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Diversity and Feeding Guild of Birds Along Gradient of Revegetated Area in Karst Ecosystem: a Case Study from Rembang, Central Java

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Abstract. In the mining industry, the provision of new habitats through land rehabilitation and afforestation is an important step to anticipate the loss of bird biodiversity. Positive impacts of rehabilitation and afforestation thus can be identified from the results of periodic monitoring. The turnover of bird communities associated with afforestation is related to changes in structural habitat features that provide food and shelter. The study aimed to understand the community assemblages and feeding guild structure in a revegetated area of karst in Rembang, Central Java. Three locations (EDP, GBC, and GBL) were selected as observation sites and characterized by different land use, vegetational age, and floral composition. Surveys were conducted using the point count method in early April for three consecutive years (2020-2022). We have identified 32 bird species from 29 genera and 22 families. Most birds are considered generalist, cosmopolitan, and well-adapted to various habitats. Total species richness (19.33±3.22 to 20.67±4.12) and value of diversity index (H' = 2.41±0.14 to 2.56±0.29) have only slightly differed among locations. Species richness and total abundance in each site tend to increase along periods of observation, suggesting that bird community changes in response to further structural habitat changes that occur as vegetations age. Furthermore, higher abundance occurred in larger areas or sites with more native plant species. The feeding guild consists of 7 groups and is dominated by insectivores, both based on the number of species (46.88%) and individuals (49.07%). The results of the study are expected to help identify more appropriate management of conservation and habitat restoration in the area.

Key words: bird, diversity, feeding guild, karst, revegetated area.

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INTRODUCTION

Birds are one of the best-known elements of the natural world, in terms of their biological, cultural, artistic, philosophical, and economic aspects (BirdLife International, 2018). Over the world, it is estimated that the diversity of birds is composed of 11.121 species (Hoyo et al., 2014 and Indonesia contains at least 1.794 species or 17% of world birds diversity; and more than one-third of globally threatened Asian bird species can be found in Indonesia (Sukmantoro et al., 2007). Bird communities are widely known to have a variety of important ecological values, including controlling pest populations on food crops, pollinators, and seed dispersers (BirdLife International, 2018) as well as balancing the food chain in ecosystems (Abie et al., 2019). Economically, birds are a source of food and provide direct economic benefits, for example in the form of income from bird-watching activities (BirdLife International, 2018).

Despite having high diversity as well as economic benefits and an important ecological role, birds are also one of the fauna groups that are susceptible to decline in population and diversity. Anthropogenic activities such as overconsumption, illegal hunting, bird trade, change of land use and deforestation, habitat fragmentation, agricultural activities, poor settlement management and the introduction of invasive species; to natural causes such as global climate change are the main causes of the crisis of bird biodiversity (Gottschalk et al., 2014; Harris et al., 2016; BirdLife International, 2018). Apart from these factors, mining and energy industries

are also known to cause a decrease in bird diversity (BirdLife International, 2018), including in Indonesia. Mining activities have the potential to alter the landscape, change and damage the conditions of soil, water and air which are habitats for birds.

In order to anticipate bird diversity loss, various forms of environmental management such as land revegetation or afforestation and the provision of new habitats and periodic monitoring have been implemented, including in the karst area of Rembang, Central Java. Monitoring results in the form of bird community dynamics are expected to be an indicator of habitat change (Rathod et al., 2015; Lestari et al., 2016), as well as being a consideration for habitat management and species conservation. Land revegetation has a positive impact, both on flora and fauna, one of which is birds which require vegetation to find food sources and make nest (Lestari et al., 2016; Romansah et al., 2018). The turnover of bird communities associated with afforestation is related to changes in structural habitat features that provide food and shelter (McCarthy et al., 2021).

The food habits itself varies for each bird species, which is also influenced by the shape of the beak. A guild is a group of species that use the same resource in the same way (Anthal & Sahi, 2017). A group of species can be considered to have the same guild based on the way to obtain resources, such as food (Pang et al., 2017). Ecological characters in birds such as food habits can be used as bioindicators of environmental disturbances by assessing their response to a given disturbance (Azman et al., 2011; Rathods et al., 2015). Research on bird feeding guilds is very important to understand the complexity of the ecosystem structure and to provide the latest information on each type of habitat in the ecosystem (Azman et al., 2011). Availability of feed is also a major aspect of species conservation efforts (Rathod et al., 2015). Foraging strategies and food choices have an important role for survival and reproductive success (Bravo et al., 2017); which one will decrease if feed is not available in sufficient quantities. Research on the ecology of feed for conservation becomes very important when it is related to the existence of protected and/or endangered species (Bravo et al., 2017; Jamwal et al., 2017). In this research, we study the community assemblages of birds and their feeding guilds from three location with different land use, floral composition and vegetation age. The results are expected to be a useful recommendation for further management of land revegetation.

METHODS

Study sites

The diversity and abundance of birds were investigated in three revegetated locations of the karst habitat of Rembang, Central Java: namely EduPark (EDP), the greenbelt of clay mining area (GBC), and greenbelt of limestone mining area (GBL) (Figure 1).

The differences in vegetation conditions in the three locations are summarized in Table 1 and depicted in Figure 2. All locations initially share similar vegetation characteristics, in the form of open habitats used for farming by the locals. At the beginning of the cement company's operations, the revegetation was carried out in most of the area. The earliest revegetation was carried out in the GBC (green belt for clay mining area) in 2017 with trees such as Moluccan albizia (*Falcataria moluccana*), Royal poinciana (*Delonix regia*), Jackfruit (*Artocarpus heterophyllous*), Mahagony (*Swietenia macrophylla*) and Teak (Tectona grandis). At the time this study was conducted, the GBC area had a dense canopy of trees. The forest floor is dominated by Cassava (*Manihot esculenta*) plants during the rainy season and several species of shrubs and grasses during the dry season.

Adjacent to GBC and separated only by ±75 m is the EduPark (EDP) where the revegetation was carried out in 2020; with the fruit-produced plant such as Durian (*Durio zibethinus*), Longan (*Dimocarpus longan*), Guava (*Psidium guajava*) and Sugar apple (*Annona squamosa*). Most of the plants are saplings and seedlings as well as various species of shrubs, wild herbs and grasses. Species richness of these plants are highest among other locations. Third location is GBL which revegetated in late 2018 and 2019 with relatively similar plant species as in GBC. This area is not used for farming by the locals so that wild shrubs and herbs are denser compared to GBC and EDP. In addition, many native plant species are found in GBL.

Bird observation

Bird observations were conducted in early April for three consecutive years (2020-2022). Four random fixed-radius (25-m radius) point count method (Bibby et al., 2000; Posa & Sodhi, 2006; Zhou & Chu, 2012) was used to census the

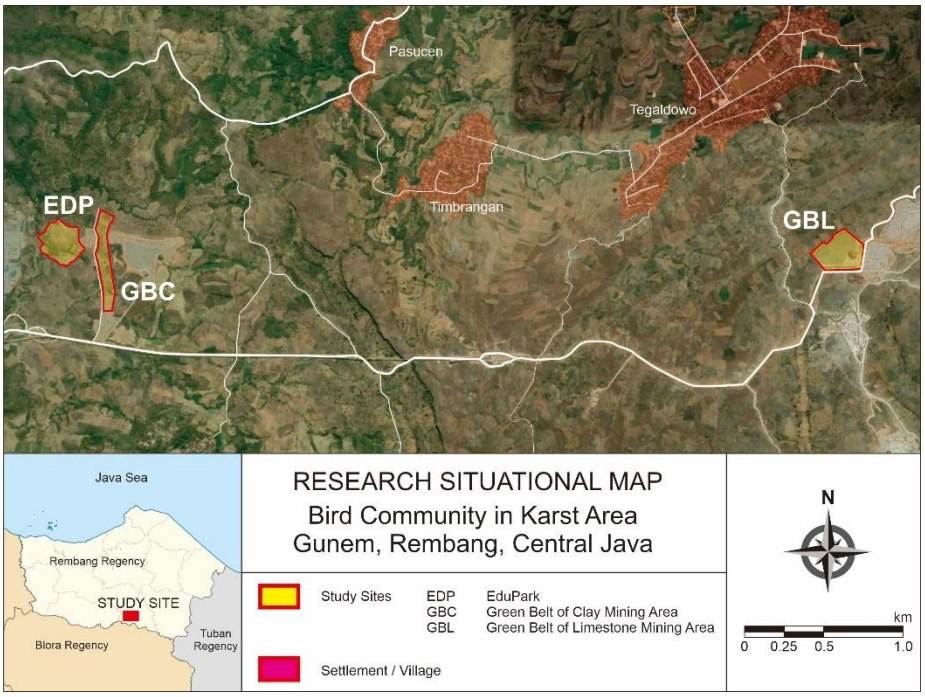

Figure 1. Research situational map in revegetated area of karst ecosystem in Rembang, Central Java

Table 1. Summary of vegetation conditions in the study area

Parameter		EDP	GBC	GBL
Area		5.8 hectare	4.6 hectare	5.1 hectare
Tree	Species richness	5	12	13
	Abundance	38	110	33
	Average height	7-8 m	7-8 m	7-8 m
Pole	Species richness	8	10	14
	Abundance	53	110	101
	Average height	3-4 m	6-7 m	4-5 m
Sapling	Species richness	32	23	36
	Abundance	661	201	1537
Ground cover	Species richness	100	59	85
Land use		Fruit-producing area	Green belt and seasonal plantation (cassava and corn)	Green belt
Surrounding habitat		Corn and rice field (only in rainy season)	Corn and rice field (only in rainy season), clay mining area	Corn field (only in rainy season), limestone mining area, teak forest with scarce native plant species
Age of vegetation		1-2 years	5-7 years	3-4 years
Degree of disturbance		Moderate	Moderate	Low to moderate

birds in each location. The observer records the birds (visually or by sound) for ± 30 minutes before moving to the next point. Generally, an observation started at 6.30 am and finished at 09.00 am in suitable weather conditions with no persistent rain, good visibility, and calm winds. Identification of bird species based on MacKinnon et al. (2010) and Baskoro (2018). Scientific names adjusted to the Daftar Burung Indonesia No. 2 by Indonesian Ornithologist Union (Sukmantoro et al., 2007).

Feeding guild structure

The avian species were grouped into several feeding guilds based on dietary requirements and foraging habitat. Various published literature

Figure 2. Typical vegetation characteristics in each observation sites: EduPark (EDP, upper left), green barrier for clay mining area (GBC, upper right) and green barrier for limestone mining area (GBL, bottom).

Table 2. Classification of avian feeding guild based on predominant diet

Feeding guild	Description
Frugivore (Fru)	Exclusively eats fruit, both from trees and above ground
Carnivore (Car)	Exclusively prey on small mammals, reptiles, amphibians, fish or birds
Granivore (Gra)	Exclusively feeds on seeds from plants or on the ground
Insectivore (Ins)	Exclusively prey on arthropods, including insects
Omnivore (Omn)	Feeds on plant (grain, seed, leaf, stem, root) and animal (insect, mollusc, fish, etc.)
Nectarivore (Nec)	Exclusively feeds on nectar from flowers
Frugivore-Insectivore (Fru-Ins)	Exclusively feeds on fruit but switch to insects when the fruit availability becomes scarce for a certain period
Carnivore-Insectivore (Car-Ins)	Exclusively carnivorous but switch to prey on insects when the availability of small mammals, reptiles, amphibians, fish or birds is low over a certain period
Insectivore-Frugivore (Ins-Fru)	Exclusively prey on arthropods but switch to feed on fruits when the insect availability becomes scarce for a certain period

works (MacKinnon et al., 2010; Phillips & Phillips, 2014; Panda et al., 2021) and web sources (BirdLife, 2022; IUCN, 2022) were used in categorizing the birds to their feeding guilds. In this study, the feeding guilds are categorized into 9 groups as listed in Table 2.

Data analysis

Species diversity among locations and observation periods was assessed using the Shannon-Wiener index (H') to understand the avian species preference for each habitat or

location (Magurran, 2004, Panda et al., 2021). A Sorensen similarity index is used to gauge the similarity of bird communities between locations (Magurran, 2004). The independent percent contribution for every feeding guild is based on the number of species (Panda et al., 2021) and relative abundance.

RESULTS AND DISCUSSION

Bird Community Assemblages

From three observation periods (2020 to 2022) we identified at least 32 bird species from 29 genera, 22 families, and 9 orders. In each observation period, the species richness tends to be similar among locations, ranging from 17-23 (19.33±3.22 on average) species in EDP, 17-22 (19.67±2.52 on average) species in GBC, and 16-24 (20.67±4.12 in average) species in GBL. However, each location has a different total species richness: EDP with 25 species, GBC with 29 species, and GBL with 27 species, respectively. In all locations, at the level of order, the most dominant is Passeriformes with 17 species or 54.84% of the total species; followed by Cuculiformes and Coraciiformes with 3 species (9.38%) each, as shown in Table 3 and Figure 3. Passeriformes is the largest bird order in the world, consisting of at least 5700 species, and represents nearly 60% of global bird species richness (Ericson et al., 2014). Therefore, members of this order are usually dominant in various habitat types. In terms of total abundance, Passeriformes made up 51.52% of all bird population, followed by Apodiformes (26.18%), Columbiformes (8.65%), and Cuculiformes (5.37%); this trend of dominance is quite similar among locations and observation periods.

At the species level, the most dominant is Cave swiftlet (*Collocalia linchi*) with a value of relative abundance is 22.13%. Other dominant species are Scaly-breasted munia (*Lonchura punctulata*, 15.19%), Sooty-headed bulbul (*Pycnonotus aurigaster*, 7.13%), and Eurasian tree-sparrow (*Passer montanus*, 5.02%). The first three mentioned species can be found in all locations while the latter found only in EDP and GBC yet have relatively high abundance. The Black-nest swiftlet (*C. maxima*) is dominant only in EDP (by 6.3% of relative abundance) although can be found in all three locations. In this study, all dominant species are known as generalist (Duco et al, 2020), cosmopolitan, and well-adapted to various habitats (Mackinnon et al., 2010; Duco et al, 2020) either natural or artificial; mainly in secondary forests, revegetated areas, plantations, and urban. Only one species was exclusively observed in the EDP and GBL, three species were exclusive in GBC, and sixteen species can be found from all three locations.

The low abundance species such as Common iora (*Aegithina Sophia*) found only in GBL, Chesnut-headed bee-eater (*Merops leschenaulti*) found only in EDP and Indian white-eye (*Zosterops palpebrosus*) found only in GBC. We also noticed the presence of the Javan kingfisher (*Halcyon cyanoventris*) and Scarlet-headed flowerpecker (*Dicaeum trochilus*) which are endemic to Indonesia. There are also two species conserved by Indonesian national law, namely the Crested serpent-eagle (*Spilornis cheela*) and Spotted kestrel (*Falco moluccensis*) which are

Table 3. A snapshot to the general community assemblages of birds in the study

Parameter	Location		
	EDP	GBC	GBL
Total observed species richness	25	29	27
Mean estimated species richness	19.33±3.22	19.67±2.52	20.67±4.12
Total abundance	349	224	283
Mean estimated abundance	116.33±23.59	74.67±14.74	94.33±32.35
Mean Shannon-Wiener index (H')	2.41±0.14	2.64±01	2.56±0.29
Dominant spcies (>5% relative abundance)	Cave swiftlet Black-nest swiftlet Scaly-breasted munia Eurasian tree-sparrow Sooty-headed bulbul	Cave swiftlet Scaly-breasted munia Sooty-headed bulbul	Cave swiftlet Scaly-breasted munia Sooty-headed bulbul

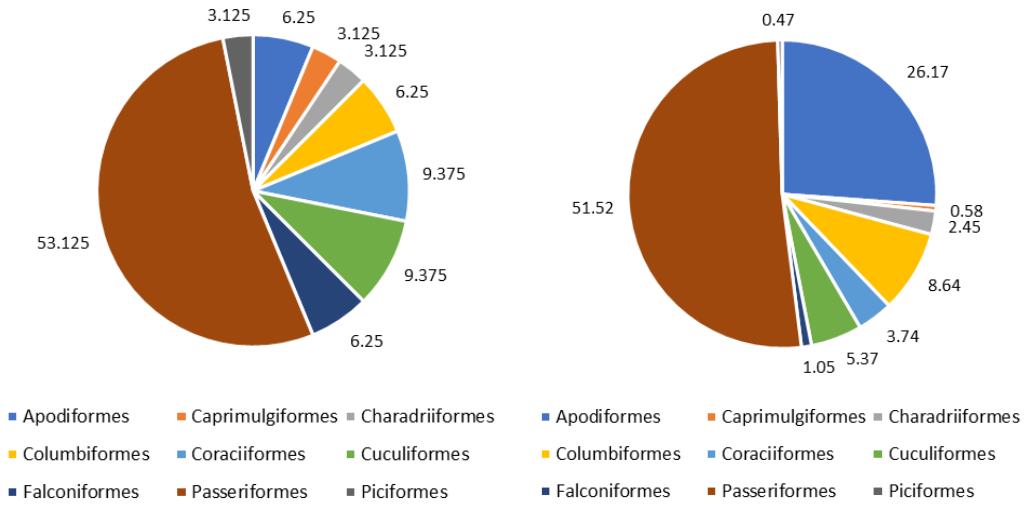

Figure 3. Diagrams showing omposition of birds at the level of order: by percent of species richness (above) and relative abundanve (below)

also listed in Appendix II CITES. Most of the bird species were observed throughout all period, with the exception are Common iora, Savanna nightjar (*Caprimulgus affinis*), Zitting cisticola (*Cisticola juncidis*), Yellow-vented bulbul (*Pycnonotus goiavier*) and Indian white-eye which are recently recorded in 2022, especially in GBC and GBL.

The species richness was always increases in each period; in 2020 there are 21 species identified, 25 species in 2021 and 31 species in 2022. Bird abundance also tends to increase in each observation period. At the EDP location, there were 94, 114 and 141 (116.33±23.59 in average) individuals in 2020, 2021 and 2022. During the same period, at the GBC location there were 58, 80 and 86 (74.67±14.74 in average) individuals while at the GBL it was 58, 105 and 121 (94.33±32.35 in average) individuals, respectively. An increase in the age of vegetation is accompanied by an increase in species richness, which GBC with older vegetation age have highest species richness. McCarthy et al. (2021) stated that bird community change in response to further structural habitat changes that occur as forests age. Vegetation age also affect bird abundance, where an increase in bird abundance occurs in each observation period along with the age of the vegetation (Heath, 2003 *in* Lestari et al., 2016). Difference in term of abundance at each location perhaps could be explained by the size of habitat (location). Highest abundance always recorded in EDP which have largest area while tho lowest density is always in GBC with smallest area. Larger area tends to support more diverse habitat or sub-habitat which helps birds to establish larger, and thus more stable, populations (Evans, 2009 *in* Zhou & Chu, 2012).

Diversity and Similarity Indices

The level of diversity at the three locations was categorized as ‘moderate’ with the average value of Shannon-Wiener index (H') for EDP, GBC, and GBL being 2.41±0.14, 2.64±01 and 2.56±0.29, respectively. The average value of H' corresponds to the species richness at the three locations, where locations with high species richness will have a higher H' value. The value of H' is also influenced by the relative abundance of a species to the total abundance of all species in the community. Thus, if at a certain location there are many different species with relatively equal abundances (or there are no dominant species), then the value of H' will increase (high). On the other hand, the presence of one or several species that are very dominant in the community has the potential to reduce the value of H' or the diversity of the community. In 2021 and 2022, the value of H’ in GBL was higher compared to GBC. This finding seems to be correlated with more diverse native plants in GBL. Many bird species are generally sensitive to the characteristics of plant communities, including the presence of native plants (Trathnigg & Phillips, 2015; Dyson, 2020) in the understorey so it is possible that the diversity is higher in GBL where there are more native plant species compared to GBC.

The results of the Sorensen community similarity analysis show that the GBL and GBC

Table 4. List of observed bird species including their assigned feeding guild, conservation and endemicity status and total abundance at each observation site

Species	English name	Feeding Guilds	Conservation Status	Endemicity	Total number of individuals		
					EDP	GBC	GBL
Aegithia tiphia	Common iora	Ins-Fru	-	-	0	0	1
Artamus leucorynchus	White-breasted wood-swallow	Ins	-	-	2	3	0
Cacomantis merulinus	Plaintive cuckoo	Ins	-	-	3	4	3
Caprimulgus affinis	Savanna nighjar	Ins	-	-	0	3	2
Centropus bengalensis	Lesser coucal	Car	-	-	2	2	2
Cinnyris jugularis	Olive-backed sunbird	Nec	-	-	13	10	13
Cisticola juncidis	Zitting Cisticola	Ins	-	-	4	2	2
Collocalia linchi	Cave swiflet	Ins	-	-	85	43	63
Collocalia maxima	Black-nest swiftlet	Ins	-	-	22	5	6
Dendrocopos analis	Frecke-breasted woodpecker	Ins-Fru	-	-	1	1	2
Dicaeum trochileum	Scarlet-headed flowerpecker	Ins-Fru	-	Indonesia	9	9	12
Falco moluccensis	Spotted kestrel	Car	1,2	-	0	1	5
Geopelia striata	Zebra dove	Gra	-	-	14	11	11
Halcyon cyanoventris	Javan kingfisher	Ins	-	Java	1	3	4
Hemiprocne longipennis	Grey-rumped treeswift	Ins	-	-	3	4	6
Hirundo tahitica	Pacific swallow	Ins	-	-	14	11	15
Lalage nigra	Pied triller	Ins	-	-	10	11	9
Lanius schach	Long-tailed shrike	Car-Ins	-	-	0	1	1
Lonchura leucogastroides	Javan munia	Gra	-	-	10	6	0
Lonchura punctulata	Scaly-breasted munia	Gra	-	-	53	32	45
Merops leschenaulti	Chestnut-headed bee-eater	Ins	-	-	2	0	0
Orthotomus sutorius	Common tailorbird	Ins	-	-	7	6	6
Passer montanus	Eurasian tree-sparrow	Gra	-	-	37	6	0
Pericrocotus cinnamomeus	Small minivet	Ins	-	-	0	3	4
Prinia inornata	Plain prinia	Ins	-	-	10	6	11
Pycnonotus aurigaster	Sooty-headed bulbul	Omn	-	-	18	18	25
Pycnonotus goiavier	Yellow-vented bulbul	Omn	-	-	0	1	1
Spilornis cheela	Crested-serpent eagle	Car	1,2	-	1	0	2
Streptopelia chinensis	Spotted dove	Gra	-	-	15	10	13
Todirhampus chloris	Collared kingfisher	Ins	-	-	4	7	11
Turnix suscitator	Barred buttonquail	Omn	-	-	9	4	8
Zosterops palpebrosus	Indian white-eye	Ins-Fru	-	-	0	1	0

have the highest similarity value of 0.912, EDP and GBC of 0.886 while EDP and GBL of 0.861. There are 25 (out of 31) shared species in GBL and GBC with relatively similar abundance, examples are the Javan kingfisher, Collared kingfisher (*Todiramphus chloris*), Cave swiftlets, Spotted kestrel, Yellow-vented bulbul (*P. goiavier*), Pied triller (*Lalage nigra*) and Small minivet (*Pericrocotus cinnamomeus*). For EDP and GBC there are 23 (out of 31) shared species while in EDP and GBL there are 21 (out of 31) shared species. Avian community assemblages are dependent on vegetation structure (Susanto et al., 2016), floristic complexity and degree of disturbance (Duco et al., 2020) as well as landscape characteristics

such as habitat connectivity and surrounding matrix (Zhou & Chu, 2012). The highest similarity between GBC and GBL seems to be caused by habitat similarity which consisted of dense tree and pole canopy. Surprisingly, the similarity between EDP and GBC was relatively high, and it seems that habitat difference has little effect on the composition and richness of bird species. This community similarity is also presumed to be influenced by the similarity of habitat types of the surrounding area in the form of relatively open cultivation areas. EDP is also adjacent to GBC, making it possible for the occurrence of edge effects and mobility of birds between the two habitats. Feeding Guild Structure

All observed species can be grouped into seven feeding guilds as listed in Table 4. Guild structure among observation sites is similar and dominated by insectivore (*Ins*) with 15 species or 46.88% from total richness or 49.065% of total population. The granivores (*Gra*) composed by 5 species (12.5% of total richness) and have high percent population (30.724%) while insectivore-frugivore (*Ins-Fru*) composed by 4 species and a much lower percent abundance (4.206%). Omnivore (*Omn*) and carnivore (*Car*) shared same number of species (3 species) but have different percent population (1.752 and 9.813%, respectively). Other feeding guilds including nectarivore (*Nec*) and carnivore-insectivore (*Car-Ins*) with only one species each.

Feeding guild *Ins* dominated by aerial species such as Cave swiflet, Black-net swiflet and Barn swallow (*Hirundo tahitica*) as well as some arboreal species, for example is Plain prinia (*Prinia inornata*) and can be easily found in all sites. The general characteristics of the vegetation which is a combination of tree canopy and open areas overgrown with shrubs is estimated to be a suitable habitat for insects and their larvae which are potential food for birds. In many previous studies (e.g. Azman et al., 2011; Rathod et al., 2015; Pang et al., 2017; Duco et al., 2020) insectivore usually dominant various habitats in tropics like secondary forest, plantations, islands and coastal area. Insectivorous birds are easily found in understorey (Pang et al., 2017), yet very sensitive to habitat modification which make them to be become the first groups to disappear when a disturbance occurs within their habitat (Duco et al., 2020).

There are three carnivorous birds observed in the sites at each observation period, even though in a low population. Paddy fields and corn plantations around observation sites may sustain many food sources (e.g. small reptiles and rodents) that attract carnivorous birds. The granivores in this study consisted of all members of Estrildidae (munias), Passeridae (sparrow), and Columbidae (doves). Most of the granivorous birds also can be found in all sites with relatively high abundance in all sites, with exception of Eurasian tree-sparrow and Javan munia (*L. leucogastroides*) which are abundant only in EDP. This group of guilds is usually abundant in disturbed habitats and is sometimes considered a pest. For instance, all granivores are commonly observed to feed near the ground on grains from plant sources such as rice and grasses which abundant in the surrounding areas.

Exclusive frugivores were not observed in the study, yet there are omnivorous and combined guilds (e.g. insectivore-frugivore and carnivore-frugivore). This finding is far from expectations since frugivorous birds are usually easy to encounter in the tropics. Their presence could be affected by both richness and abundance of the food plant as well as vegetation structure (Moegenburg & Levey, 2003 in Duco et al., 2020). Insectivore-frugivore will exclusively prey on arthropods but will switch to feeding on fruits when the insect availability becomes scarce for a certain period. There are four species of *Ins-Fru* in this study, namely Common iora, Fricke-breasted woodpecker (*Dendrocopos analysis*), Scarlet-headed flowerpecker, and Indian white-eye. The total population is low, except for the Scarlet-headed flowerpecker that can be found in all observation sites. We identified three species belonging to the omnivore guild, dominated by the family of Pycnonotidae (bulbuls) which can adapt to seasonal conditions of insect and fruit availability (Azman et al., 2011). The bulbuls are generalist and have wide dietary breadths in disturbed habitats (Duco et al., 2020); they are also known for their importance for forest restoration in the lowland forests (Corlett, 2017).

CONCLUSION

The presence of endemic and/or threatened species highlights the need for well-managed restoration and conservation of the karst habitat, through massive afforestation and policy making. Local management policies should emphasize a reduction of further development near forested areas and promote more eco-friendly agricultural practices to maintain the diversity of birds on the site. Regarding the results, although total observed species richness is highest in GBC, the

mean estimated species richness in GBC is slightly lower compared to GBL. In 2021 and 2020, the diversity index was also higher in GBL, partly due to lower levels of disturbance and more native plant species in GBL. Therefore, planting more native and indigenous plant species are more recommended for afforestation and habitat restoration, since areas with native plant species are more attractive to birds. Many studies also suggest that revegetation sites composed of native plants and maintained to have complex vegetation structures will facilitate the recolonization of original wildlife. Related to the absence of frugivorous birds in this study, we also recommend planting more species of fruit-producing trees and shrubs. Frugivorous birds are important for forest restoration or the development of existing natural forests through seed dispersal.

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