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Edge Effect on Bird Community in Ternate, North Maluku, Indonesia

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Abstract

The edge is a meeting place between two ecosystems, or it can also be interpreted as a boundary where two habitats meet and interact. The presence of edges can create an edge effect and increase richness and species abundance. In the present study, we analyzed how edge and vegetation diversity affect a) bird communities and b) how birds respond to edges. Observation plots were placed in jamblang stands and coconut plantations (*edge and interior*)*. Bird communities were observed using point counts with a fixed radius of 25 m, and the distance between plots was 50 m. A survey of vegetation diversity was conducted using a combination of the transect and plot methods. The research showed that the highest species richness and diversity of birds* (*128 individuals of 18 species*) *and vegetation* (*168 individuals of 20 species*) *were found at the edge, although there were only slight differences in the number of species in each habitat. This was influenced by the structure and composition of the vegetation at the observation site. Nevertheless, this proves that the edge effect shapes the composition of bird communities. There are 9 species of bird can be mapped into 4 response models: generalis neutral, generalist edge exploiter, specialist edge exploiter, and edge specialist.*

Keywords: *bird community, edge effect, vegetation composition, Ternate*

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Introduction

Because of habitat fragmentation, the global number of habitat edges is increasing. Road construction, housing development, agriculture intensification, and forest logging have been shown to lead to an elevated number of artificially created habitat edges (Fahrig, 2003). According to Mardiastuti (2015), the edge is a meeting place between two or more adjacent ecosystems, such as forests and the surrounding ecosystem, vegetation on the right and left of a road or river, stands that have different succession stages, and stands in plantation forests of different ages. The effect of edge can be due to a) changing abiotic conditions such as radiation influx, temperature, wind, and humidity; b) direct biotic effects resulting in changed abundance and distribution of a species caused by the physiological tolerance species; or c) indirect biological effects such as predator-prey interaction, parasitism, or competition (Murcia, 1995).

Edges can have a positive effect on bird life because of the increased abundance and species richness at forest edges (Johnston, 1947). Edge effects are likely to be most influential on narrow strips or small areas of habitat. Consequently, these are important issues for the management of corridors and small blocks. Larger areas are also vulnerable, where disturbances, construction, and other activities create edges. So far, there has been no consensus on the question of how far an edge effect can penetrate a habitat patch, for example, 200 m (Wilcove et al., 1986), <150 m (Laurence, 2000), 125 m (Tamnge, 2013), and 200 m to 1 km to deep forest (Canaday, 1997). Most studies found an edge effect penetrating no farther than 150 m into the habitat, presumably approximately 50 m from the edge (Batary & Baldi, 2004). Keyser et. al. (1998) found edge effect only in small, not larger forest, but Immanuddin (2009) and Dale et al. (2000) reported that abundance and species richness is not higher or lower increasing distance from edge to interior.

The number of vegetation species in a forest may have additional effects on bird diversity (Salek et al., 2010). Generally, there should be a positive relationship between habitat heterogeneity, such as increased tree diversity, and the diversity of associated species, such as birds (Balaz & Balazova, 2012). The assumption is that heterogeneous environments provide a greater number of habitat niches and environmental resources, leading to increased species diversity (Vivian-Smith, 1997)). In habitats dominated by one species, such as *jamblang* stands (*Syzigium cuminii*) and coconut plantations (*Cocos nucifera*), it is less species-rich than forests.

Ternate has several types of habitat, such as old mixed gardens, coastal forests, lakes, and coconut plantations. However, these habitats are like patches. However, we believe that these habitats can be used as alternative habitats for birds. We analyzed how the edge area and vegetation diversity in *jamblang* stands and coconut plantations affect a) bird communities and b) how birds respond to the presence of edges. We expected bird communities to respond to edge presence and vegetation diversity through abundance and bird diversity.

Methods

Study sites and plot selection The study was conducted in Tolire, which is located 10 km from the center of Ternate City. Administratively, Tolire is a part of Takome Village

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(Figure 1). Tolire has several types of habitat, such as *C. nucifera* plantations, *S. cumini* stands, Tolire lakes, and old mixed plantations. Observation plots were placed only in *jamblang* stands and coconut plantations (edge and interior). The *jamblang* is customary land belonging to the Sultan of Ternate. The Sultan gave permission to the local community to plant the land with *jamblang,* because it is a native species of the Ternate. Planting activities took place in 2005. Meanwhile, the coconut plantation that has been used as the observation location is owned by the community since 1992, which is located around the mount of Gamalama. This coconut plantation has long been abandoned by the owner, so the condition of the plantation almost resembles that of a secondary forest. The canopy in coconut plantations tends to be dense. Both research locations are patch areas with an area of less than 1 ha.

Data collection and analysis The study was conducted in Takome, which has an area of 16 ha and is located at an elevation of 8–200 m asl. Observation plots were placed in a coconut and *jamblang* plantation (interior) and edge habitat (transition area between *jamblang* and coconut plantation). This study was conducted from August to September 2021. Observational activities were conducted in the morning (6–9 am) and evening (15–18 pm). Repetition of observation in each habitat was carried out 14 times in 7 days, so the total observation of birds in the research site was 21 days (126 hours). Observations were not performed on rainy days.

Bird communities were observed using the poin count method (Bibby et al., 2000). The point count method is an effective census technique because a stationary observer has a greater chance of identifying and hearing birds even if the birds are in bushes. The observation time for all birds detected both visually and by sound was 10 minutes. Then, the next 5 minute was used to move to the next point. The distance between one plot to each plot was 50 m and the observation radius was 25 m (Figure 2). The zero distance between plots is considered so that bird identification can be done easily because the vegetation cover at the study site tends to be quite dense. Each observation location consisted

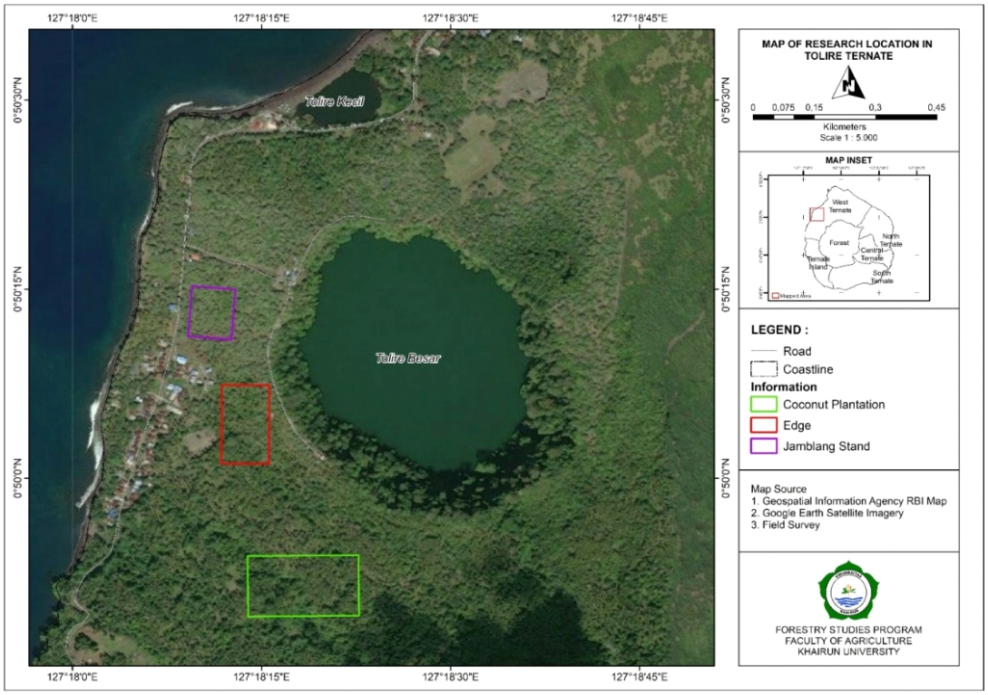

Figure 1 Map of bird watching locations in Tolire, Ternate.

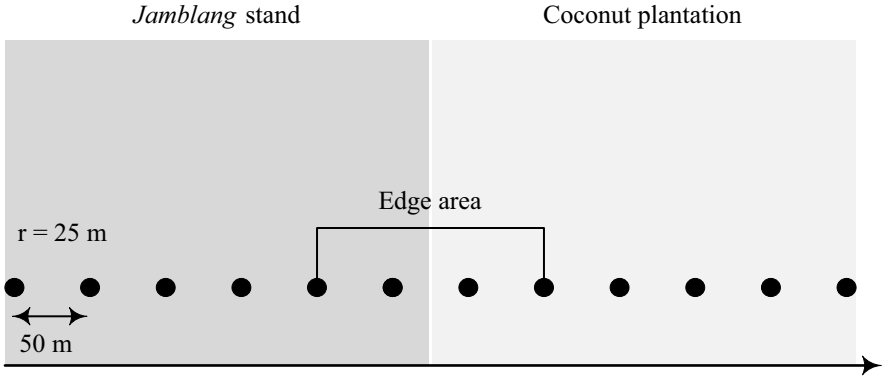

Figure 2 Ilustration of bird observation plot.

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of 10 points. Bird identification was performed using the field guide book of birds in the Wallacea Region (Coates & Bishop, 2000).

The vegetation was observed using a combination of transect and plot methods (Kusmana, 1997) (Figure 3). The size of plots for vegetation analysis in forested areas was differentiated according to the level of the growth group (Table 1). Vegetation observations for each habitat consisted of 5 plots. The purpose of vegetation analysis is to determine the distribution of various species in an area. Direct observations can help us determine the dominant vegetation in an ecosystem.

Species diversity of birds and vegetation was calculated using the Shannon-Wiener index of diversity (Magurran, 2004). The similarity analysis was calculated using the Bray Curtis index on the PAST.4 software. The analysis of bird responses to the edge refers to Sisk and Margules (1993). They categorized birds on the edge as generalist and specialist species. Generalist types are divided into three i.e.: a) edge neutral, b) edge exploiter, and c) edge avoider. Edge-neutral is a species that can be found in both edge and interior habitats. Meanwhile, edge exploiters are species that can be found in the interior, but the density increases towards the edge. Whereas, edge avoiders are species that can be found in interior habitat, but the density decreases in edge. Specialist species only occupy certain habitats and are not found in other habitats.

Vegetation inventory data were analyzed to determine species composition and dominance. The dominance of a species is indicated by the important value index (IVI). The IVI value was obtained from the sum of the values of relative density, relative frequency, and relative dominance.

Results and Discussion

Bird communities Altogether, we registered 328 bird individuals representing 24 species and 18 families at three habitats (Table 2). Each habitat had different types of birds. *Jamblang* stand had 87 individuals of 16 species, coconut plantation had 113 individuals of 17 species, and edge habitat had 128 individuals of 18 bird species (Table 3). The results showed that the edge habitat had a slightly higher number of species than the other habitats. The highest number of species was found at the edges. Based on the research results, the highest diversity is owned by the edge, while the lowest diversity is in the *jamblang* stand (Figure 4). Two species of seabirds were identified at the research location: *Fregata minor* and *Haliastur indus*. Both species were observed flying past the observation plots. This is because the plot location was approximately 500 m from the coast. According to Coates and Bishop (2000), *F. minor* was found throughout Wallacea and its breeds in February–September. Meanwhile, *H. indus* is the general determinant, and its distribution is from sea level to a height of 2,400 m asl.

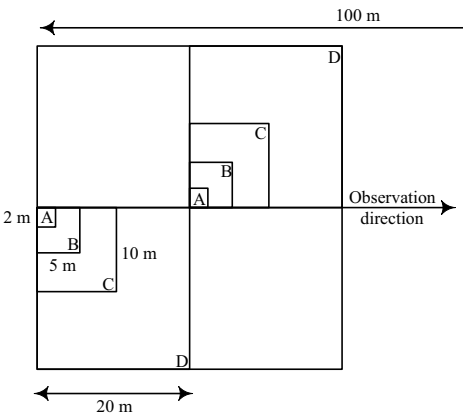

Figure 3 Shape and size of vegetation inventory.

The highest diversity and evenness index were observed in the edge habitat, followed by the coconut plantation and the *jamblang* stand. A higher diversity index indicates that species of birds in a habitat type are diverse, while a higher evenness index indicates that the proportion of individuals in a habitat type is evenly distributed. The proportion of individual values less than 0.5 shows that bird species have a number of outlier individuals. According to Desmukh (1992), diversity concerns not only species richness but also the evenness of the abundance of individuals of each species. He said that diversity becomes greater if the population abundance is the same as others. Begon et al. (2006) stated that species diversity is often used to determine the stability of a community.

The similarity index was used to determine the similarity of bird species found in different habitats. The highest similarity index (SI) is in the edge and *jamblang* stand at 0.70 (70%). Meanwhile, the lowest SI was identified in the coconut plantation and *jamblang* stand (SI = 0.57 or 57%) (Figure 5). According to Odum (1971), the SI value criteria were 1–30% is low, 31–60% is medium, 61–91% is high, and >91% is very high. The bird species found in both locations (edge and *jamblang* stand) are forest and urban species that can adapt to changes in environmental conditions. According to Adelina et al. (2016), the high SI value is due to the wide range of birds so that they are able to live in a variety of habitats and use space in that habitat almost the same, even though these two habitats have slightly different conditions. Desantoro et al. (2020) added that the similarity of bird species in different location related to the distribution of birds that adapt to the environment, competition, strata vegetation, food availability, natural selection, and other natural factors.

According to Rowley et al. (1993), edges provide habitat for wild species that prefer edge habitats and are not all harmfull. Many birds, such as violet-necked lory and parrot molluccan, use edges for perching and nesting. Because edges are meeting places between adjacent habitats, they are often rich in species (mixing of forest species, edge species, farmland species, and plantation species). Kark (2007) stated that research conducted at the boundaries of a wider ecoregion allows for the presence of more rare species.

The composition of vegetation on the edge consists of

Table 1 Category of vegetation growth level and plot area

Category	Diameter (cm)	Plot area (m × m)
Trees	>20	20 × 20
Poles	10–19	10 × 10
Sapling	<10 dan height ≥1.5 m	5 × 5
Seedling	height < 1.5 m	2 × 2

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Table 2 Number of species of each habitat

No	Scientific name	Common name	Location		
			Jamblang stand	Edge	Coconut plantation
1	*Fregata minor*	Great frigatebird	0	1	0
2	*Haliastur indus*	Brahminy kite	1	1	1
3	*Megapodius freycinet*	Dusky scrubfowl	3	0	1
4	*Macropygia unchall*	Barred cuckoo-dove	1	0	3
5	*Ptilinopus monacha*	Blue-capped fruit-dove	2	5	2
6	*Eos squamata*	Violet-necked lory	0	11	2
7	*Eclectus roratus*	Eclectus parrot	0	1	1
8	*Cacomantis variolosus*	Brush cuckoo	3	3	0
9	*Centropus bengalensis*	Lesser coucal	2	7	2
10	*Collocalia esculenta*	Glossy swiftlet	3	4	6
11	*Halcyon diops*	Blue-and-white kingfisher	1	0	1
12	*Lalage aurea*	Rufous-bellied triller	0	0	1
13	*Pycnonotus aurigaster*	Sooty-headed bulbul	3	2	0
14	*Corvus orru*	Torresian crow	0	2	0
15	*Myiagra galeata*	Dark-grey flycatcher	3	3	0
16	*Piezorhynchus alecto*	Shining flycatcher	3	9	6
17	*Monarcha pileatus*	White-naped monarch	0	0	1
18	*Rhipidura leucophrys*	Willie wagtail	9	9	10
19	*Pachycephala griseonota*	Drab whistler	1	0	0
20	*Aplonis mysolensis*	Moluccan starling	0	1	1
21	*Aplonis panayensis*	Asian glossy starling	3	8	30
22	*Nectarinia aspasia*	Black sunbird	7	12	21
23	*Nectarinia jugularis*	Olive-backed sunbird	42	38	24
24	*Passer montanus*	Tree sparrow	3	9	0
	Total		90	126	113

Table 3 Bird communities at three locations

Location	n	S	f	H’	E	Mean ± SD
Jamblang stand	87	16	15	1.980	0.71	3.6 ± 8.5
Edge	128	18	16	2.428	0.84	5.3 ± 7.9
Coconut plantation	113	17	15	2.123	0.75	4.7 ± 8.3

Notes: n = total individual, S = number of species, f = number of family, H' = Shannon-wiener diversity index; E = evenness index; mean = mean value, SD = standar deviation.

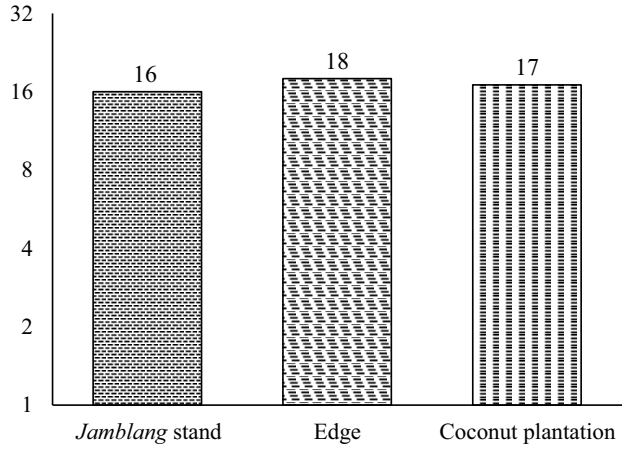

Figure 4 Composition of species at the three observation location.

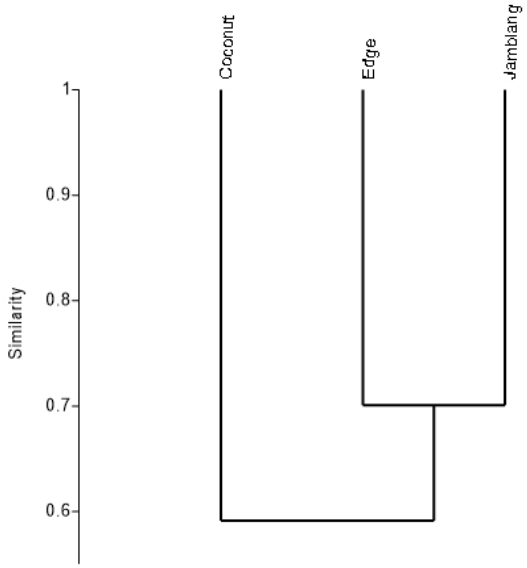

Figure 5 Composition of species at the three observation location.

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fruit-producing trees such as *Durio zibethinus*, flowering trees such as *Mangifera indica* and *S. cuminii*, intolerant trees (*Samanea saman*), shrubs, and reeds. The canopy at the edge is classified as diverse so that it can be optimally used by birds. The presence of birds in a habitat is related to the appearance of the vegetation structure. This is reinforced by the opinion of Peterson (1980) and MacArthur and MacArthur (1961) that one factor in the distribution of bird species is influenced by the structure of vegetation. The diversity and composition of vegetation, as well as vegetation stratification, are part of the dominant elements that affect the presence of various birds in a habitat. Moreover, a layer of canopy provides plenty of space, thus providing a variety of places for the benefit of bird activity in accordance with the character of the bird itself (Partasasmita et al., 2017).

The most common species found at the edge are olive-backed sunbirds, black sunbirds, and violet-necked lory. According to Coates and Bishop (2000), these species are common and can be found on forest edges, secondary growth areas, shrubs, yards, and cultivated land with few trees. However, these three have different preferences for food. Olive-backed sunbirds and black sunbirds are honey-eating species, whereas violet-necked lory is a fruit-eating species. However, three of them chose insects as their side diet. The availability of insects at the edge is quite abundant so that they can be used by birds. The data shows that open area was free to get sunlight and was overgrown by several types of flowering plants; *S. cumini*, *M. indica*, and *P. pterocarpum*. According to Sayono et al. (2005), insects are sensitive to light intensity, contrasting colors, and ultraviolet refraction. Therefore, these two factors attract the attention of insects at the edge so that insects can be used by birds as main and side food.

The highest similarity index was in the edge and *jamblang* stand. This means that the composition of birds in the two locations tends to be the same. Although the edge area has a higher amount of vegetation compared to the *jamblang* stand, both habitats are open areas, so that the types of birds occupying both types of habitat are birds that prefer open areas. Ecologically, bird communities in the tropics are determined by the structure of vegetation (Woinarski & Tidemann, 1991; Greenler & Ebersole, 2015). Some experts say that open areas can be beneficial for some species and disadvantageous for others. This is because edges have different characteristics when compared to other land uses. Rowley et al. (2002) revealed that edge area can affect wildlife, particularly bird through a) changes in the microclimate; b) different inhabitants, edge species; c) weed invasion; d) impact from adjacent land use; and e) noise and movement.

Bird response The ability of birds to adapt to edge habitat forms two types of bird species, namely generalist and specialist species. Each research site had a different niche species. Based on observations, a total of 24 species were identified in the three research sites, 41% of which could be mapped into the bird response model as generalist (generalist edge neutral and generalist edge conspicuous) and specialist (specialist edge conspicuous and edge specialist). Willie-wagtail, lesser coucal, eurasian tree sparrow, and torresian crow are four species that used as examples to represent each response model (Figure 6).

Our results showed a positive edge response of birds with higher species richness and abundance at the edge compared to interiors. This positive response of birds to edges has been reported in several scientific studies (Rowley et al., 2002; Salek et al., 2010; Terraube et al., 2016). It was recorded that 37.5% of species could be mapped as 4 response model, whereas 62.5% could not be mapped because the density did not characterize the response model. Competition for resources forms two types of niche, namely generalist and specialist. Generalists are species that are tolerant of edge and interior environments and can adapt to environmental changes that occur, while specialists are species that are tolerant of certain environmental conditions and have narrow ecological niches.

The types of birds classified as generalist edge neutral are olive-backed sunbird, willie-wagtail, and brahminy kite. According to Coates and Bishop (2000), these three are quite common in secondary growth areas, lake shores, forest edges, rural areas, small towns, cultivated land, open roads in the forest, and around the coasta. In particular, brahminy kite can be found in mountain forests. This species perches on tree tops and flies high, so it is easily monitored in every type of habitat. Meanwhile, willie-wagtail is a bird that adapts to various types of habitat in Ternate. This species is identified throughout Ternate (coastal area to the mountain), and its sound can be heard until midnight. Meanwhile, the birds identified as generalist edge expploiters are blue-capped fruit doves, lesser coucals, and shining flycatchers. Coates and Bishop (2000) explained that the lesser coucal was a common species, usually inhabiting forests and shrubs growing alongside tall grasses. Blue-capped fruit doves are endemic to North Maluku and can be found in secondary growth, forest edges, and coconut plantations. The shining flycatcher is an uncommon species that inhabits forest edges, grows secondarily, and is sometimes observed in forests.

Species that are classified as specialist edge exploiters are birds that are only observed in one type of interior, but the density increases towards the edge, for example, violet-necked lory and eurassian tree sparrow. Violet-necked lory is usually common, inhabiting primary and secondary forests, forest edges, coconut plantations, and growth shrubs. The eurassian tree sparrow is locally known as a commonly introduced species and is observed in urban and rural areas. The bird included as an edge specialist is a torresian crow. This species is common locally, inhabiting open areas on the coast, in rural and urban areas, and in cultivated land with few trees. Meffe and Carol (1994) stated that local extinctions can occur if specialist species are not able to adapt to the new habitat. The results of the study found that 6 species were categorized as rare species; species with low abundance of 1 to 2 individuals during the observation time. The exixtence of rare species is common in the tropics. The high number of rare species in a habitat indicates that the area is only occupied by a small number of species. Some rare species include violet-necked lory, willie-wagtail, white-naped monarch, brahminy kite, and great frigatebird. The observation location is close to the coast, so there is a chance

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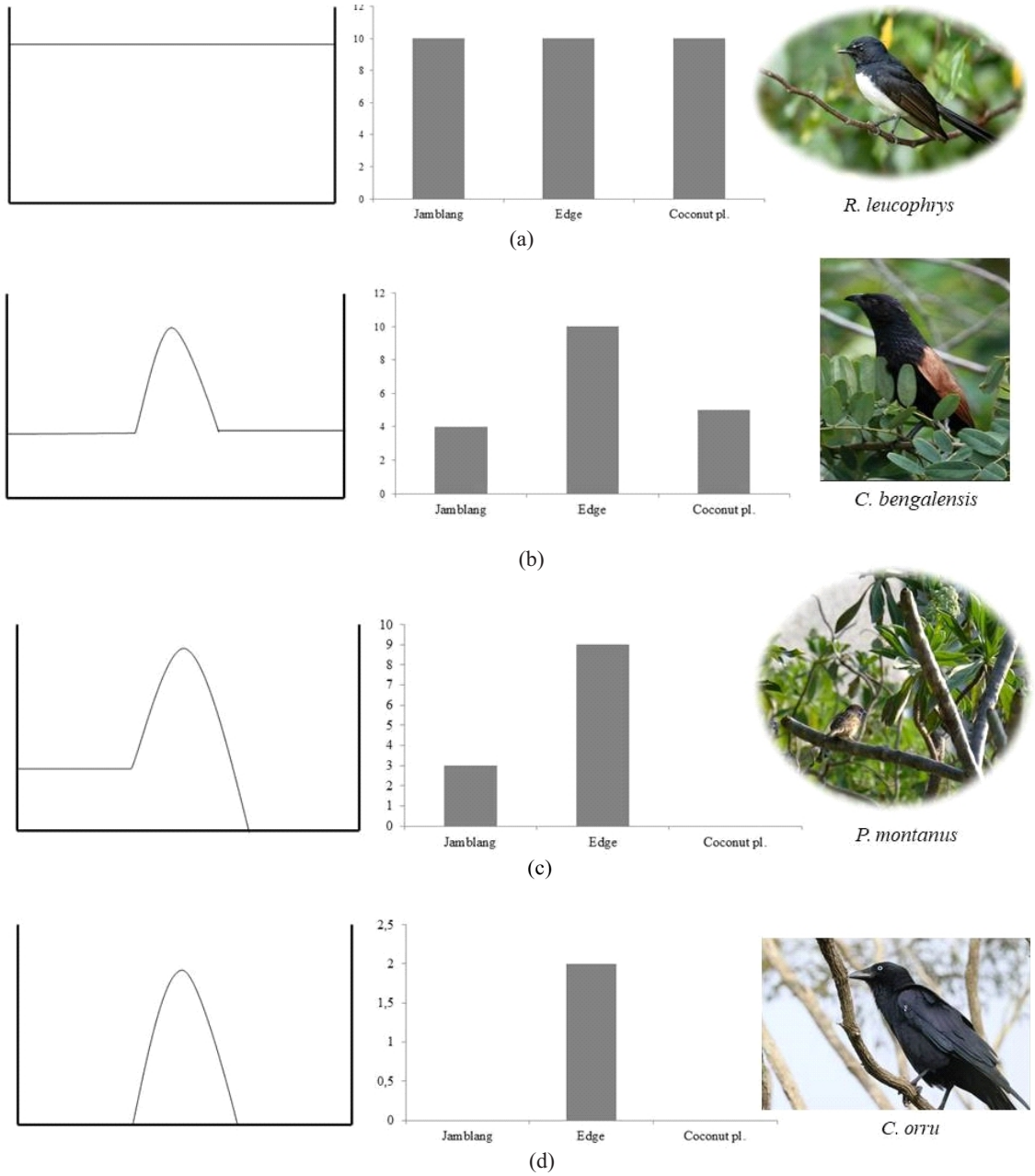

Figure 6 Four bird response models (a) generalist edge neutral, (b) generalist edge exploiter, (c) specialist edge exploiter, and (d) edge specialist.

of meeting a great frigatebird.

Vegetation diversity The data show that the edge has more types of vegetation compared to the other habitats. We found 20 species in the edge, 15 species in the coconut plantation, and 10 species in the *jamblang* stand (Table 4). The highest index of vegetation diversity and evenness was in the edge (H' = 2.551; E = 0.85). Meanwhile, the highest similarity index of vegetation was in the coconut plantation and *jamblang* stand (IS = 0.65) (Figure 7). Each habitat was dominated by different types of vegetation. In the *jamblang* stand, the highest IVI was owned by *S. cuminii* (246.06%) and *M. indica* (53,94%), whereas the highest IVI in the edge was owned by *C. nucifera* (139.70%), *D. zibethinus* (66.66%), and *Imperiata cilindrica* (35.79%).

The edge area has more vegetation than the interior (*jamblang* stand, coconut plantation). The composition of vegetation at the edge is not only a mixed type of two adjacent communities. In contrast, edges have their own distinctive species and are not characteristic of the interior of any habitat. The high species richness and diversity at the edge is consistent with the conservative perspective of forest edge diversity (Odum, 1971; Risser, 1995). This may have conservation implications for Ternate. Conservation attempts should not only focus on interior habitat, but the edge between different stand types must also be taken into account. Our research location was designated as an ecotourism area by the forest management unit of Ternate-

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Table 4 Vegetation diversity at three locations

Location	n	S	H'	E	Mean ± SD
Jamblang stand	268	10	1.390	0.60	10.3 ± 30.5
Edge	168	20	2.551	0.85	6.5 ± 8.4
Coconut plantation	121	15	2.280	0.84	4.6 ± 7.6

Notes: n = total individual, S = number of species, H' = diversity index, E = evenness index; mean = mean value; SD = standar deviation

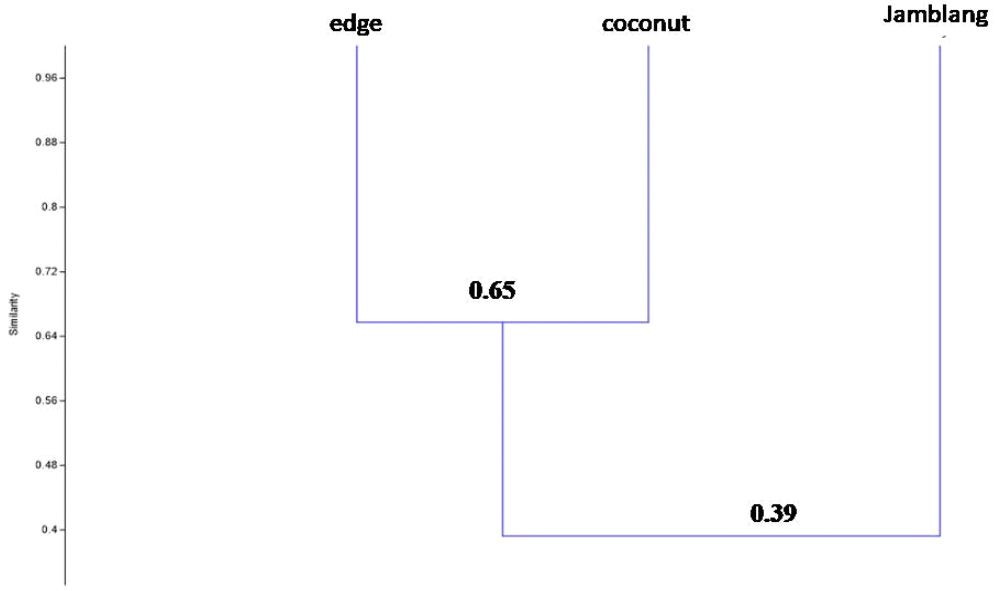

Figure 7 Index of vegetation similarity in three study sites.

Tidore in 2019, so the management of the ecotourism area needs to be in harmony with wildlife. Ternate is dominated by old mixed plantations consisting of clove, nutmeg, and coconut. These three types of plants are superior products in Ternate.

The highest diversity index of vegetation was found in edge and coconut plantations. This is because both habitats have almost the same composition of vegetation types, although the spacing of vegetation in the edge habitat tends to be sparse. In the edge area, the forest floor is illuminated by sunlight. Meanwhile, the canopy cover in coconut plantations tends to be denser, so that the air around the observation location feels cooler than in other habitats. This is in accordance with the research of Erdos et al. (2013), which argues that the value of ecological indicators such as temperature and light intensity in edge areas is higher than that in forest areas. Although more precise measurements would be necessary, it can be assumed that at least some environmental factors are intermediate within edges. Similarly, the values of certain environmental variables of forest edge have been found intermediate in study by Magura et al. (2001) and Heithecker and Halpern (2007). According to Ries et al. (2004), transitional values of environmental factors within edges result from ecological flows between habitat patches.

Coconut plantations had the second highest amount of vegetation after edges, but bird diversity in coconut plantations was classified as the least. According to Syahran (2021), tree canopy architecture influences bird preferences as a living habitat (a place to find food, rest/perch, and interact). It was observed that coconut trees are only used by several species, such as olive-backed sunbird, blue-and-white kingfisher, wiliie-wagtail, and torresian crow. This is in accordance with the research of Alotia et al. (2019), which was carried out on coconut plantations in North Minahasa Regency and stated that the biodiversity of birds in the coconut plantation habitat was in the medium category (diversity index was 2.70). This is presumably due to the monopodial shape of the coconut trunk so birds do not have a choice of other canopy strata to use and coconuts are rarely used by birds as feed,

Nevertheless, coconut plantations are one of the potential habitats to support bird survival in Ternate. This is because the coconut plantation area accounts for 24% of the total area in Ternate. Coconut plantations have characteristics similar to those of secondary forests. If not managed intensively, it usually has a canopy that tends to be tight so that it can be used by birds in closed habitats. Alikodra (2002) stated that habitat plays an important role in supporting wildlife life. Determination of habitat by birds depends on their daily life and activities, such as nesting, sheltering, perching, mating, resting, eating, and others (Syafrudin, 2011). The vegetation in coconut plantations is dominated by tree species with large diameters, such as *D. zibethinus, S. saman, C. canarium,* and *A. heterophyllus.*

Conclusion

The results of the study showed the highest abundance and diversity of birds and vegetation on the edge. The results of this study indicate that the existence of the edge affects the bird community, although there are only slight differences in the number of bird species in each habitat. This is influenced by the composition and structure of the vegetation. There were 37.5% species that could be mapped into 4 model responses of birds as generalist (generalist neutral and generalist edge exploiter) and specialist (specialist edge exploiter and edge specialist).

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