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Exploring butterfly diversity in urban landscapes: A case study from Depok, Indonesia

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ABSTRAK

Kota Depok merupakan salah satu kota satelit Jakarta dengan tingkat urbanisasi yang tinggi, sehingga mengakibatkan berkurangnya ruang hidup bagi kupu-kupu. Ruang terbuka hijau (RTH) *memainkan peran ekologi yang penting dan berpotensi menjadi habitat bagi berbagai jenis kupu-kupu di kawasan perkotaan. Keberadaan RTH berpotensi menyediakan tumbuhan pakan dan preferensi lingkungan yang mendukung ruang hidup kupu-kupu. Penelitian potensi RTH sebagai habitat kupu-kupu di kawasan perkotaan untuk menentukan keanekaragaman, kelimpahan, kepadatan, dan keseragaman jenis kupu-kupu di RTH Kota Depok. Penelitian dilakukan di lima RTH di Kota Depok menggunakan teknik pengambilan sampel* Visual Encounter Survey (VES). *Kami menemukan bahwa RTH Depok menunjukkan H' dan E kupu-kupu yang moderat dengan kepadatan rata-rata 10,04 individu/ha. Suhu dan kelembapan RTH tidak menentukan variabel populasi; sedangkan intensitas cahaya dan luas area secara signifikan berhubungan dengan kelimpahan, H'* Shannon-Wiener*, dan densitas kupu-kupu. E Pielou tidak ditentukan oleh variabel abiotik apa pun. RTH Depok menunjukkan potensi yang kuat sebagai tempat perlindungan yang mendukung keanekaragaman kupu-kupu di ekosistem perkotaan.*

Kata kunci: Lepidoptera, keanekaragaman, Kota Depok, RTH, urban

ABSTRACT

Depok City is one of Jakarta's satellite cities with a high level of urbanisation that is reducing the living space for butterflies. Green open spaces (GOS) *play an important ecological role and have the potential to become habitats for a diverse range of butterfly species in urban areas. The existence of GOS has the potential to provide food plants and environmental preferences that support the living space of butterflies. Research needs to be conducted to determine the potential of these GOS as habitats for butterfly diversity in urban areas. This study aims to determine the diversity, abundance, density, and evenness of butterfly species in Depok City's GOS. The study was conducted in five GOS in Depok City using the* Visual Encounter Survey (VES) *sampling technique. We found Depok's GOS showed moderate butterfly diversity and species evenness indices with an average density of 10.04 individuals/ha. GOS's temperature and humidity does not determine the population variables; while light intensity and area sizes significantly related to abundance,* Shannon-Wiener's *H' and density of butterflies.* Pielou's *E is not determined*

by any abiotic variables. Depok's green spaces show strong promise as refugia supporting butterfly diversity in urban ecosystems.

Keywords: Biodiversity, Depok City, GOS, lepidoptera, urban

INTRODUCTION

The Green Open Spaces (GOS) play an important ecological role as habitats for plants and animals, including butterflies (Diana et al., 2015; Nelyzza, 2023). Butterflies are cosmopolitan organisms and serve as environmental bioindicators as each species has specific environmental preferences (Azahra et al., 2016). They are important natural pollinators as also play a role at the second trophic level in ecosystems as herbivores. While they serve as important urban biodiversity component, their diversity in urban area is prone to anthropogenic activities. Their abundance in an area, especially an urban setting, is highly influenced by the abundance food plants, temperature, humidity, light intensity and vegetation cover. Anthropogenic disturbances are a known factor that influence their abundance in urban area (Wang et al., 2025; Diana et al., 2015).

One of most important threat for the diversity urban butterflies is the shrinkage of natural habitat. The reduction of green area alters the microclimate and food source vegetation (Azahra et al., 2022). Changes in the function of green spaces into industrial and residential areas indirectly reduce the living space of butterflies. Depok is a satellite city of Jakarta that has experienced changes in the function of GOS every year. Urbanisation in Depok is relatively high, with the percentage of built-up land in 2006 at 48.18%, in 2013 at 59.97%, and in 2019 at 66.04% (Aji et al., 2020). The increase in land use for built-up areas is inversely proportional to the use of land as GOS. The area GOS in Depok City between 2013 and 2021 has decreased by 20.2% (Gunadi et al., 2025). This happens especially in the privately own GOS, where rice fields, shrubs and open land continue to decline in size (Aji et al., 2020), even though according to the official website of the Depok City Government, in 2025 there will be 24 public GOS spread across eleven sub-districts, a good sign for biodiversity (https://sig-maps.depok.go.id/). However, in overall area, the decline of green spaces in Depok may impact badly for biodiversity as it increases in ground surface temperature which may threat sensitive group of organisms (Widyanti et al., 2025).

Research on the role of GOS as biodiversity refugia, including butterflies, is important to ensure their sustainability and persistence in urban habitat. It is therefore important to access the role of both private and public GOS in Depok as potential habitat for urban biodiversity, which then perhaps useful as bioindicator of ecosystem balance. As those GOS may differ in their open and closed vegetation area, temperature, humidity, light intensity and other variables, that it is interesting to compare several GOS as important harbour for butterfly species diversity.

METHODOLOGY

Studies sites and species sampling

The study was conducted from September to October 2025 between 09:00 and 15:00 Western Indonesia Time. We chose five GOS in Depok as the research locations,

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determined based on the criteria of public or private GOS (**TABLE 1**) with open vegetation areas, closed vegetation areas, and surface water sources such as rivers, lakes, or reservoirs.

TABLE 1. Data collection locations and coordinates

Numb.	STATUS	NAME	SUB-DISTRICT	COORDINATES
1	Public	Setu Jatijajar	Tapos	-6.423, 106.859
2	Private	Studio Alam TVRI	Sukmajaya	-6.418, 106.843
3	Public	Taman Lembah Gurame	Pancoran Mas	-6.394, 106.808
4	Private	D'Kandang Amazing Farm	Sawangan	-6.415, 106.784
5	Private	Taman Bunga Wiladatika	Cimanggis	-6.370, 106.893

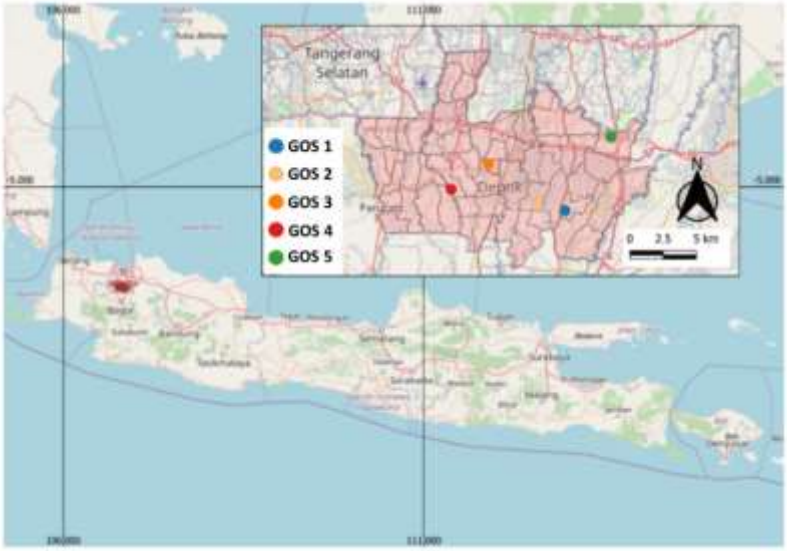

FIGURE 1. Map of data collection locations

Data collection was carried out using the *Visual Encounter Survey* (VES) technique by tracing paths that adapted to the diverse landscapes of the five GOS. Data collection at each location was carried out once. The tools used included a butterfly net (pole length 2 m, circle diameter 0.5 m, and net length 1.5 m), a *Redmi Note 13* smartphone camera, a *Kyoritsu model 5201 illumination meter* to measure light intensity, and a *Yenaco Super Deluxe Wet and Dry thermometer* to measure air temperature and humidity. Butterflies were identified using identification books (Hardy & Lawrence, 2017; Ruslan et al., 2021; Schulze, 2010) and the *iNaturalist* website (https://www.inaturalist.org/). Nomenclature also follows iNaturalist.

We calculate the abundance (number of individuals of x species in a GOS), density (D = N/A, where D = Density; N = Number of individuals of a species; A = Area), *Shannon-Weiner's* diversity index ($H' = - \Sigma (p_i \times \ln(p_i))$, where H': *Shannon-Weiner's* diversity index; p_i: the relative abundance of species I; ln: the natural logarithm, and *Pielou's* evenness index (E = H'/ln S, where E: Evenness; H': *Shannon-Wiener's* diversity index; S: total number of species found) of each GOS.

Data analysis techniques

We describe the species (families) list in a table; the density, abundance, diversity and evenness of each GOS in tables and pie charts, descriptively. The relationship

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between the environmental variables (temperature, humidity, light intensity and area sizes) and the population variables (abundance, diversity, density and evenness) was measured using *Spearman's rank correlation* test. This nonparametric test is most appropriate to our data due to the small sample size and the non-normal distribution of environmental and ecological data.

RESULTS AND DISCUSSION

TABLE 2. Number of butterfly individuals and species in 5 GOS in Depok City

Family	Species	GOS 1	GOS 2	GOS 3	GOS 4	GOS 5	Total
Lycaenidae	*Arhopala centaurus* (Fabricius, 1775)	0	0	0	0	3	**3**
	Castalius rosimon (Fabricius, 1775)	0	5	4	0	0	**9**
	Catochrysops strabo (Fabricius, 1793)	0	1	0	0	0	**1**
	Jamides celeno (Cramer, 1775)	0	12	0	0	4	**16**
	Loxura atymnus (Cramer, 1782)	0	6	0	0	0	**6**
	Zizula hylax (Fabricius, 1775)	13	31	17	6	26	**93**
Nymphalidae	*Acraea terpsicore* (Linnaeus, 1758)	0	3	0	0	11	**14**
	Doleschallia bisaltide (Cramer, 1777)	2	0	0	0	0	**2**
	Elymnias hypermnestra (Linnaeus, 1763)	9	2	0	0	3	**14**
	Euploea camaralzeman (Butler, 1866)	0	0	1	1	0	**2**
	Euploea leucostictos (Gmelin, 1790)	0	2	0	0	0	**2**
	Euthalia aconthea (Cramer, 1777)	1	0	1	0	0	**2**
	Hypolimnas bolina (Linnaeus, 1758)	11	2	3	10	10	**36**
	Hypolimnas misippus (Linnaeus, 1764)	0	7	0	0	0	**7**
	Junonia atlites (Linnaeus, 1763)	4	0	12	0	1	**17**
	Junonia hedonia (Linnaeus, 1764)	3	4	0	16	15	**38**
	Junonia iphita (Cramer, 1779)	1	1	0	2	3	**7**
	Junonia orithya (Linnaeus, 1758)	3	5	0	0	5	**13**
	Lethe europa (Fabricius, 1787)	0	0	0	1	1	**2**
	Lethe minerva (Fabricius, 1775)	0	0	0	2	1	**3**
	Mycalesis perseus (Fabricius, 1775)	1	1	0	10	3	**15**
	Neptis hylas (Linnaeus, 1758)	1	30	0	7	3	**41**
	Tanaecia palguna (Moore, 1857)	1	0	0	0	0	**1**
	Ypthima nigricans (Snellen, 1892)	15	21	4	18	6	**64**
Papilionidae	*Graphium doson* (Felder & Felder, 1864)	1	0	0	0	0	**1**
	Papilio demoleus (Linnaeus, 1758)	0	1	1	0	0	**2**
	Papilio demolion (Cramer, 1776)	1	0	0	5	6	**12**
	Papilio lowii (Druce, 1873)	0	0	0	0	1	**1**
	Papilio memnon (Fruhstorfer, 1903)	1	0	0	1	0	**2**
	Papilio polytes (Linnaeus, 1758)	0	3	0	1	0	**4**
Pieridae	*Appias libythea* (Fabricius, 1775)	3	6	0	1	5	**15**
	Catopsilia pomona (Fabricius, 1775)	0	0	0	0	34	**34**
	Cepora nerissa (Fabricius, 1775)	2	3	0	8	42	**55**
	Delias momea (Boisduval, 1836)	2	0	0	0	0	**2**
	Eurema hecabe (Linnaeus, 1758)	70	58	3	5	31	**167**
	Leptosia nina (Fabricius, 1793)	20	17	26	28	33	**124**
	Total	**165**	**221**	**72**	**122**	**247**	**825**

GOS 1 Setu Jatijajar; GOS 2 Studio Alam TVRI; GOS 3 Taman Lembah Gurame.; GOS 4 D'Kandang Amazing Farm.; GOS 5 Taman Bunga Wiladatika. The coordinate position of each GOS is in Table 1.

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The number of individuals found in the five GOS was 827 individuals from 36 species, 25 genera, and 4 families. Taman Bunga Wiladatika (GOS 5) was the location with the most butterflies, 247 individuals. The highest number of butterfly species was found at Studio Alam TVRI (GOS 2) with 24 species from 19 genera. The location with the fewest individuals and species was Taman Lembah Gurame (GOS 3) with 72 individuals from 10 species. **TABLE 2** shows the number of individuals and species of butterflies in each GOS.

TABLE 2 shows that the highest number of butterfly species is from the family Nymphalidae, with 18 species in all five GOS. The highest number of individuals is found in the Pieridae family (297 individuals). They are *Eurema hecabe* (Linnaeus, 1758) and *Leptosia nina* (Fabricius, 1793) were the two most abundant species in the five GOS, with 167 individuals (20.2%) and 124 individuals (15.0%), respectively (**TABLE 2**, **FIGURE 2**). This finding is similar with other research, stating that *Eurema hecabe* (Linnaeus, 1758) was the most abundant butterfly species in GOS in several cities in Indonesia (Azahra et al., 2016, 2022). *Eurema hecabe* and *Leptosia nina* was then followed by *Zizula hylax* (Fabricius, 1775; 11.2%), *Ypthima nigricans* (Snellen, 1892; 7.7%), and *Cepora nerissa* (Fabricius, 1775; 6.7%). These five highest individuals and highest percentage (abundance) may be the species most suited to urban GOS area, as perhaps the most adapted to temperature and human disturbance as stated by Irsa et al. (2022) and Kim et al. (2015). Both researches stated that these species may adapt to urban environment by relatively fast life cycle and diverse host plants. However, these may yet to be observed in Depok.

The species with the lowest numbers were *Catochrysops strabo* (Fabricius, 1793), *Tanaecia palguna* (Moore, 1857), *Graphium doson* (Felder & Felder, 1864), and *Papilio lowii* (Druce, 1873), each of which was found in only one individual. The circumstances behind the low encounter of these four species are not clear, as research stated that in urban setting *Catochrysops strabo* (Fabricius, 1793) is not rare, while *Graphium doson* (Felder & Felder, 1864), is common (Nair et al., 2014).

The percentage of species in the diagram shows the composition of butterfly species diversity. In the five GOS in Depok City, the results of the *Shannon-Wiener* diversity index analysis were 2.74, which is classified as moderate. The GOS with the highest butterfly diversity index was Taman Bunga Wiladatika with 2.54, while the lowest diversity index was found in Taman Lembah Gurame with 1.77. Butterfly diversity in GOS is generally influenced by the heterogeneity of nectar plants, human disturbance, and the size of the GOS (Aguilera et al., 2019; Han et al., 2025). Taman Bunga Wiladatika is the location with the largest area and the most diverse availability of flowering plants, making it relatively more supportive of butterfly diversity compared to other locations.

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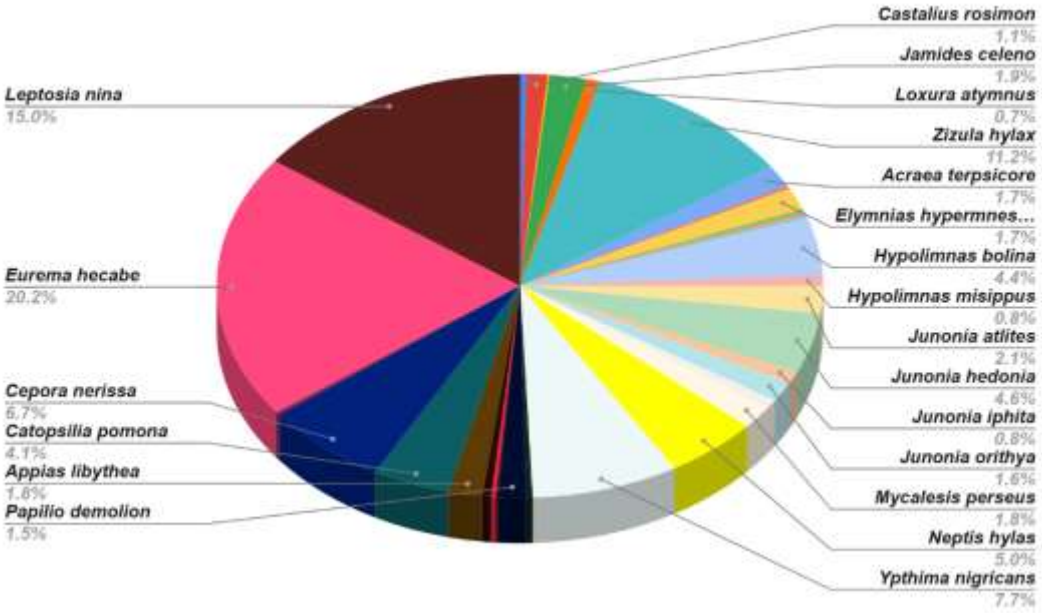

FIGURE 2. Butterfly species proportions in the five GOS

TABLE 3. Results of data analysis and environmental variables

GOS	ABUNDANCE (IND. NO.)	H'	DENSITY (IND/HA)	E	LIGHT INTENSITY (LUX)	TEMPERATURE (ºC)	HUMIDITY (%)	AREA (HA)
1	165	2.12	8.64	0.41	19640	33	76	19.1
2	221	2.48	11.05	0.45	19770	35	77.5	20
3	72	1.77	21.82	0.41	14740	30	83	3.3
4	122	2.23	15.25	0.46	18355	33	66	8
5	247	2.54	7.72	0.46	20000	33	68.5	32
AVERAGE	165.4	2.228	12.896	0.438	18501	32.8	74.2	16.48

H': Shannon-Wiener's diversity; E: Pielou's evenness

TABLE 3 shows the overall butterfly density of 10.04 ind./ha, with the Taman Lembah Gurame is GOS as the location with the highest density, that is 21.82 ind./ha. The overall evenness index is 0.41, indicating a moderate balance of individuals among species. Species evenness in an area is influenced by the presence of highly adaptive species (Azizah et al., 2021). In the case of butterflies, species with diverse food plants have the potential to dominate or reduce species diversity in an area (Fang et al., 2023). Food plant diversity can only be available in areas with sufficient land area.

The five GOS showed relatively uniform environmental conditions, with high average light intensity (18,501 lux) and warm average temperatures (32.8°C), which are within the ideal range (20–40°C) for butterfly flight activity (Azahra et al., 2016). The area of GOS (ranging from 3.3 ha to 32 ha) and humidity (ranging from 66% to 83%) varied.

The *Spearman's rank correlation* test (**TABLE 4)** reveals interesting relationship between variables. Temperature and humidity did not correlate with any population variables. This means that abundance, diversity, density and evenness of butterflies in all five GOS did not determined by the temperature and humidity in all GOS. As motile animal, it is logical that butterfly may move around between microhabitat in each location

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disregarding its temperature and humidity. We speculate the food availability in each GOS is more important than temperature and humidity as determinants of abundance, diversity, density and evenness of butterflies. However, we did not measure the food plants of the butterflies in each location.

TABLE 4. Spearman's correlation p-values matrix. Spearman's correlation in brackets when significant

Variables	Light Intensity (lux)	Temperature (^{O}C)	Humidity (%)	Area (m^2)
Abundance	**0.000**** (1.00)	0.215	0.624	**0.000**** (1.00)
Diversity	**0.037*** (0.90)	0.391	0.391	**0.037*** (0.90)
Density	**0.037*** (-0.90)	0.45	0.505	**0.037*** (-0.90)
Evenness	0.42	0.559	0.111	0.42

Light intensity and area sizes are the significant determinant for the abundance , diversity and density of butterflies in all GOS. However, evenness is not. Light intensity of sunlight plays a role in thermoregulation, foraging, and flight orientation (Liao et al, 2019). An important factor of the significant correlation between light intensity and abundance, diversity and density of butterflies may be the behavior of basking. Butterflies may in need of open areas to absorb light energy in the open area (Liao et al, 2019). The negative correlation in the density means that the butterflies are spaced distantly, more individuals and greater diversity occur in larger and brighter sites, those individuals may be spread out over space, lowering density on a per-area basis. This is confirmed by the abundance and diversity, where higher light will influence higher abundance and diversity of butterflies. This significant result in light intensity may be a basis of managerial suggestion in diversifying GOS vegetation with various plant life forms, providing various types of light penetration throughout GOS.

The second significant variable is the area sizes of the GOS toward the abundance, diversity and density of butterflies. The strong relation between area and diversity is a phenomenon, well-known as anthropogenic island biogeography phenomenon. Other studies in other groups of organisms, for example pteridophytes, showed similar strong area-diversity correlation (Sedayu, et al. 2024). Larger areas tend to have higher habitat heterogeneity, expanding opportunities for food sources (nectar) and refugia, thereby supporting higher diversity (Horák et al, 2021). GOS with larger area, such as Setu Jatijajar, Studio Alam TVRI, and Taman Bunga Wiladatika, tend to provide better habitat heterogeneity, allowing for the survival of more diverse species and reducing the dominance of a single species. Small GOS such as Taman Lembah Gurame, despite having good temperature and light conditions for butterflies in general, have the potential to experience habitat fragmentation effects. Narrow and isolated habitat areas have the potential to cause highly adaptive butterfly species to dominate due to their ability to utilize limited resources.

CONCLUSIONS

The GOS in Depok City has the potential to become a habitat refugia for butterfly diversity in urban areas. The Nymphalidae family is the family with the highest number of species found. The butterfly diversity and evenness indices were moderate, and there

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were no dominant species. High light intensity and area sizes are strongly correlated with abundance, diversity and density.

AUTHOR CONTRIBUTIONS

R.D.D., N.N.S. and S.A.S, project conception, methodology, data analyses; M.I.N manuscript review and editing.

CONFLICTS OF INTEREST STATEMENT

There are no conflicts to declare.

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