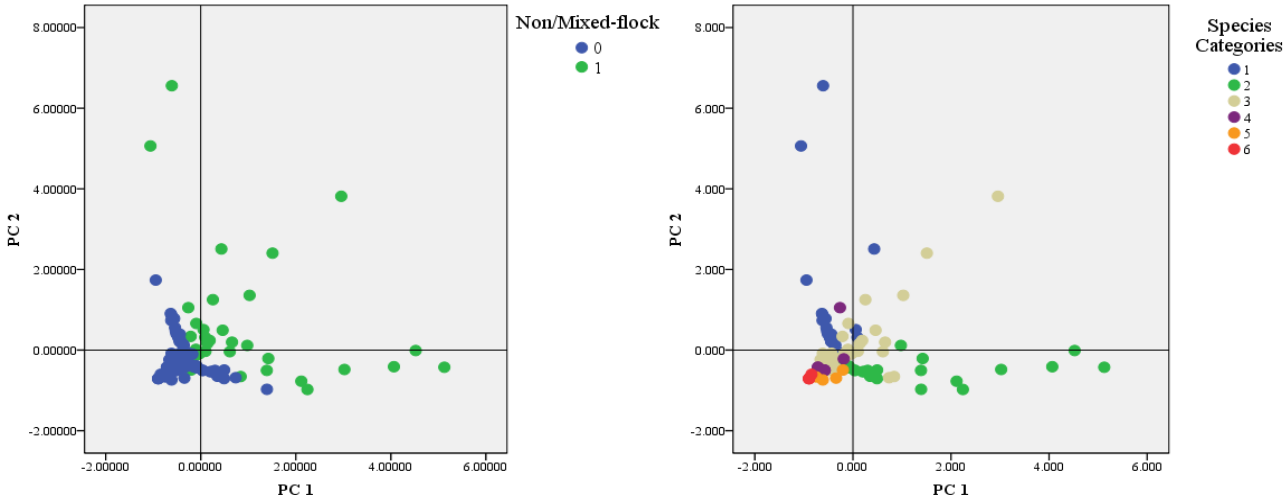

Figure 2. PCA of bird community in the forest edge of BBSNP showing grouping of non and mixed-species flocks (left) and grouping of species categories (right) (Categories: 1=Avoider-forest interior specialist, 2=Avoider-agriculture interior specialist, 3=Exploiter-edge specialist, 4=Well-adapted at forest, 5=Well-adapted at agriculture, 6=Generalist).

4. CONCLUSIONS

This study evaluated the use of indicator species as a surrogate for ecosystem health, and investigated the use of indicator value (IV) to assess mixed-species bird flock as an indicator of habitat disturbance. The results showed that Indicator Value can be used to assess ecosystem health by selecting indicator species associated to different habitat condition. This study has identified Sooty-headed Bulbul (*Pycnonotus aurigaster*), Little Spiderhunter (*Arachnothera longirostra)*, and Black-capped Bulbul (*Pycnonotus melanicterus)* for agriculture area, forest, and edge consecutively suggesting that they are indicators for each habitat. In addition, mixed-species flocks may also serve as surrogate for forest edge as they tended to form at edge. Mixed-species flocks tended to be composed of edge specialists, followed by agriculture interior specialists and forest interior specialists. This suggests that areas surrounding the forest edge provide less food source for the bird community. However, Indicator Value is insufficient when applied to mixed-species flock analysis using PCA. Monitoring is needed to ensure the validation of indicator species performance as well as further research to verify mixed-species flocks as indicator for habitat alteration.

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