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Can cities provide butterfly-friendly habitats?

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Abstract. *Winarni NL, Nuruliawati, Anugra BG, Junaid AR, Widayanti S, Aslan, Nugroho A, Miga I, Kurniawan MB, Liestanti M, Lutfiani RA, Wulandari Y. 2023. Can cities provide butterfly-friendly habitats? Biodiversitas 24: 2334-2341.* Cities are progressively changed over time, creating land use changes with reduced green space areas. On the other hand, urban habitats offer a range of opportunities for biodiversity including butterflies which also act as an ecological health indicator. In Indonesia, like Jakarta Greater Area, or the so-called Jabodetabek which comprised Jakarta and its satellite cities, Bogor, Depok, Tangerang, and Bekasi, is highly urbanized. However, its capabilities to support the butterfly community are still little known. Thus, this paper aims to identify Jakarta Greater Area's potential as urban habitat for butterflies through a citizen science approach namely KupuKita. The data were collected from June 2021 to November 2022. The survey used KupuKita platform, an online questionnaire established in 2021, which focused on three families, Nymphalidae, Papilionidae, and Pieridae. Its species richness, diversity and community pattern were analyzed consecutively by using Shannon-Wiener and Simpson's Index. Next, the results were also analyzed towards the vegetation strata (grasses, shrubs, and trees) as observed during the data collection. The results suggested that Jakarta, Tangerang, and Bekasi have the least diverse butterfly community in comparison to Depok and Bogor. The butterfly community in Depok and Bogor was similar, both high in richness and diversity. Such similarity was potentially due to the wide arrays of remaining habitats that supported butterfly communities in three strata. The shrubs support more species richness rather than other strata. Bogor and Depok were potentially support more species in all three strata. Hence, because of the closely plant-butterfly relationships, vegetation interventions are crucial to increase the complexity of vegetation and create a butterfly-friendly habitat.

Keywords: Butterflies, citizen science, diversity, KupuKita, species richness, urban habitat

Abbreviations: Jabodetabek: Jakarta, Bogor, Depok, Tangerang, Bekasi

INTRODUCTION

Urbanization is a complex and dynamic multidimensional process over multiple scales through rapidly changing human populations and changing land cover (Seto et al. 2013; Maheng et al. 2021). The rate of urbanization around the world has accelerated in recent centuries (Hansen et al. 2005; Fragkias et al. 2013). According to the United Nations Development Program, the high rate of urbanization is due to the increasing human need for their basic needs (Ramírez-Restrepo and MacGregor-Fors 2017). This has led to a decline in environmental quality as numerous urban green spaces have been transformed into residential zones and other urban infrastructure (Kusmana 2015; Zain et al. 2015). Urban biodiversity declines as there are fewer green spaces (Güneralp and Seto 2013). The existence of urban green spaces plays an important role in the conservation of biodiversity in urban areas (Rupprecht et al. 2015; Ives and Kelly 2016; Aronson et al. 2017).

Over time, the quantity of trees and the size of green spaces in urban areas are altered by the dynamics of urban settlements and buildings (Douglas and Philip 2014). Despite the fact that homogeneous species often predominate the flora and fauna in urban green spaces, the existence of urban green spaces can also support the conservation of various species (Aronson et al. 2014; Ives and Kelly 2016; Lepczyk et al. 2017; Maheng et al. 2021). At least a city needs to retain a patch of >50 ha of vegetation to sustain threatened species in the city (Beninde et al. 2015). Additionally, the city's biodiversity can be increased by increasing the planting of native plants in urban green spaces (Threlfall et al. 2017).

Engagement of the non-professional in ecological research has been growing vastly in the past decade as an important contribution of conservation efforts (Wang et al. 2016; Soroye et al. 2018). Citizen science reduces both financial and time costs to survey an area (Prudic et al. 2018). Data collected by citizen science provide information on the distributions of species, and therefore help scientists from estimating species richness and diversity patterns to understanding the response of species to environmental change such as urbanization (Soroye et al. 2018). While data quality must be taken into account, citizen science reportedly contributes to higher diversity of butterflies in urban areas compared to standard methods conducted by trained observers (Prudic et al. 2018).

Butterflies are sensitive to climate and change in habitat because of their dependency to plants (Blair 1999; Dennis et al. 2017). Because of this sensitivity and the well-documented taxonomy, ecology, and life histories, butterflies play a role as biodiversity indicator as a measure of biodiversity and environmental health (Dennis et al. 2017). For example, in an urban landscape habitat, several species are good indicators for the change of land cover while others are indicators for wetland habitat (León-Cortés et al. 2019). Butterfly species richness is also correlated to other taxa such as birds (Blair 1999; Sing et al. 2019).

Jakarta Greater Area, or so-called Jabodetabek consists of Jakarta as the capital city and its satellite cities Bogor, Depok, Tangerang Bekasi. The population in Jakarta Greater Area is 11.76% of Indonesia's total population, with the highest population in Jakarta (Hasibuan et al. 2014) leaving less urban green areas. Few studies on butterfly community in Jakarta suggested that Jakarta may be able to support butterfly community but has not been discussed in detail the diversity patterns (Azahra et al. 2022; Ruslan et al. 2022). Thus, this paper aims to identify the butterfly species richness and diversity patterns which built upon the results of the citizen science activities conducted in Jakarta Greater Area. In addition, it will provide the baseline data for related stakeholders on how to enhance butterfly-friendly habitat in urbanized areas.

MATERIALS AND METHODS

Study area

This research was conducted in Jakarta, Indonesia and its satellite cities, Jakarta, Bogor, Depok, Tangerang, Bekasi (abbreviated as Jabodetabek or Jakarta Greater Area) during 2021-2022, covering home gardens, urban green areas, parks, and roadside. We defined home gardens as any gardens within an individual housing area, urban green spaces as large areas destined and managed specifically for urban forest or botanical gardens, while parks are other smaller green spaces within the neighborhood areas including recreational areas, cemeteries, community playgrounds, etc. Roadside was defined as any vegetation along the roadside including pedestrians (Figure 1).

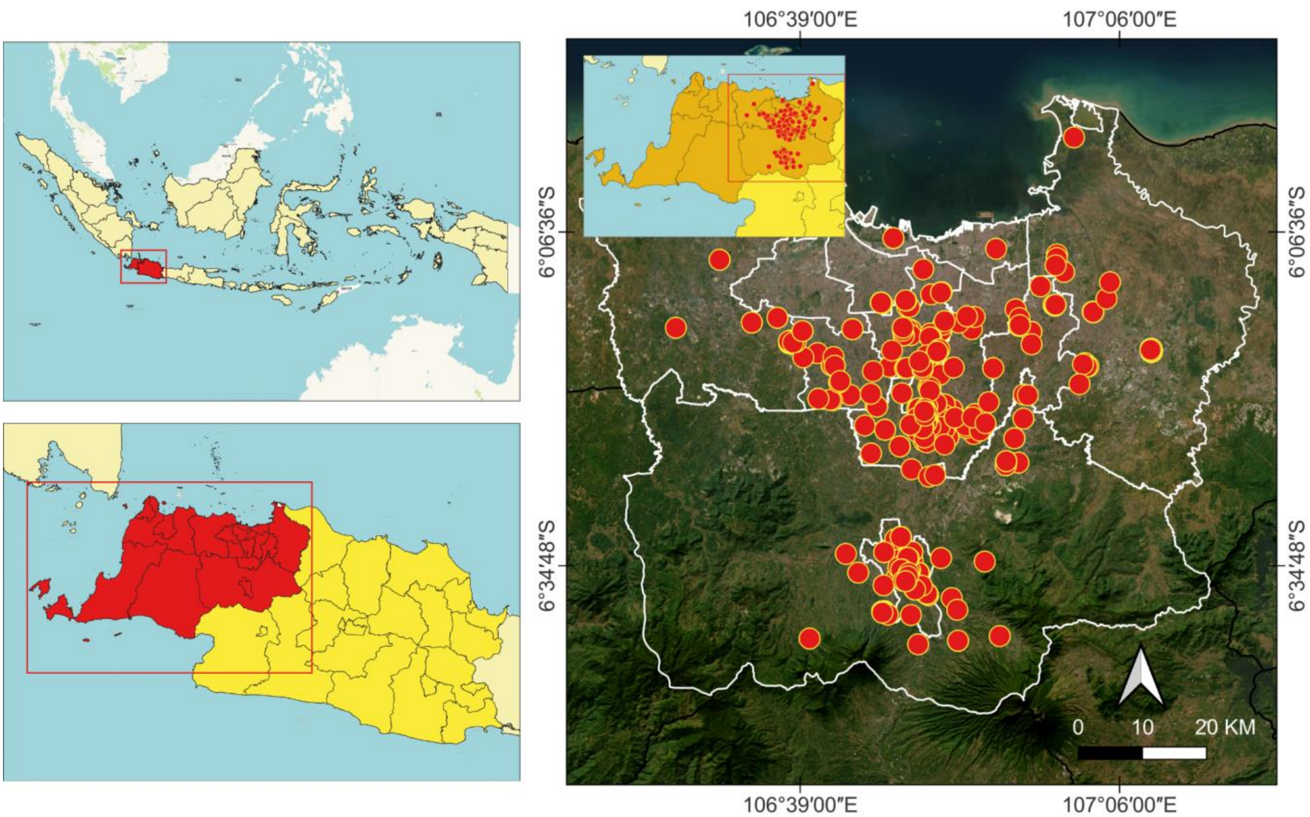

Figure 1. Survey locations in Jabodetabek, Indonesia and the detected sites of butterflies (black dots)

Procedures

The data were collected using KupuKita (https://kupukita.org) platform which was established in March 2021 as an urban citizen science platform for butterfly watching in Indonesia. KupuKita used KoboToolBox (https://www.kobotoolbox.org/) as an online data submission platform (Chau 2020; Panitsa et al. 2021). The platform was enclosed with pictorial guide of butterfly species to assist identification. Three families were included in this KupuKita platform, i.e., Nymphalidae, Papilionidae, and Pieridae because they are considered as the largest size butterflies to ensure correct identification by observers. Other smaller size families (Lycaenidae and Hesperiidae) were not included as they can be easily overlooked by untrained observers (Corbet and Pendlebury 1992; Vann 2008). Species name was based on Corbet and Pendlebury (1992), as well as Peggie and Amir (2006).

Butterfly observation was carried out independently by citizen science observers using a combination of Pollard walk and point count methods. Based on these methods, observers have the ease to walk around or stand on a point and record the butterfly data within 50 m for 10-15 minutes (Pollard 1977). The distance between points was approximately 50-100 m. To avoid double counting, species that were already recorded at a point should not be recorded again. Prior to independent observations, observers joined trainings carried out by KupuKita and were encouraged to take pictures of the butterflies they have seen, and was validated by KupuKita team (authors).

Data analysis

We used data collected during June 2021-November 2022. We analyzed species richness and diversity using Shannon-Wiener index and Simpson’s Index using https://chao.shinyapps.io/iNEXTOnline/ for each location (Jakarta, Bogor, Depok, Tangerang, Bekasi) and constructed the sample-based rarefaction curves (Chao et al. 2005). Shannon-Wiener is based on the assumption that individual species are randomly sampled from a large community with all species represented in the sample, while the Simpson diversity index is weighted towards dominance species in the sample (Magurran 2004). Then, we defined species based on stratum to help understand the distribution patterns of the butterfly species. Stratum 1 for species occupies the habitat floor including grasses; stratum 2 for species that occupies shrubs; and stratum 3 for species that occupies the trees, including the canopies. We also defined species into urban adapters and urban avoiders based on urban tolerance classification following Koh and Sodhi (2004). Then, we carried out Bray-Curtis similarity coefficient to analyze β diversity. The Bray-Curtis coefficient measures the biotic distinctness of the community composition and was depicted with cluster analysis (Magurran 2004).

RESULTS AND DISCUSSION

Results

In total, this citizen science effort recorded 50 species from 1983 records. These were comprised of 34 species Nymphalidae, 10 species Papilionidae, and 6 species Pieridae. The most common species were *Appias olferna* (Swinhoe 1890), *Leptosia nina* (Fabricius 1793), *Eurema* sp. from family Pieridae, and *Hypolimnas bolina* (Linnaeus 1758) from family Nymphalidae. However, the composition of most common species was different between cities. There were two additional species, *Junonia orithya* (Linnaeus 1758) and *Neptis hylas* (Linnaeus 1758) which were abundant in Bekasi and Tangerang but not in other cities (Table 1).

Depok and Bogor significantly support higher species richness and diversity than other cities. Depok has the highest species richness with 49 species, followed by Bogor with 48 species. The least number of species was Jakarta with 32 species. The butterfly diversity between Depok and Bogor was similarly high. In contrast, Bekasi, Jakarta, and Tangerang were similarly lower. The rarefaction curves for species richness and Shannon-Weiner diversity index showed similar patterns. The Simpson’s index, however, did not show much different patterns among the cities that indicated the similar number of most abundant species in the sample (Figure 2). In Jabodetabek, there existed two to three species that were notably abundant (with a relative abundance greater than 0.1) (Table 2). In terms of community evenness, the butterfly community in Depok has higher evenness than other cities (Table 1).

Table 1. Species richness, diversity, and evenness in Jakarta Greater Area, Indonesia

Parameters	Bekasi	Bogor	Depok	Jakarta	Tangerang	Total
Number of records	305	568	492	157	461	1983
Number of species	34	48	49	32	40	51
Sp in Home gardens	28	38	31	17	26	47
Sp in Parks	20	35	45	23	12	46
Sp. in Roadside	21	26	10	10	18	47
Sp. in Urban green areas	4	40	14	15	32	37
Sp. in Stratum 1 (grasses)	12	16	16	9	14	16
Sp. in Stratum 2 (shrubs)	13	19	19	15	14	19
Sp. in Stratum 3 (trees)	8	12	13	8	11	15
Simpson (1-D)	0.9114	0.9437	0.9457	0.8916	0.9116	
Shannon (H)	2.845	3.308	3.401	2.634	2.864	
Evenness (Ln H/S)	0.5061	0.5692	0.6124	0.4351	0.4382	
Most common species (relative abundance>0.1)	*Appias olferna* *Eurema* sp. *Junonia orithya*	*Leptosia nina* *Hypolimnas bolina*	*Leptosia nina* *Appias olferna*	*Appias olferna* *Leptosia nina*	*Leptosia nina* *Eurema* sp. *Neptis hylas*	

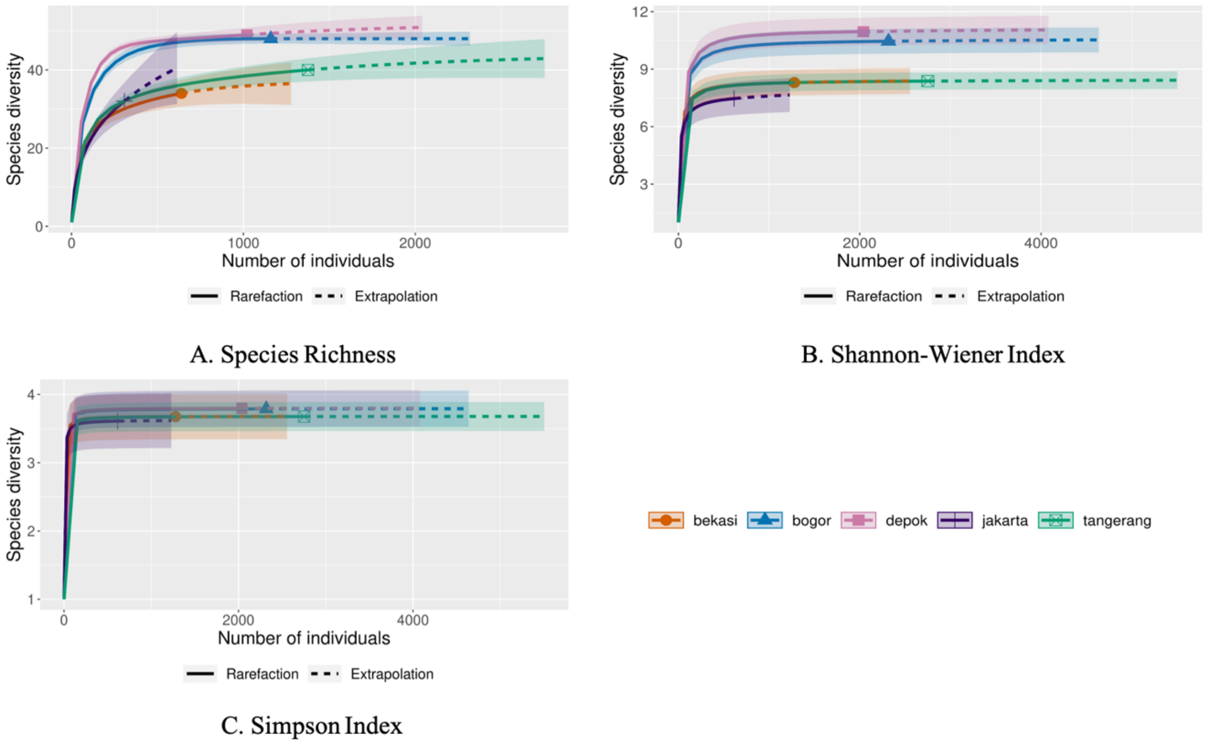

Figure 2. Abundance curves of species richness, Shannon-Wiener diversity index, and Simpson index of Jakarta Greater Areas, Indonesia (straight line) with rarefaction curves (dotted line)

Although we understand that there were data limitation such as there were not enough representations of DKI Jakarta, this in fact reflected the distributions of observers which tend to live in satellite cities than Jakarta (Hasibuan et al. 2014). However, we acknowledged the inconsistencies in the amount of data because of the observation distributions were not equal between cities as the caveat of this study.

There were overall distributions patterns among the species. For example, Bogor has more species recorded in the green areas while Bekasi has the least species. Species richness occupied the roadside was likely low in all cities except Bekasi and Tangerang. In addition, there were more species recorded in the roadside of Bekasi and Bogor, than other cities. In terms of stratum, there were more species recorded in shrubs than other strata. Bogor and Depok potentially support more species in all three strata, but not other cities. For example, *Acraea violae* (Fabricius 1775), a species which occupies grasses tended to be detected in Bogor and Depok. All species found in grasses were all urban adapters. The least strata represented are the trees and canopies. Almost all the species flying high in the trees were urban adapters except *Catopsilia pomona* (Fabricius 1775) and *Delias hyparete* (Linnaeus 1758). Most Papilionidae species which usually fly high around the trees and canopies were mostly recorded in Bogor and Depok, such as *Graphium doson* (Felder & Felder 1864), *Graphium agamemnon* (Linnaeus 1758), and *Papilio polytes* (Linnaeus 1758) (Table 2).

The Bray-Curtis pairwise comparison of beta diversity suggested that Depok and Bogor (0.947) butterfly community tended to be similar, followed by Depok-Tangerang (0.897). In contrast, the butterfly community in Jakarta was the least similar to other cities (Figure 3, Table 3).

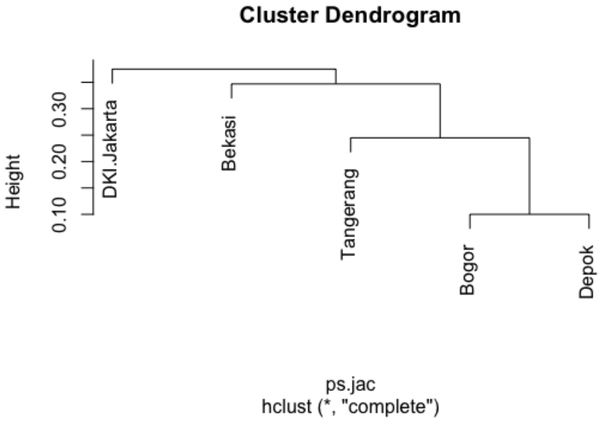

Figure 3. Cluster analysis based on Bray-Curtis similarity coefficient

Table 2. List of species with urban tolerance, stratum, and relative abundance of butterfly species in Jakarta Greater Area, Indonesia

Species	Urban tolerance	Strata	Bekasi	Bogor	Depok	Jakarta	Tangerang
Acraea violae	Urban adapter	Grasses	0.014	0.023	0.010	0.000	0.004
Amathusia phidippus	Urban avoider	Trees	0.000	0.010	0.011	0.003	0.000
Appias lyncida	Urban avoider	Shrubs	0.000	0.023	0.001	0.003	0.001
Appias olferna	Urban adapter	Shrubs	0.188	0.070	0.132	0.208	0.076
Ariadne ariadne	Urban avoider	Shrubs	0.050	0.003	0.011	0.003	0.013
Catopsilia pomona	Urban adapter	Trees	0.041	0.026	0.021	0.003	0.031
Cyrestis lutea	Urban avoider	Shrubs	0.000	0.002	0.008	0.000	0.000
Danaus chrysippus	Urban avoider	Shrubs	0.036	0.005	0.010	0.003	0.000
Delias hyparete	Urban adapter	Trees	0.039	0.035	0.011	0.016	0.014
Doleschalia bisaltide	Urban adapter	Shrubs	0.008	0.005	0.026	0.007	0.034
Elymnias hypermnestra	Urban adapter	Shrubs	0.013	0.019	0.044	0.052	0.015
Elymnias nesaea	Urban avoider	Shrubs	0.000	0.009	0.008	0.000	0.001
Euploea mulciber	Urban adapter	Shrubs	0.006	0.016	0.028	0.016	0.012
Eurema sp.	Urban adapter	Grasses	0.164	0.088	0.037	0.130	0.166
Euthalia aconthea	Urban adapter	Shrubs	0.002	0.006	0.011	0.010	0.007
Euthalia adonia	Urban avoider	Shrubs	0.000	0.006	0.009	0.020	0.004
Graphium agamemnon	Urban avoider	Trees	0.020	0.032	0.018	0.010	0.035
Graphium antiphates	Urban avoider	Trees	0.000	0.000	0.007	0.000	0.000
Graphium doson	Urban avoider	Trees	0.016	0.030	0.008	0.013	0.004
Graphium sarpedon	Urban avoider	Trees	0.002	0.014	0.001	0.000	0.001
Hypolimnas bolina	Urban adapter	Shrubs	0.033	0.108	0.063	0.075	0.047
Ideopsis juventa	Urban avoider	Shrubs	0.000	0.020	0.013	0.000	0.000
Junonia almana	Urban adapter	Grasses	0.019	0.006	0.009	0.000	0.001
Junonia athlites	Urban adapter	Grasses	0.017	0.014	0.011	0.013	0.012
Junonia erigone	Urban adapter	Grasses	0.000	0.006	0.021	0.000	0.000
Junonia hedonia	Urban adapter	Shrubs	0.027	0.026	0.032	0.072	0.035
Junonia iphita	Urban adapter	Grasses	0.003	0.007	0.013	0.003	0.006
Junonia orithya	Urban adapter	Grasses	0.116	0.018	0.031	0.036	0.024
Leptosia nina	Urban adapter	Grasses	0.077	0.138	0.136	0.166	0.173
Lethe europa	Urban avoider	Shrubs	0.003	0.002	0.009	0.036	0.001
Losaria coon	Urban avoider	Trees	0.000	0.003	0.000	0.000	0.000
Melanitis ieda	Urban adapter	Grasses	0.002	0.021	0.010	0.000	0.004
Moduza procris	Urban avoider	Shrubs	0.002	0.007	0.009	0.003	0.000
Mycalesis janardana	Urban adapter	Grasses	0.019	0.008	0.009	0.000	0.007
Mycalesis mineus	Urban adapter	Grasses	0.000	0.003	0.008	0.003	0.017
Mycalesis orseis	Urban adapter	Grasses	0.002	0.007	0.008	0.000	0.001
Mycalesis perseus	Urban adapter	Grasses	0.000	0.006	0.012	0.003	0.022
Neptis hylas	Urban avoider	Shrubs	0.025	0.008	0.014	0.010	0.105
Pachliopta aristolochiae	Urban avoider	Trees	0.000	0.006	0.001	0.000	0.001
Papilio demoleus	Urban avoider	Trees	0.028	0.008	0.026	0.049	0.019
Papilio demolion	Urban avoider	Trees	0.013	0.003	0.000	0.007	0.000
Papilio memnon	Urban avoider	Trees	0.006	0.025	0.021	0.000	0.003
Papilio polytes	Urban avoider	Trees	0.000	0.024	0.012	0.003	0.011
Phaedyma columella	Urban avoider	Shrubs	0.006	0.012	0.024	0.007	0.010
Phalanta phalantha	Urban avoider	Shrubs	0.000	0.003	0.009	0.000	0.000
Polyura athamas	Urban avoider	Trees	0.000	0.000	0.011	0.000	0.004
Polyura hebe	Urban avoider	Trees	0.000	0.000	0.008	0.000	0.001
Ypthima baldus	Urban adapter	Grasses	0.000	0.043	0.045	0.003	0.066
Ypthima horsfieldii	Urban adapter	Grasses	0.003	0.013	0.015	0.000	0.000
Ypthima philomela	Urban adapter	Grasses	0.003	0.035	0.013	0.013	0.015

Table 3. Bray-Curtis's pairwise comparison in Jakarta Greater Area, Indonesia

	Bekasi	Bogor	Depok	Jakarta
Bogor	0.825			
Depok	0.790	0.947		
Jakarta	0.769	0.810	0.775	
Tangerang	0.805	0.860	0.897	0.789

Discussion

Butterfly community in Jakarta greater area

Butterflies are able to use different parts of urban habitats in different ways (Koh and Sodhi 2004; Tam and Bonebrake 2016). In Jakarta Greater Area, butterflies occupied parks and urban green areas, home gardens, to roadside. Vegetated habitats, particularly the availability of host plants, were essential for butterflies (Curtis et al. 2015; Tam and Bonebrake 2016). The most common species such as *A. olferna*, *L. nina*, *Eurema* spp. were oftenly observed within the lowest stratum of habitats, visiting grasses and other weed flowers. They are usually associated to human-disturbed habitat (Ilhamdi et al. 2023). *Cleome rutidosperma* DC. is a common weed plants utilized as host plants of these species (Mukherjee et al. 2016; Mukherjee et al. 2018). Another common species, sexually-dimorphic *H. bolina* was observed in the shrub stratum (Kemp and Jones 2001). These four species were urban adapters, or generalist species (Koh and Sodhi 2004). In comparison with birds which have three different types of habitat specialization (urban exploiter, urban adapter, and urban avoider) (Mardiastuti et al. 2020; Winarni et al. 2022), there are only two types of habitat specialization in butterflies, i.e., urban adapter and urban avoider. It is because there are no butterflies exploit human built-in habitats such as buildings (Sing et al. 2019). The additional most common butterflies, *J. orithya* in Bekasi was usually observed on grasses (Hawkeswood 2022). The *N. hylas* was one of the most abundant species in Tangerang which probably reflects the available and also suitable habitats. The *N. hylas* is usually related to shrubs and agricultural areas (Rusman et al. 2016).

These findings complement the information on butterfly communities in the Asian cities (Tam and Bonebrake 2016; Mukherjee et al. 2018; Sing et al. 2019; Jaturas et al. 2020; Nacua et al. 2020). In many Asian cities, there are more built-in areas resulting the more cultivated vegetations rather than native vegetations (Mukherjee et al. 2018). Roadside tend to have less butterfly species richness (Chong et al. 2014; Chong et al. 2019). In contrast to our findings, in Hongkong and Singapore, *C. pomona* was recorded as dominant species (Tam and Bonebrake 2016). Another abundant species in Hongkong and Kuala Lumpur which was similar to this study, is *Eurema* spp. which was mostly occupied the urban parks (Sing et al. 2016; Tam and Bonebrake 2016). Another species, *A. olferna* is also common in Kuala Lumpur (Sing et al. 2016).

Butterflies especially species with higher dispersal ability are able to move between habitats, even in fragmented landscapes or non-vegetated habitats (Tam and Bonebrake 2016). In the fragmented landscapes, the patchy habitats would increase the costs of finding suitable plants for laying eggs or nectar source (Schtickzelle et al. 2007). Species such as *C. pomona* was sometimes seen fly high crossing large roads including tolls (N. Winarni pers. observation). In Hongkong, this species has the widest range of nectar plant usage (Tam and Bonebrake 2016) and known as migrant species (Peggie and Amir 2006), which may explain the wide flying range foraging for suitable plants.

There are potentially more species in Jakarta Greater Area since this study covered only 3 families, Nymphalidae, Papilionidae, and Pieridae, excluding Lycaenidae and Hesperiidae. These results also suggested that voluntary-driven data is promising to provide overall distribution and diversity patterns of butterfly community (Prudic et al. 2017, 2018; Washitani et al. 2020), although we acknowledged that more coverage are needed to obtain better patterns, especially for Jakarta. The development of another citizen science observation platform such Kupunesia will also enrich the information on butterfly species distribution in Jakarta Greater Area as well as Indonesia (Peggie et al. 2022).

Jakarta greater area as butterfly-friendly habitats

Butterfly responds differently to different level of urbanization which depend on distribution area and historical background of the cities (Ramírez-Restrepo and MacGregor-Fors 2017). Hence, Jabodetabek is progressively changed from time to time with more built-up areas (Nagasawa et al. 2015; Rustiadi et al. 2015) leaving less green areas with less native plant species. Looking back at the historical process, the remaining forested habitats were changed into paddy fields and agricultural areas before finally changed into built-in habitats. Among Jabodetabek, Jakarta as the central area of government administration was also the center of development. Rustiadi et al. (2015) revealed that in 1972, the built-in areas in Jakarta was still limited but gradually expanded to the south. Such expansion spread out following major highways (Rustiadi et al. 2015).

Both Depok and Bogor have similar butterfly species richness and diversity. Located between Jakarta and Bogor, Depok was likely close to Bogor in terms of the remained green areas (Zain et al. 2015). Bogor, which tend to have lower air temperature compare to other cities, exhibits the more diverse land uses, such as, forest, dry fields, agriculture areas, and lakes, that has more ecological networks in the surroundings areas (Arifin and Nakagoshi 2011; Zain et al. 2015; Wartaman et al. 2018), and may still show connections to Depok. Depok has Universitas Indonesia's Urban Forest, and still exhibits different land uses including dry fields, agriculture areas, lakes, although in smaller amount of areas (Wartaman et al. 2018; Debataraja et al. 2021; Winarni et al. 2021). Between Jakarta, Depok, Bogor, and Tangerang, the latest has the least urban green areas (Zain et al. 2015). Bekasi might be similar to Tangerang in terms of available urban green areas (Wartaman et al. 2018).

The key to biodiversity-friendly urban green spaces in to manage the different arrays of available habitats such as riparian corridors, parks, home gardens, to highly engineered green infrastructures such as green roofs (Aronson et al. 2017). A simple vegetation interventions have been significantly increased the occupancy of urban wildlife (Threlfall et al. 2017) However, cultivated vegetation alone could not increase butterfly species richness (Chong et al. 2014). Choices of plants are important to attract butterflies (Shackleton and Ratnieks 2016). For example, conversion of lawns into grassy meadows or pollinator meadows would increase structural complexity of the vegetation and attract butterfly visitations. Butterflies are therefore, a good indicator for restoration program (Douglas and Philip 2014). A managed lawn will also reduce runoff and controlling erosion (Aronson et al. 2017) that will helps to avoid flood during rainy season. In addition, urban green spaces significantly reduced the air temperature (Zain et al. 2015).

In conclusion the butterfly diversity patterns indicated that only Depok and Bogor offer more favourable habitats for butterflies. Butterflies in these cities could be found across various strata, including grasses, shrubs, and trees. In order to improve butterfly-friendly habitats, cities should provide a range of habitats that offer host and food plants for butterflies.

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