IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Green spaces at PUSRI have the potential as refuge habitats for urban birds in the city of Palembang

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Abstract: Urban green spaces are becoming important in cities as these spaces provide refuge habitat for urban biodiversity. In recent years, there has been a notable trend in the urban industry towards embracing green spaces. In this study, we aimed to examine the ability of green spaces at PUSRI as a refuge habitat for urban bird species around Palembang. To address this question, we measured the number of birds using the point count method, analyzed three diversity metrics (Shannon, Margalef, and Pielou) and their feeding guilds, and discussed the accompanying consequences. A total of 2.044 individual birds from 40 species and 25 families were recorded during the survey. Most of them are categorized as Least Concern (LC), with only two species classified as "Endangered", i.e., the Java Sparrow, and "Vulnerable", i.e., the Javan Myna. Indonesian regulation lists three species as protected, including the Brahminy Kite, the Black-winged Kite, and the Java Sparrow. Three diversity metrics showed an index value ranging from medium to high. Regarding feeding guild classification, 19 species are insectivore, seven each belonging to granivore and frugivore, four carnivore, two piscivore, and the remaining belong to nectarivore. The presence of various bird species and all urban feeding guilds in the green spaces at PUSRI, as well as the good value index of the three diversity metrics, demonstrate the potential of these green spaces to serve as a refuge habitat for urban birds in the city of Palembang.

Keywords: bird, urban green spaces, PUSRI, Palembang.

I. INTRODUCTION

Urban ecosystems are the primary living areas for the world's population. In 2018, approximately 55% of the world's population lived in cities, and this is predicted to increase to 68% by 2050 (United Nations, 2019). Despite being designed to meet human needs, urban ecosystems also support a variety of plants and animals (Beninde *et al.*, 2015). However, as urbanization expands to accommodate growing populations (United Nations, 2019; Schutz and Schulze, 2015), there is a growing concern about the degradation of green spaces within the urban landscape (Fontana *et al.*, 2011; Evans *et al.*, 2009). Habitat loss and fragmentation, coupled with global climate changes, pose challenges to urban biodiversity (Seress and Liker, 2015; Zhang *et al.*, 2023). Therefore, adapting to changing conditions is necessary for urban biodiversity to escape the risk of local extirpation (Vasquez and Wood, 2022).

Urban green spaces, such as parks and gardens, are becoming increasingly important for promoting biodiversity in cities (Aronson *et al.*, 2017). With the loss of natural habitats due to urbanization, these green spaces provide refuge for many plant and animal species (Soga *et al.*, 2014), helping to maintain urban biodiversity. By incorporating native plants and creating diverse habitats, for instance, urban green spaces can support a wide range of species, including birds, insects, and small mammals, that may struggle to survive in urban areas (Fontana *et al.*, 2011; Soga *et al.*, 2014; Aronson *et al.*, 2017).

Birds are commonly used as indicators of habitat quality due to their well-known ecology (Fontana *et al.*, 2011; Read, 2000). In an urban context, birds are often regarded as an ideal model group for studying the ecological effects of urbanization (Croci *et al.*, 2008; Zhang *et al.*, 2023) due to their responsiveness to habitat change (Read, 2000). Numerous studies have identified several general patterns in how urban birds respond to habitat changes, including a reduction in species richness (Evans *et al.*, 2009; Sandström *et al.*, 2006) and the decline of specialist species along with the different gradient disturbances (Devictor *et al.*, 2007). Therefore, studying the ecological dynamics of birds can be a valuable tool for assessing the overall environmental conditions, monitoring habitat health, and guiding conservation efforts in a wide range of ecosystems, including green spaces in urban areas (Chamberlain *et al.*, 2009).

In recent years, there has been a notable trend in the urban industry toward embracing green spaces (Vasquez and Wood, 2022), such as those implemented by PT Pupuk Sriwidjaja Palembang, which allocates an area of about 107.29 hectares or 37.5% of its total concession for conservation purposes. PT Pupuk Sriwidjaja Palembang is aware that the existence of green spaces provides

refuge for urban biodiversity and offers various social and economic benefits to urban communities. This growing trend in the urban industry towards prioritizing green spaces reflects a positive shift towards more sustainable and livable urban environments.

This study aimed to examine the effectiveness of green spaces at PT Pupuk Sriwidjaja Palembang in sustaining urban bird species around Palembang. To address this question, we measured the number of birds at PT Pupuk Sriwidjaja Palembang, analyzed their ecological properties, and discussed the accompanying consequences. We believe this study's result can be a valuable insight into more sustainable urban biodiversity conservation and urban landscape management.

II. RESEARCH METHODOLOGY

Study site

PT Pupuk Sriwidjaja Palembang (hereafter referred to as 'PUSRI') is located on Mayor Zen Street, Sungai Selayur, Ilir Timur II Subdistrict, about 7 km from the center of Palembang City (Pupuk Sriwijaya Palembang, 2021). This area is located 14 meters above sea level, with an average air temperature ranging from 22.00-35.20ºC, air humidity between 73.4-83.25%, and an average rainfall of 60-587.50 mm per year (Statistics of Palembang Municipality, 2022). Geographically, PUSRI is located between the two nearest protected areas, i.e., Punti Kayu Nature Tourism Park (approximately 8 km) and Padang Sugihan Wildlife Sanctuary (approximately 20 km). PUSRI is the first Indonesian company to produce urea fertilizer and has constantly increased its production capacity from 100.000 to 570.000 tons per year due to the increasing demand for fertilizer in Indonesia (Pupuk Sriwijaya Palembang, 2021).

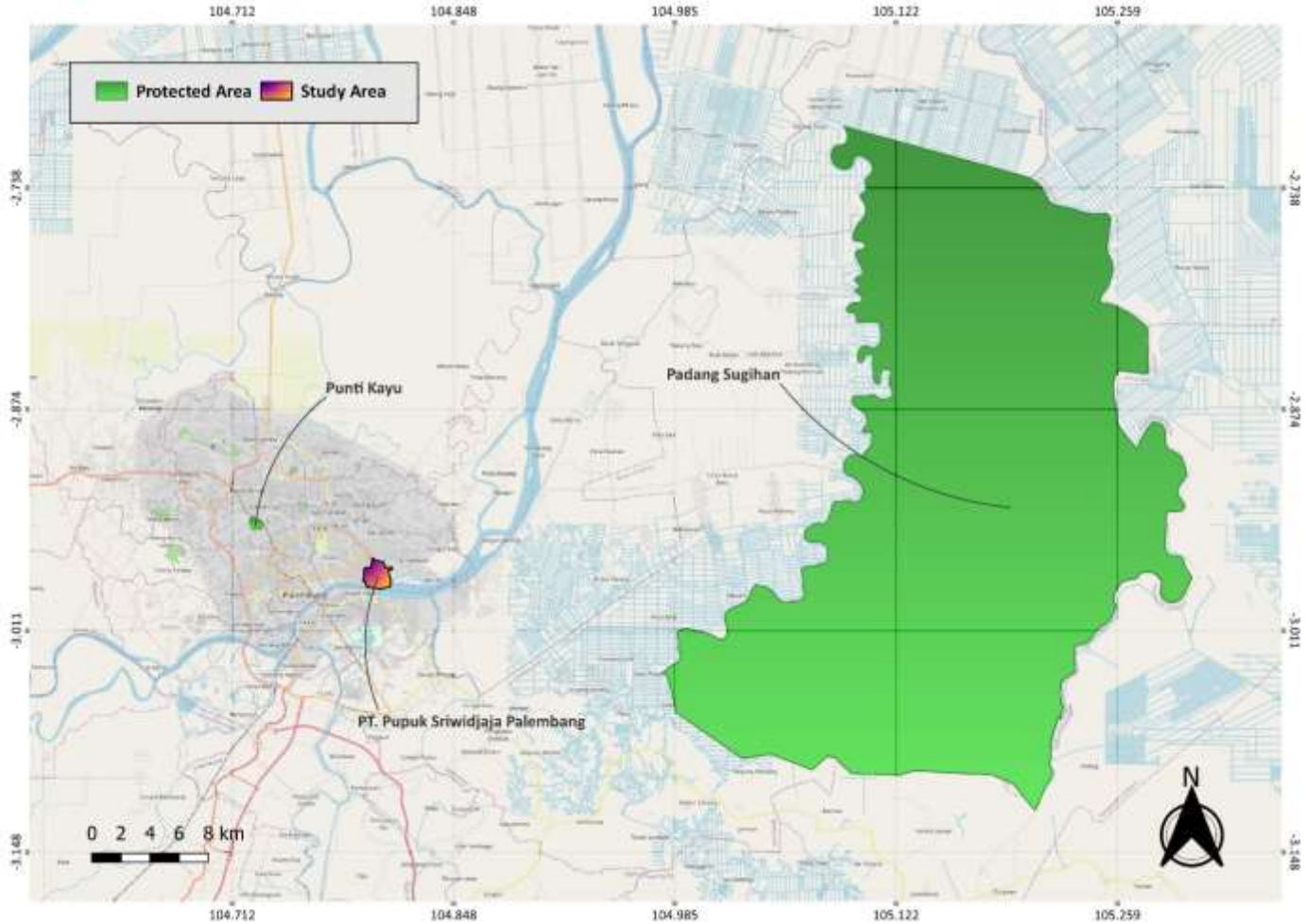

Figure 1. Map showing the study site and two adjacent protected areas, Punti Kayu and Padang Sugihan.

In general, massive development in urban areas has reduced green spaces (Villaseñor *et al.*, 2020), which ultimately negatively impacts biodiversity in urban areas, particularly birds (Seress and Liker, 2015). Recognizing the significance of green spaces in urban areas, PUSRI has established three Conservation Areas in 2014: The Green Barrier Area, Rare Plant Cultivation Area, and Captive-breeding Area. In 2023, PUSRI officially expands its conservation areas by designating Residential and Office Areas as part of its green spaces.

Data Source

Our study utilized two types of data, primary and secondary. The primary data consists of bird data collected through field surveys within the green spaces of PUSRI. In contrast, the secondary data were obtained through a literature review of existing studies on birds conducted both inside and outside the study area. The collection of secondary data was conducted by searching on Google Scholar, using the keywords "birds," "PUSRI," and "Palembang".

Bird data collection

Data collection was carried out intensively for four days, started from July 21 to 24, 2022, within the green spaces of PUSRI, i.e., Green Barrier Area (GBA), Rare Plant Cultivation Area (RPCA), Captive-breeding Area (CBA), and Residential and Office Areas (ROA). Preliminary surveys were conducted before data collection, including collecting supporting data, interviews and consultations, and rapid observations. This activity aimed to collect initial information and potential obstacles that could reduce the effectiveness of data collection. One example is related to the presence of walls or fences and the company's internal regulations, such as traffic rules. This information is crucial for the efficiency of data collection. All information was then used to select and place observation points and data collection routes. In addition, the preliminary survey also played a role in habituating or familiarizing the birds in the study area. Based on the preliminary survey, 18 bird observation points were obtained. Five points represent the Green Barrier Area (points 1-5), two represent the Captive-breeding Area (points 9 and 10), one point for the Rare Plant Cultivation Area (points 10), and the rest (points 6-8 and 11-18) represent the Residential and Office Area.

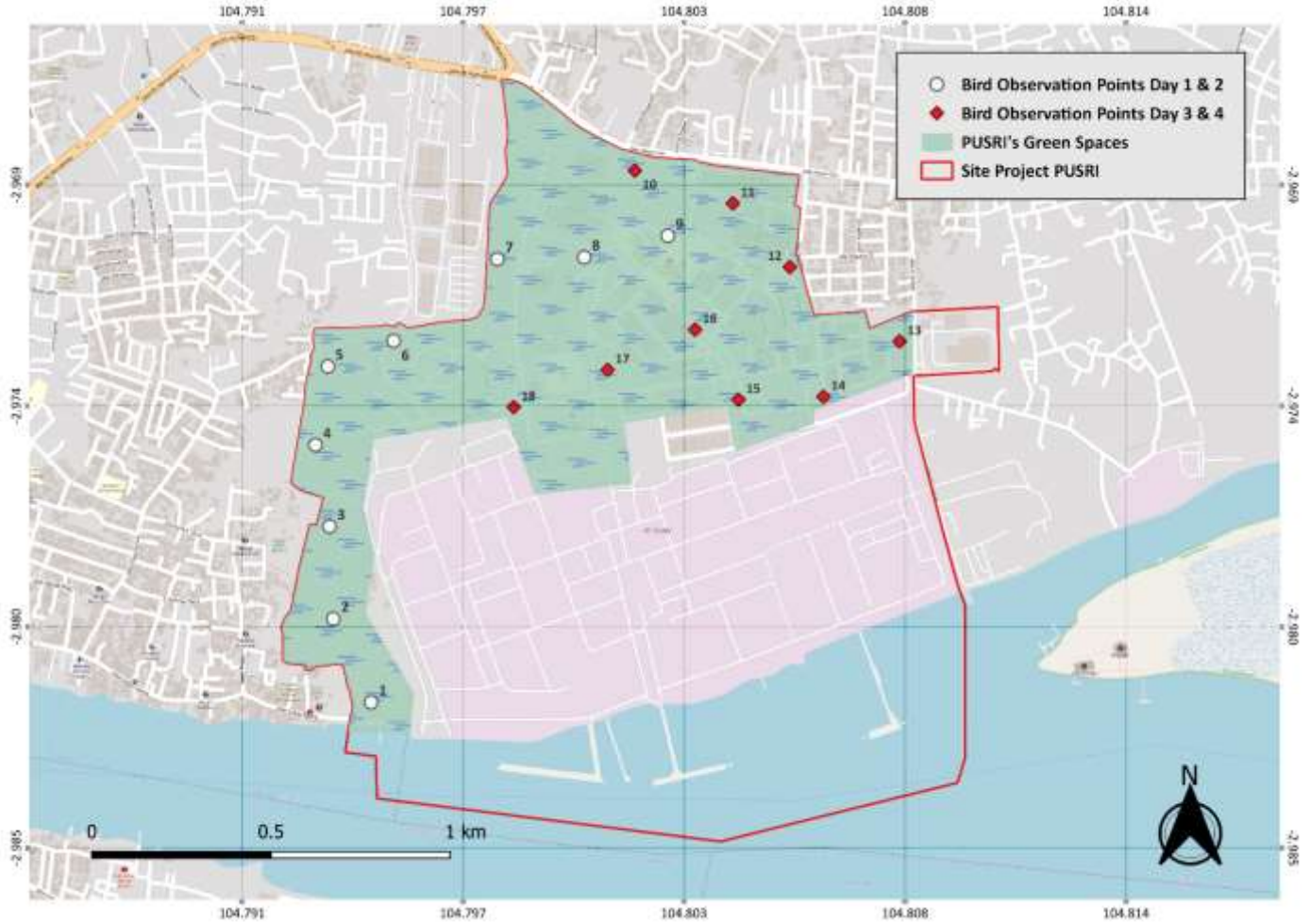

Figure 2. Map of the study area with 18 bird observation points. Bird observation was divided into two parts. On the first and second day, the observation was conducted at points 1-9. On the third and fourth day, observation was conducted at points 10-18.

Bird data collection was carried out using the distant point count method with a radius of 50 m (Bibby *et al.*, 2000). A minimum distance of 200 meters was given between the center points of observations in order to reduce the risk of double-counting (Gregory *et al.*, 2004). Observation at each point lasted 10 minutes (Fuller and Langslow, 2009). Observations were conducted just before sunrise - 10:00 and between 14:30 to 18.00 or adjusted according to weather conditions (Bibby *et al.*, 2000; Gregory *et al.*, 2004). Variables recorded include bird species, abundance, time, and other important information found during observation. Identification and nomenclature followed HBW and BirdLife International (2022).

Data Analysis

The data obtained within and outside the observation radius were used to create a list of species richness at PUSRI. The species list was supplemented with conservation status information based on IUCN, CITES, and national regulations, i.e., MoEF (2018). We analyzed the feeding guild classification according to Rumblat *et al.*, (2016), deGraaf *et al.*, (1985), and deGraaf and Wentworth (1986). For the analysis of the Shannon-Wiener Index, Margalef Index, and Pielou Index, we only used the bird species within the 50 m radius. The analysis was performed using the Vegan package (Oksanen *et al.*, 2022) in the R statistical program (R Core Team, 2022). Additionally, we used secondary data, including previous research both inside and outside PUSRI, to conduct a comparative analysis of the potential of green spaces at PUSRI as a refuge habitat for urban birds in Palembang.

III. RESULT AND DISCUSSION

Birds at PUSRI's Green Spaces

A total of 2.044 individual birds from 40 species and 25 families were recorded during a survey conducted in the green spaces PUSRI. This number is the total encountered inside and outside the radius of observation points. From the total, 28 species of birds were found in the Residential and Office Area, 18 in Captive-breeding Area, 17 in Rare Plant Cultivation Area, and 30 in Green Barrier (see Appendix 1). For the Green Barrier Area, bird species recorded in this study were almost twice higher than the previous study conducted by Sevli *et al.*, (2016), who recorded 17 species and 13 families. Green Barrier is an artificial forest ecosystem with limited access, developed as a conservation area and a buffer zone. Compared to the other three green spaces, Green Barrier has the minimum level of human activity with a variety of flora and habitats. The lack of disturbance combined with the high variation of habitat and vegetation is a strong reason for this area to be preferred as a home for birds. This finding aligns with the study by Fontana *et al.*, (2011) and Zhang *et al.*, (2023), who found that the high diversity of vegetation is a determining factor that positively correlates to bird richness in an ecosystem.

Environmental pressure, such as land conversion, has forced various species to seek refuge habitats, a suitable area that can provide food sources and protection from disturbances (Møller, 2012; Vasquez and Wood, 2022; Villaseñor *et al.*, 2020). Compared with the two nearest protected areas, Punti Kayu and Padang Sugihan, the bird richness in PUSRI does not differ significantly from those protected areas. Research by Iqbal *et al.*, (2016) found 44 bird species and 24 families in Punti Kayu Nature Tourism Park. Meanwhile, Saputra (2021) found 33 species and 20 families in the Padang Sugihan Wildlife Sanctuary. This comparison shows that PUSRI has the potential as a refuge habitat for urban birds. Additionally, the strict security regulations implemented in the PUSRI area provide a safer environment for birds, protecting them from human disturbances, including poachers, which are widespread in Indonesia. The strict regulation and diverse habitats, including ponds, meadows, parks, wetlands, and forests (Zhang *et al.*, 2023), make PUSRI an ideal refuge habitat for various urban bird species.

According to the IUCN red list, the vast majority of bird species found in PUSRI are categorized as Least Concern (LC), with only two species, Java Sparrow *Lonchura oryzivora and* Javan Myna *Acridotheres javanicus*, classified as "Endangered" and "Vulnerable" respectively. The Java Sparrow *Lonchura oryzivora* was found in Residential and Office Areas. The Javan Myna *Acridotheres javanicus* is often seen foraging with a herd of deer in the Captive-breeding Area. Additionally, the Javan Myna can also be found in the Green Barrier, usually perched in the tallest trees.

Regarding CITES, only one species in PUSRI is included in Appendix II, the Java Sparrow *Lonchura oryzivora*, while the other species are not included in any appendix. Three species are protected according to Indonesian regulation (P.106): the Brahminy Kite *Haliastur indus*, the Black-winged Kite *Elanus caeruleus*, and the Java Sparrow *Lonchura oryzivora*.

Diversity Metrics

The ecological condition of green spaces at PUSRI was assessed based on Margalef's, Pielou's, and Shannon's indices. Margalef's index reflects the number of species within an ecosystem or habitat, ranging from 0 to positive values. In contrast, Pielou's index quantifies the degree of evenness in the distribution of individuals among different species in an ecological community with values ranging from 0 to 1. The Shannon index represents species richness and evenness, which normally ranges from 0 to positive values (Daly *et al.*, 2018; Herrmann *et al.*, 2022). The Shannon value generally falls within the range of 1.3 to 3.5, with a few instances exceeding 4 (Roswell *et al.*, 2021; Magurran and McGill, 2011).

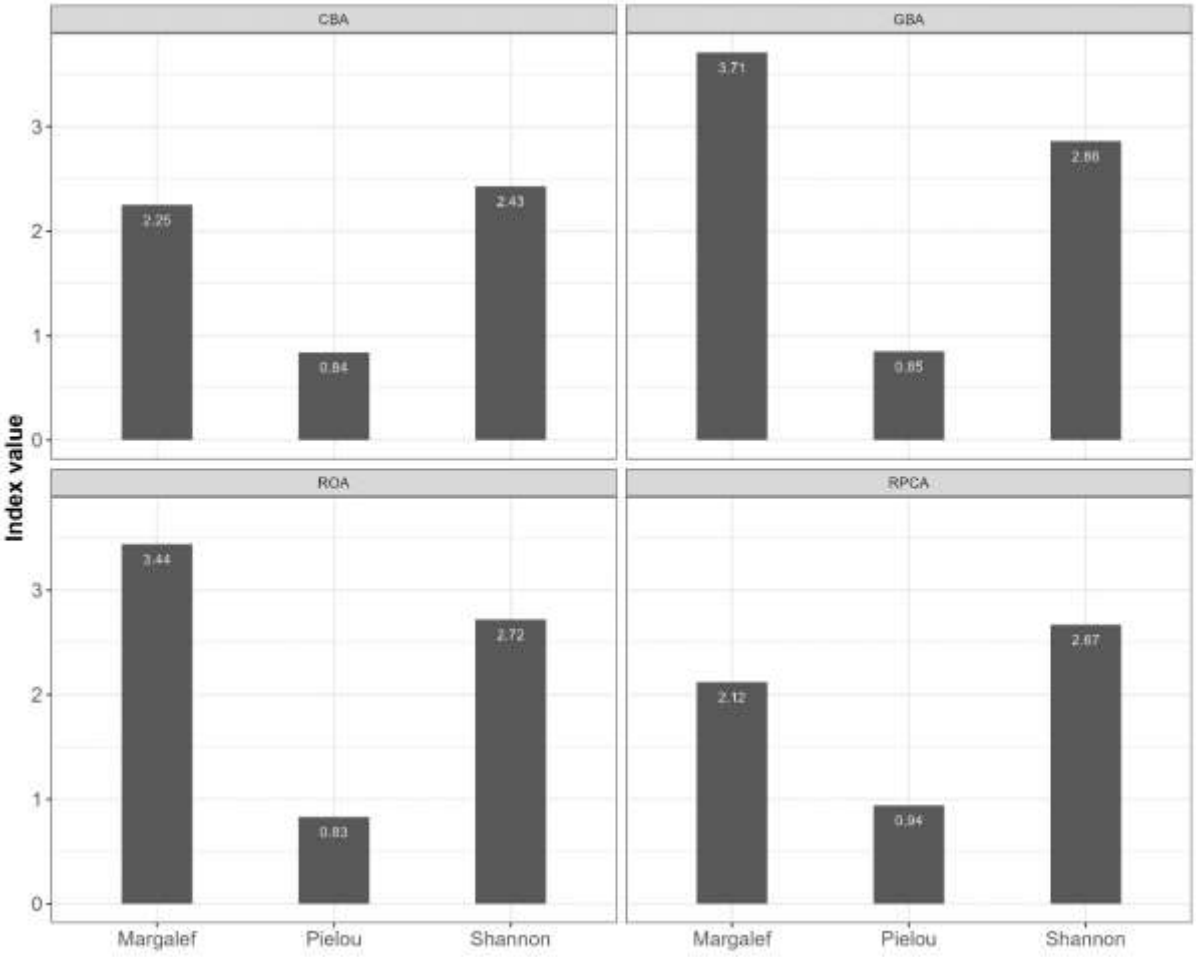

Figure 3. Three diversity metrics for each of the green spaces of PUSRI. CBA = Cavitve-breeding Area, GBA = Green Barrier Area, ROA = Residential and Office Areas, and RPCA = Rare Plant Cultivation Area. Margalef = Richness Index, Pielou = Evenness Index, and Shannon = Diversity Index.

As depicted in Figure 3, RPCA has Margalef's index of 2.12, Pielou's index of 0.94, and Shannon's index of 2.67. These values suggest relatively lower species richness, moderate species evenness, and moderate species diversity. The lower values of Margalef's and Shannon's indices may indicate fewer species present at this site than at other sites. Meanwhile, ROA has the highest Margalef's index among the four sites, with a value of 3.44, indicating higher species richness. However, the Pielou's index was relatively low at 0.83, indicating lower species evenness, and the Shannon index was moderate at 2.72, suggesting moderate species diversity. This indicates that although ROA may have a higher number of species, the abundance of species may not be evenly distributed.

Furthermore, CBA has Margalef's index of 2.25, Pielou's of 0.84, and Shannon's of 2.43. These values suggest moderate species richness, moderate species evenness, and moderate species diversity. In the meantime, GBA has the highest values of Margalef's index (3.71) and Shannon's index (2.86) among the four sites, indicating higher species richness and diversity. However, Pielou's index was moderate at 0.85, suggesting moderate species evenness.

Overall, the index values of all green spaces at PUSRI fall within the moderate to high range, indicating that green spaces at PUSRI can play a significant role in preserving bird diversity in the urban ecosystem of Palembang.

Bird Community Structures

The structure of a bird community can be a strong indicator of the ecological condition of a habitat or ecosystem. Birds have unique ecological characteristics, and their responses vary depending on their habitat's conditions, making them effective biological indicators to determine any disturbance in the environment or ecosystem (Cody, 1981; Gray *et al.*, 2007; O'Connell *et al.*, 2000). Disturbances that affect the availability of food sources can significantly impact bird responses, usually leading to fluctuations in the abundance and diversity of bird species (Gray *et al.*, 2007; Wong, 1986). This makes the approach related to food sources often used to observe bird community structure, one of which is through the composition of feeding guilds. Differences in the composition of feeding guilds will provide an overview of the ecological dynamics of a habitat or ecosystem.

Feeding guilds can be briefly described as groups of birds that utilize the same food source in the same way (O'Connell *et al.*, 2000). Our study found that 19 species or 47.5% of the total species, are classified as insectivore, seven species (17.5%) each belongs to granivore and frugivore, four species (10%) are carnivore, and two species (5%) belong to piscivore, and the remaining 2.5% is nectarivore.

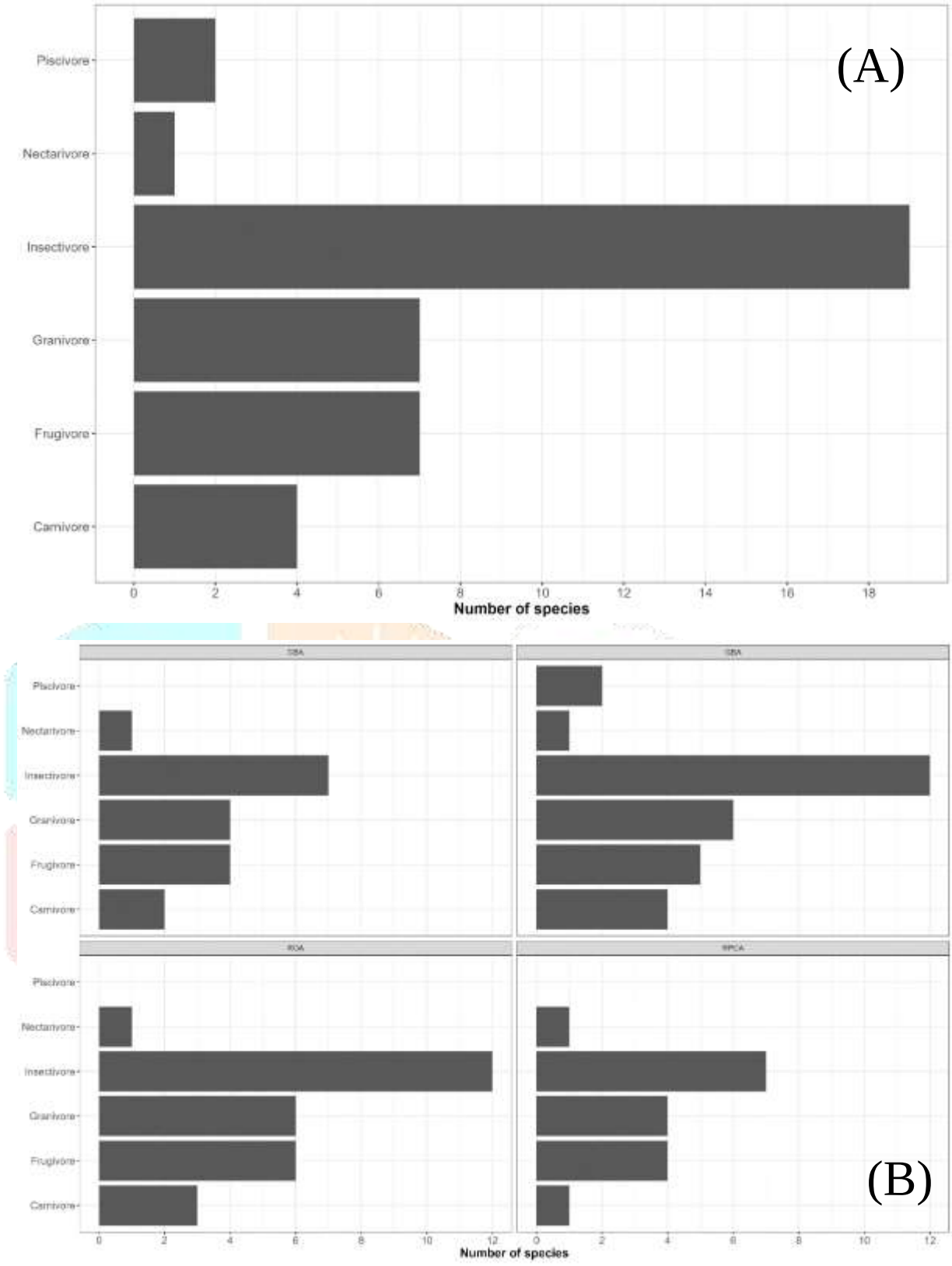

Figure 4. Structure of feeding guild in PUSRI's ecosystem (A) and each green space at PUSRI (B).

The large population of insectivorous species in all green spaces suggests that the insect population in PUSRI during this study was abundant. This is common in urban or residential areas (deGraaf *et al.*, 1985; deGraaf and Wentworth, 1986; Rumblat *et al.*, 2016), given the nature of insects which are generally more adaptive in urban areas (Seress and Liker, 2015).

The second-largest group consists of frugivores and granivores, indicating that fruits and seeds are the second most abundant types of food in PUSRI. In terms of size, species in this group have relatively small to medium sizes, such as Bulbuls, Pigeons, Barbets, Munias, and Flowerpeckers. Nathaniel and Wheelwright (1985) argue that plants with small fruit or seed sizes are relatively more attractive to frugivore and granivore than plants that produce large fruit or seed. This may also indicate that the size of the available fruits and seeds produced by the plants in PUSRI during this study was relatively small.

Furthermore, despite their small proportion, the presence of carnivore and piscivore in PUSRI strongly suggests that the area can provide food for these groups, such as fish, reptiles, amphibians, and small mammals, although their numbers may be limited. As species from these groups generally occupy the top of the food chain, their existence is crucial in maintaining a balanced food chain (Ritchie and Johnson, 2009) in PUSRI.

The number of nectarivore found in PUSRI's green spaces was the least. This condition indicates a lack of nectar availability during the study period, resulting in a few species of nectar-eating birds being attracted to PUSRI. A similar result was discovered in a study by Rumblat *et al.,* (2016) in the green space of Jakarta, where nectar-eating birds were found in the smallest numbers. They argue that the main reason is the narrow foraging niches and dependence on flowering plants. Therefore, providing plants with different flowering times throughout the year is crucial in ensuring year-round nectar availability. This will help maintain the presence of nectar-feeding birds in the area.

Future Implications

According to this study, the green spaces at PUSRI can host 40 species of birds from 6 different feeding guilds. The number of those feeding guilds observed in PUSRI is at the maximum level for urban green spaces (Sari, 2022). The diversity of feeding guilds reflects the variety of food resources and habitat types available in PUSRI. According to Fontana *et al.,* (2011) dan Zhang *et al.,* (2023), the complexity of bird species in an ecosystem is closely linked to the abundance of food sources and the variety of habitats. Although it cannot be confirmed that all bird species rely solely on PUSRI for food, it can be inferred that green spaces at PUSRI can support all bird species in that area. Moreover, PUSRI's green spaces, which span 107.29 ha, exceed the minimum size mandated for green open spaces (0.25 ha) by the Government Regulation of the Republic of Indonesia 63/2002. Consequently, green spaces at PUSRI are crucial as a hotspot and refuge habitat for urban birds in Palembang.

The variety of bird species in PUSRI is a valuable asset for the company to develop biodiversity programs in the future, one of which may involve designing an educational park. Educational parks can raise public awareness and provide an understanding of the roles and functions of birds, with the hope of encouraging the community to protect birds and their habitats. The design of educational parks can include various features such as information boards providing ecological descriptions, bird feeders, observation points or pathways, and ex-situ conservation units in the form of captive breeding for endangered bird species.

IV. CONCLUSION

Green spaces at PUSRI play a vital role for urban birds in Palembang. This role is demonstrated by its ability to host 40 species of birds from 24 families. Three diversity metrics ranged from medium to high, indicating that PUSRI has a stable and productive environment. The presence of all urban feeding guilds also illustrates the ability of PUSRI to act as a refuge habitat for urban birds in the city of Palembang. As an implication of the high complexity of species and the existence of protected and endangered species, PUSRI is required to continue to maintain and improve the quality of the environment and promote conservation programs, such as designing educational parks that have a positive value for environmental and human development.

Many exciting questions could still be further explored, such as the similarity patterns of bird species within and outside the PUSRI area and whether there are any relationships between bird species in both areas. Additionally, it would be worthwhile to investigate whether any species utilize PUSRI's green spaces as temporary habitats and determine the spatial and temporal patterns. The answers to these questions will provide valuable insights for future urban bird conservation efforts in Palembang.

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Appendix 1. List of birds recorded at PUSRI with guild categorization and conservation status information based on IUCN (EN = Endangered, VU = Vulnerable, LC = Least Conscern), CITES (No = Not listed in any appendix, App II = Listed in Appendix II), and national regulations (P.106, No = Unprotected, Yes = Protected). CBA = Captive-breeding Area, GBA = Green Barrier Area, ROA = Residential and Office Area, and RPCA = Rare Plant Cultivation Area.

Family	Scientific Name	Indonesian Name	P.106	IUCN	CITES	Guild	ROA	CBA	RPCA	GBA
Acanthizidae	*Gerygone sulphurea*	Remetuk Laut	No	LC	-	Insectivore	✓	✓	✓	✓
Accipitridae	*Haliastur indus*	Elang Bondol	YES	LC	-	Piscivore	✓			✓
Elanidae	*Elanus caeruleus*	Elang Tikus	YES	LC	-	Carnivore				✓
Alcedinidae	*Halcyon chloris*	Cekakak Sungai	No	LC	-	Carnivore	✓	✓		✓
	Halcyon smyrnensis	Cekakak Belukar	No	LC	-	Carnivore	✓	✓	✓	✓
Apodidae	*Aerodramus fuciphagus*	Walet Sarang-putih	No	LC	-	Insectivore	✓	✓		✓
	Collocalia esculenta	Walet Sapi	No	LC	-	Insectivore	✓	✓	✓	✓
Ardeidae	*Ardea intermedia*	Kuntul Perak	No	LC	-	Piscivore				✓
	Butorides striata	Kokokan Laut	No	LC	-	Piscivore				✓
Artamidae	*Artamus leucoryn*	Kekep Babi	No	LC	-	Insectivore	✓			✓
Campephagidae	*Lalage nigra*	Kapasan Kemiri	No	LC	-	Insectivore	✓			
Caprimulgidae	*Caprimulgus affinis*	Cabak Kota	No	LC	-	Insectivore	✓			
	Caprimulgus macrurus	Cabak Maling	No	LC	-	Insectivore			✓	
Columbidae	*Chalcophaps indica*	Delimukan Zamrud	No	LC	-	Granivore				✓
	Geopelia striata	Perkutut Biasa	No	LC	-	Granivore	✓	✓	✓	✓
	Spilopelia chinensis	Tekukur Biasa	No	LC	-	Granivore	✓	✓	✓	✓
	Treron vernans	Punai Gading	No	LC	-	Frugivore			✓	
Cuculidae	*Cacomantis merulinus*	Wiwik Kelabu	No	LC	-	Insectivore	✓	✓		
	Centropus bengalensis	Bubut Alang-alang	No	LC	-	Insectivore				✓
	Chrysococcyx basalis	Kedasi Australia	No	LC	-	Insectivore	✓			
	Eudynamys scolopaceus	Tuwur Asia	No	LC	-	Frugivore	✓	✓		
Dicaeidae	*Dicaeum trochileum*	Cabai Jawa	No	LC	-	Frugivore	✓	✓		✓
Estrildidae	*Lonchura leucogastroides*	Bondol Jawa	No	LC	-	Granivore	✓			✓
	Lonchura punctulata	Bondol Peking	No	LC	-	Granivore	✓	✓	✓	✓
	Padda oryzivora	Gelatik Jawa	YES	EN	App II	Granivore	✓			
Hirundinidae	*Hirundo javanica*	Layanglayang Batu	No	LC	-	Insectivore				✓
Laniidae	*Lanius schach*	Bentet Kelabu	No	LC	-	Insectivore				✓
Megalaimidae	*Psilopogon haemacephalus*	Takur Ungkut-ungkut	No	LC	-	Frugivore	✓	✓	✓	✓
Meropidae	*Merops philippinus*	Kirikkirik Laut	No	LC	-	Insectivore			✓	✓
Nectariniidae	*Anthreptes malacensis*	Burungmadu Kelapa	No	LC	-	Nectarivore	✓	✓	✓	✓
Oriolidae	*Oriolus chinensis*	Kepodang Kuduk-hitam	No	LC	-	Frugivore	✓			✓
Passeridae	*Passer montanus*	Gereja Erasia	No	LC	-	Granivore	✓	✓	✓	✓

Family	Scientific Name	Indonesian Name	P.106	IUCN	CITES	Guild	ROA	CBA	RPCA	GBA
Picidae	*Picoides moluccensis*	Caladi Tilik	No	LC	-	Insectivore	✓	✓	✓	
Pycnonotidae	*Pycnonotus aurigaster*	Cucak Kutilang	No	LC	-	Frugivore	✓	✓	✓	✓
	Pycnonotus goiavier	Merbah Cerukcuk	No	LC	-	Frugivore	✓		✓	✓
Rallidae	*Amaurornis phoenicurus*	Kareo Padi	No	LC	-	Insectivore			✓	✓
Sturnidae	*Acridotheres javanicus*	Kerak Kerbau	No	VU	-	Insectivore	✓	✓		✓
	Acridotheres tristis	Kerak Ungu	No	LC	-	Insectivore				✓
	Aplonis panayensis	Perling Kumbang	No	LC	-	Frugivore	✓			
Cisticolidae	*Orthotomus ruficeps*	Cinenen Kelabu	No	LC	-	Insectivore	✓	✓	✓	✓
						Grand Total	**28**	**18**	**17**	**30**