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# Urbanized ecosystem resilience through the flight of butterflies


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## Abstract

With the increasing number of built-up areas in urban areas, including Jabodetabek, which reduces green open space, consequently will reduce the ecosystem services for the urban environment, such as decreased air quality, increased noise, temperature increases, and decreased recreation and cultural services. Meanwhile, the presence of butterflies which often show correlation with other taxa such as birds and their sensitivity to environmental changes makes butterfly a good indicator for ecosystem changes. This study aimed to describe the ecological resilience of Greater Jakarta through the butterfly community using a citizen science approach, the results of which can be used to evaluate the ecological network of butterfly distribution in urban environments. During March-November 2021, butterfly monitoring has been carried out in Jabodetabek with an online citizen science approach, the results of which can be seen in real time on the kupukita.org. The study managed to record as many as 50 species of butterflies consisting of 3 families, Nymphalidae, Papilionidae, and Pieridae. The most widely recorded species were *Leptosia nina*, Appias olferna, Eurema sp., and Hympolimnas bolina. Until November 2021, there were 140 people who had participated in independent butterfly monitoring which resulted in 564 data entries. A total of 50 types of butterflies are spread in 6 clusters based on their Encounter Rate which is also an illustration of the level of ecological response of the Jabodetabek butterflies. Cluster 1 is the species with the highest ER in all habitat types, cluster 2 is the species with a higher ER in green open spaces, cluster 3 is the species with the higher ER on roadsides, cluster 4 is the species with similar ER in four habitat types, cluster 5 is a rare roadside species but is still frequently found in the other three habitat types, and lastly, cluster 6 is the group with the rarest species. Overall, this study suggests that yards that offer food and host plants can support the urban habitat of butterflies in cities.

# 1. Introduction

## 1.1. Background

Today, rapid urban expansions have dominated many large cities in Southeast Asia (Nor et al. 2017). Most of the world's population resides in the cities (LaPoint et al. 2015). Because of the growing populations, built-up areas tend to be doubled in several cities including Jakarta between 1989-2014 (Nor et al. 2017). The problems of urbanizations are complex. There are constant threats due to climate change to food security, clean air and clean water, services that are actually provided by green spaces (Solecki and Marcotullio 2013). Alas, if this population growth increases along with its level of consumption such as an increase of gas emission due to high mobilized civilization, this will lead to an inevitable contribution of climate change (Satterthwaite 2009).

Despite the growing built-up areas in many cities, green spaces are still remained and play an important role in providing habitat to biodiversity including butterflies, as well as providing ecosystem services to urban environment such as improvement of air quality, reduce noise, temperature regulations, to recreations and cultural services (Bolund and Hunhammar 1999; Solecki and Marcotullio 2013). Butterflies are everywhere including urban environment. They reside in urban forest, parks, and even homegardens (Koh and Sodhi 2004) and provide services to the ecosystem as they are pollinators to many plants, even in urban areas (Bergerot et al. 2010; Dylewski et al. 2019). In addition, diet specialist butterflies are positively correlated to exotic flowers (Bergerot et al. 2010). Their presence showed correlation to other taxa such as birds and their sensitivity to changes in the environment makes them good indicators of ecosystem changes (Oostermeijer and van Swaay 1998; Ramírez-Restrepo and MacGregor-Fors 2017a). Butterflies provide services to the ecosystem as they are pollinators to many plants, even in urban areas (Bergerot et al. 2010; Dylewski et al. 2019). However, their potential to understand ecosystem resilience in the urban environment have not been explored in Southeast Asia, including Indonesia (Ramírez-Restrepo and MacGregor-Fors 2017b).

Jabodetabek, or Jakarta and its satellite cities, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek) are highly urbanized cities comprised of 11.76% of total populations of

Indonesia (Hasibuan et al. 2014). The condition where built-in areas are larger in Jakarta and green open areas are larger in the suburbs neighboring cities (Zain et al. 2015) makes Jabodetabek an ideal case study to evaluate ecological resilience base on butterflies. Lepidoptera, or diurnal butterflies have been mostly studied in the forest habitats (Hill et al. 1995; Hamer et al. 1997; Fermon et al. 2005; Peggie and Harmonis 2014; Koneri and Maabuat 2016) and only a few in urban habitats (Estalita 2012; Nisa et al. 2013). Because of the potential homegardens in residential areas as butterfly habitat, citizen science is a closest, suitable and crucial approach in understanding the ecological resilience of the urban environment.

The COVID-19 pandemic has pushed most people to slow down their activities, as well as to do remote working from their home as possible. Not often, to cope with mental health and well-being, an increased healthy lifestyle through physical activities such as exercise and gardening also recorded as a positive side effect of this pandemic, especially if its countries applied restriction on civil activities such as lockdown mechanism (Callow et al. 2020; Bu et al. 2020) or a large-scale social restriction within such time period. Therefore, in such situation, encouraging the community movement to contribute in citizen science would be would be beneficial for both social and environmental aspects.  This citizen science movement would benefit the community in understanding the importance of homegardens to enhance urban resilience as well as building voluntary-driven data (Wang Wei et al. 2016). The research roadmap described three stages of enhancing urban resilience through butterfly community – build, monitor, and develop. The year one is the stage where citizen science is developed and butterfly distributions are described. Because butterfly watching is still unpopular, the stage followed by monitoring the citizen science and how well they understand the connections between biodiversity, ecosystem services and habitat.  A meta-analysis of butterfly and urban habitat will complement this stage.  The third stage is promoting habitat for urban biodiversity which can be enhanced through supporting homegardens (Figure 1).

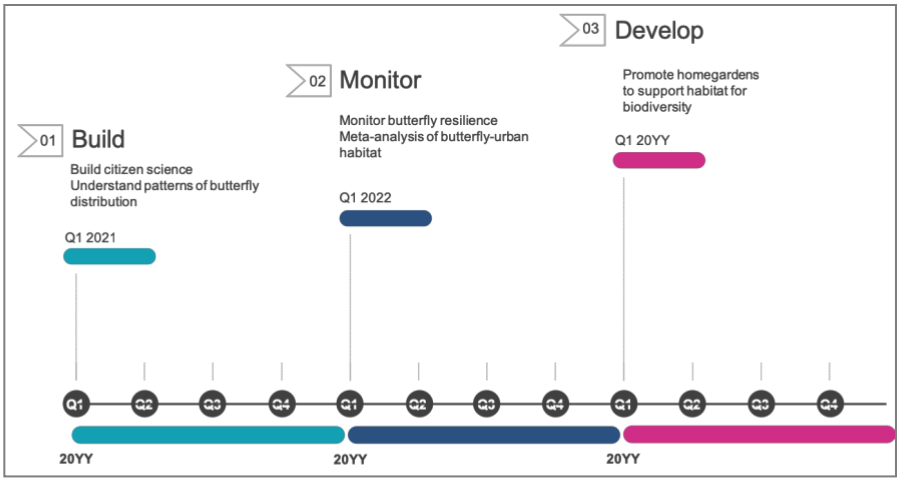

Figure 1. Roadmap of research

### 1.2. Objectives

The aim of this research is to describe the ecological resilience of Jabodetabek through butterfly community. In detail, the objectives are as follows:

a. Determine resilience of butterfly community in different urban gradient by using citizen science approach
b. Evaluate ecological network of butterfly distribution in urban environment

### 1.3. Extected Output

The output of the proposed studies are as follows:

*Component 1. Developing community-driven data collection system*. From the first component, the outputs comprised of:

- Target points for butterfly survey have been visited and surveyed as planned
- Data on butterfly distributions in Jabodetabek is collected

*Component 2. Determine the butterfly community in different urban gradient and evaluate ecological network of butterflies in urban environment*. From the second component, the outputs comprised of:

- Patterns of butterfly community structure in Jabodetabek are obtained
- Relationship between butterfly distributions and NDVI is analyzed as planned
- Analysis of distribution prediction is conducted as planned

## 2. Benefit and importance of research

This proposal will be the first large-scale butterfly monitoring efforts in the home gardens of Indonesia, which will be used to determine how the urban environment has shaped biodiversity, and will likely shape the urban resilience further in the future. The project proposed a tangible activities which mitigates against possible future lockdowns. It mobilises the public to help provide the biodiversity information from their gardens as well as increasing public awareness on enhancing the function of their homegardens to support urban wildlife and thus enhancing ecosystem services. Our model combines both actual field survey supervised by node leaders and citizen-science and therefore, community-driven data can be evaluated overtime and node leaders can assess areas that have not been surveyed. This first large-scale monitoring model is therefore potential for intellectual property rights.

## 3. Methodology

The study area will be spread within Jabodetabek area as satellite cities of Jakarta.

<u>Component 1. Developing community-driven data collection system</u>

Although butterflies are recognizable group and conspicuous, monitoring of this taxa may not be easy. Unlike birdwatching which now is quite popular, butterfly watching is still unpopular. Therefore, we plan to develop voluntary-driven butterfly survey in Jabodetabek which are still guided by university students. We plan to conduct training of trainer (ToT) to university students and graduates in butterfly watching around the neighborhood. We will develop nodes of monitoring across Jabodetabek. The selected students will then be responsible for each node in Jabodetabek. Each node leader will develop a field team to conduct field survey and distribute the online questionnaires in their node areas, and collate data.

In parallel, we will develop website for urban butterflies with associated link to online survey. The online survey for citizen science will be developed together which contains pictures of common urban butterflies with user's friendly features. We will focus on easy-to-identify large species such as the Nymphalidae, Papilionidae, and Pieridae to ensure correct identification. Pictures of different species will be provided to aid the identification. Node leader and students will also responsible to carry out the actual field survey. This will also help us to evaluate the differences of data collection conducted by community-driven data collection and trained observers and later can be used to identify knowledge gap for conservation awareness.

Component 2. Determine the butterfly community in different urban gradient and evaluate ecological network of butterflies in urban environment

The data will then be analysed to determine the butterfly community structure in different urban gradient and to evaluate the ecological network of butterflies in the urban environment. We will differentiate urban habitats into residentials, roadside and other green spaces and look at how different butterfly species use different urban habitats as well as determine the scales of urban tolerance among different species of butterfly. We assume that there are patterns of urban tolerance among the butterflies as well. We will then also analyze the distribution of butterfly species using Normalized Difference Vegetation Index (NDVI) and look at how butterfly survive in remained green areas in Jabodetabek.

## 4. Results and Discussions

Project preparation: developing community-driven data collection system

During the preparation stage, team recruitment and division of tasks have been carried out during mid-March 2021. In this stage, two internal meetings have been held with the agenda of team introductions, discussion of timeframes and activities as well as division of tasks. Regular team coordination was decided to be done through Whatsapp Group and through bi-weekly internal coordination meetings. During the discussion, we agreed on the name of citizen science for butterfly data collection. Based on the discussion, the name of the movement was KupuKita (citizen science for the preservation of butterflies around us). Furthermore, the development of KupuKita's contact address is also carried out such as e-mail, social media, etc.

Developing questionnaire/online survey

The preparation of the questionnaire has been carried out in two stages, namely the preparation of the questionnaire structure and the transformation of the questionnaire into online survey media. The preparation of the questionnaire structure has been carried out during the end of March 2021. This stage includes agreement on the variables needed for future butterfly data collection and collecting supporting photos to be displayed in the questionnaire such as photos of each type of butterfly that are likely found in Greater Jakarta. The questionnaire is composed of 4 parts:

1. Observer information (6 questions)
2. Observation location information (4 questions)
3. Information on the types of butterflies found (3 types of questions categorized by families)
4. Information on observed butterfly habitat (5 questions)

Furthermore, the questionnaire was transformed into an online survey media. Considering the ease of data collection, feature of the question and its integration into the web platform that will be used in the future, KoboToolBox was chosen as an online survey media in collecting butterfly data. The online questionnaire transformation has been carried out from early April to mid-April 2021. The forms used in data collection can be viewed here: http://bit.ly/formkukita.

Developing platform (web)

Web development was completed during late March to early April 2021. Web development was also carried out through three stages, namely the preparation of web structure and content, web design development and web domain determination. The structure and content development of the web was carried out during the 4th week of March. Meanwhile, the website is composed of 6 parts, namely:

1. Home (at a glance about KupuKita's activities)
2. Guideline (guideline for data entry and butterfly observation)
3. Contribution (filling in butterfly data)
4. Today's butterfly (real time)
5. Team
6. Frequently Asked Questions (FAQ)

Web design development is carried out through the GoogleSites platform. GoogleSites was chosen because it has user-friendly and interactive features. The development activity has been completed in mid to late April 2021. Domain determination has also been carried out after web development is carried out by subscribing to the paid GoogleDomains service every year. Here is KupuKita's website: https://www.kupukita.org/.

Training of trainer

The KupuKita program has conducted its inaugural online training on 12-13 June 2021 which was attended by 30 participants from Greater Jakarta and West Java with various age and occupational backgrounds. Starting from small participants who are still in elementary school to students, private employees, housewives and photographers. The second day of training continued with data collection independently by the training participants from their respective homes. The participants were invited to try out the KupuKita platform as well as being guided by the KupuKita team through the Whatsapp Group in using the provided platform and in identifying butterflies. Then the data was collected independently for 7 days after the training to improve the ability and experience of the participants in observing butterflies. During these 7 days, participants continued to discuss via Whatsapp Group, especially in sharing suggestions and opinions regarding butterfly identification. Full report can be seen in Appendix 1.

<u>Distribution of questionnaire/online survey and data collection</u>

Questionnaires were distributed and promoted through regular trainings, as well as through social media such as Instagram. A total of 169 people have participated in the trainings. The following was the list of trainings conducted.

Table 1. Trainings conducted by KupuKita

| **Date** | **Title of trainings** | **Partners** | **Number of days** | **Number of participants** |
|---|---|---|---|---|
| 12-13 June 2021 | Training of Trainers | - | 2 | 30 |
| 28-29 August 2021 | General | - | 2 | 25 |
| 4 September 2021 | Kawan Kupu Goes to School | Semut-semut The Natural School Depok | 1 | 46 |
| 8 September 2021 | Kawan Kupu Goes to School | SDIT Al-Qudwah Depok | 1 | 50 |
| 6 November 2021 | Kawan Kupu Goes to Komunitas Literasi | Forum Taman Baca Mandiri Depok | 1 | 18 |

Component 2. Determine the butterfly community in different urban gradient and evaluate ecological network of butterflies in urban environment.

Currently 50 species have been recorded consisting of 3 families, Nymphalidae, Papilionidae, and Pieridae. The most widely recorded species were *Leptosia nina*, *Appias olferna*, *Eurema* sp., and *Hympolimnas bolina*. Until November 2021, there were 140 people who had participated in independent butterfly monitoring which resulted in 564 data entries. The real time results of observations can be seen through the website kupukita.org.

In overall, the butterfly community in Jakarta and its satellite cities composed of 6 clusters, from the most common species, *A. olferna*, *L. nina*, *Eurema* sp., and *H. bolina* (Cluster 1) which are included in one group, to the rarest groups such as *Graphium sarpedon*, and *Papilio demolion*. (Figure 2).

Cluster 1 members were the species with the highest ER (Encounter Rate) in all habitat types. Furthermore, the remaining cluster membership was based on ER across all habitat types. Cluster 2 membership tended to be based on higher ER in green open spaces. Cluster 3 was composed of species with higher ER on the roadside, while members of Cluster 4 have relatively the same ER in all four habitat types. Cluster 6 with 20 species was the cluster with the rarest species. Member of this cluster was very rare on roadsides but occasionally visited parks. Cluster 5 consisted of 6 species that were also rare on the roadside but still common in the other three habitat types (Figure 3). With discriminant analysis, the prediction of clustering was considered correct by 97.87% for each cluster membership.

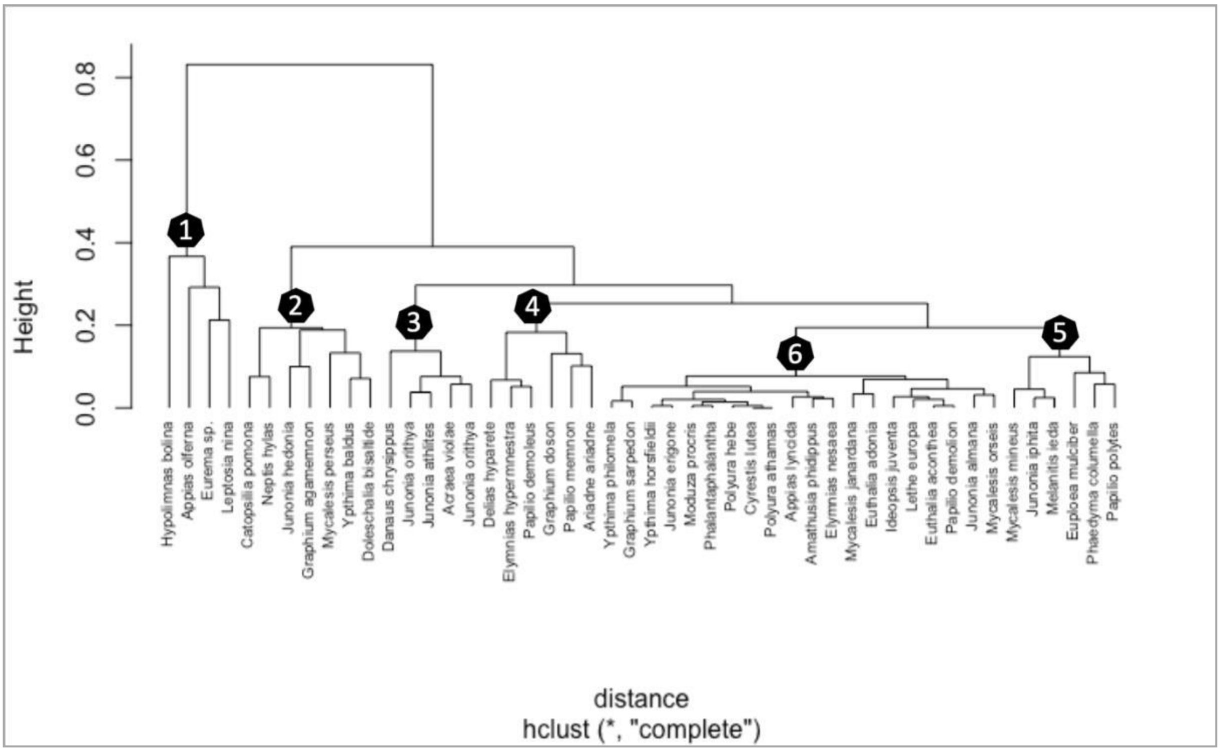


Figure 2. Predicted distributions of butterfly cluster in Jabodetabek

Meanwhile, the prediction of butterfly distribution in Jabodetabek based on NDVI (Normalized Difference Vegetation Index) can be seen in Figure 3. In general, the relationship between clusters and NDVI showed that green open spaces showed a higher NDVI value while the lowest NDVI was shown in home gardens.

Table 2. Prediction of cluster distribution related to NDVI values in four habitat types

| Cluster | Home gardens | Green Open Spaces | Parks other than green spaces | Roadside |
|---|---|---|---|---|
| 1 | 0.429 | 0.610 | 0.494 | 0.462 |
| 2 | 0.432 | 0.655 | 0.472 | 0.497 |
| 3 | 0.430 | 0.494 | 0.439 | 0.499 |
| 4 | 0.433 | 0.597 | 0.508 | 0.509 |
| 5 | 0.423 | 0.546 | 0.423 | 0.595 |
| 6 | 0.428 | 0.661 | 0.514 | 0.515 |

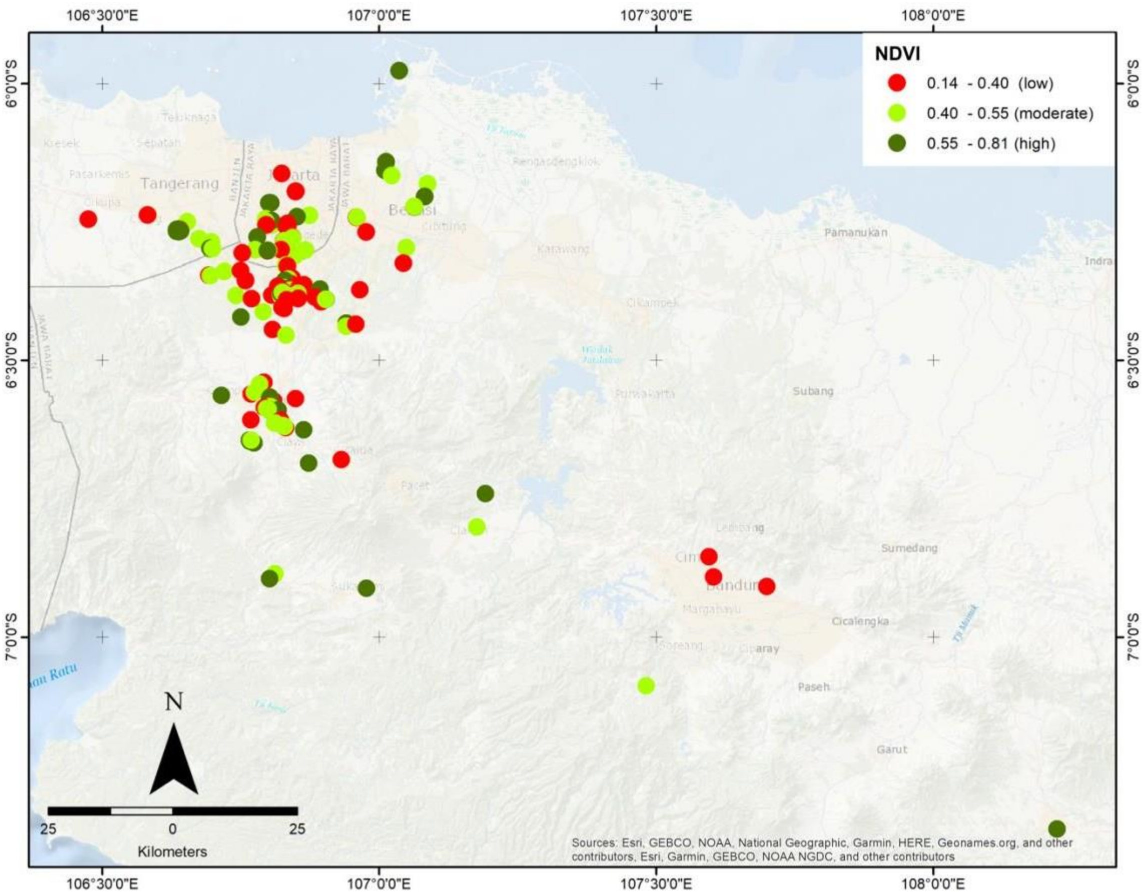


Figure 3. Butterfly distribution prediction based on NDVI

## 5. Conclusions

Most of the data was taken from the home gardens, followed by parks other than green open spaces, roadsides, and green open spaces. This citizen science project managed to record 50 species including the four most common species *Appias olferna*, *Leptosia nina*, *Eurema* sp., and *Hypolimnas bolina*. Parks had the highest species richness, followed by home gardens, with the least species richness was on the roadside. Based on the Encounter Rates (ER), the Jabodetabek butterfly community as a whole consisted of 6 clusters, species with the highest ER in all habitat types, species with higher ER in green open spaces, species with higher ER on the roadside, species with higher ER similar across the four habitat types, species that are rare on the roadside but still frequently found in the other three habitat types, and finally, the group with the rarest species. The distribution prediction based on NDVI shows that green open areas tended to have high NDVI values, while the lowest NDVI values tend to be in home gardens. However, home gardens that offer food and host plants for butterflies are promising to support the urban habitat of butterflies in cities.

## 6. Principal Investigator and Other Researcher

In implementing the project, this initiative is a collaborated team from the Research Center for Climate Change-University of Indonesia (RCCC-UI), Tambora Muda, and SEAMEO-BIOTROP. RCCC-UI is one of the leading research centers within the University of Indonesia and carries out its vision and mission, especially in climate change research to improve research and training on climate change in Indonesia; bring together national and global climate change stakeholders; develop scientific breakthroughs on climate change studies. Team members have complementary skills, a strong track record in dealing with urban wildlife including butterflies, and GIS, relevant experience managing research projects, and a track record of making an impact. This team consists of senior researchers and early-career researchers:

- Dr. Nurul L. Winarni (RCCC-UI) is the principal investigator and will lead as well as managing the overall project.
- Ir. Widayanti M.Si. is an affiliate scientist from SEAMEO-BIOTROP who is also an entomologist. She support and ensure that the project will give tangible results
- Dr. Aslan. He help bringing this initiative into tangible spatial modelling of urban resilience. He will be responsible for GIS analysis.
- Bhisma G. Anugra (RCCC-UI) is a master student at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia. He is experienced in ecological surveys. He will be responsible for overseeing daily field works, data entering and analysis, as well as data reporting.
- Nuruliawati (Tambora Muda) is a biologist and has various experience in bird and butterfly research. She was responsible for monitoring area management. Tambora Muda is a national network of young Indonesian conservationists (http://www.tamboramuda.org/) and therefore can support mobilizing their members.

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**Appendices**

Appendix 1. Naskah Citizen Science Explains the Butterfly Community of Urban Jakarta Greater Area

Citizen Science Explains the Butterfly Community of Urban Jakarta Greater Area

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**ABSTRACT**

The highly urbanized city of Jakarta and its satellite cities, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek) still provide potential habitats for urban butterflies. KupuKita, a citizen science platform for urban butterfly monitoring was developed in early 2021. This study was to explore the initial results of KupuKita in examining the butterfly species diversity and community structure as a response to urbanization. The KupuKita is an online platform, featured with geolocations of observers as well as pictorial species list, and other information. Until September 2021, there were 93 observers with a total of 361 submissions, resulting 1275 records. Most of the submissions were taken from home gardens, followed by parks, roadside, and green spaces. This citizen science project was successfully record 47 species including the four most common species *Appias olferna, Leptosia nina, Eurema* sp., and *Hypolimnas bolina.* Parks comprised the highest species richness, followed by home gardens, with the least species richness was in roadside. Based on encounter rates (ER), the overall community suggested that there were 6 groups of butterflies, species with the highest ER in all habitat types, species with higher ER in green spaces, species with higher ER in roadside, species with similar ER in the four habitat types, species which were rare in roadside but still frequently present in the three habitat types, and lastly, the group with the most rare species. In overall, the study suggested that home gardens which offer food and host plants may support the urban habitat for butterfly in the cities.

Keywords: butterflies, citizen science, home gardens, Jakarta, urban

## 1. Introduction

Today, rapid urban expansions have dominated many large cities in Southeast Asia (Nor et al., 2017). Most of the world's population resides in the cities (LaPoint et al., 2015). Because of the growing populations, built-up areas tend to be doubled in several cities including Jakarta between 1989-2014 (Nor et al., 2017). The problems of urbanizations are complex. There are constant threats due to climate change to food security, clean air and clean water, services that are actually provided by green spaces (Solecki and Marcotullio, 2013). Alas, if this population growth increases along with its level of consumption such as an increase of gas emission due to high mobilized civilization, this will lead to an inevitable contribution of climate change (Satterthwaite, 2009).

Despite the growing built-up areas in many cities, green spaces are still remained and play an important role in providing habitat to biodiversity including butterflies, as well as providing ecosystem services to urban environment such as improvement of air quality, reduce noise, temperature regulations, to recreations and cultural services (Bolund and Hunhammar, 1999; Solecki and Marcotullio, 2013). Butterflies are everywhere including in urban environment. They reside in urban forest, parks, and even home gardens (Koh and Sodhi, 2004) and provide services to the ecosystem as they are pollinators to many plants, even in urban areas (Bergerot et al., 2010; Dylewski et al., 2019). In addition, diet specialist butterflies are positively correlated to exotic flowers (Bergerot et al., 2010). Their presence showed correlation to other taxa such as birds and their sensitivity to changes in the environment makes them good indicators of ecosystem changes (Oostermeijer and van Swaay, 1998; Ramírez-Restrepo and MacGregor-Fors, 2017). However, their potential to understand ecosystem resilience in the urban environment have not been explored in Southeast Asia, including Indonesia (Ramírez-Restrepo and MacGregor-Fors, 2017).

Jakarta greater area which include its satellite cities, Bogor, Depok, Tangerang, and Bekasi (Jabodetabek) are highly urbanized cities comprised of 11.76% of total populations of Indonesia (Hasibuan et al., 2014). While the built-in areas are larger in Jakarta, the green open areas are larger in the suburbs neighboring cities (Zain et al., 2015) makes Jabodetabek an ideal case study to evaluate ecological resilience base on butterflies. In Indonesia, Lepidoptera, or diurnal butterflies have been mostly studied in the forest habitats (Fermon et al., 2005; Hamer et al., 1997; Hill et al., 1995; Koneri and Maabuat, 2016; Peggie and Harmonis, 2014) and only a few in urban habitats (Estalita, 2012; Nisa et al., 2013). Because of the potential home gardens in residential areas as butterfly habitat, citizen science is a closest, suitable and crucial approach in understanding the ecological resilience of the urban environment. Citizen science is also an emerging trends of engaging people to contribute to science (Mueller et al., 2011). Citizen science helps to fulfil the gaps in research data, such as species distribution and diversity, phenological patterns (Dennis et al., 2017; Prudic et al., 2018; Squires et al., 2021).

The COVID-19 pandemic has pushed most people to slow down their activities, as well as to do remote working from their home as possible. Not often, to cope with mental health and well-being, an increased healthy lifestyle through physical activities such as exercise and gardening also recorded as a positive side effect of this pandemic, especially if its countries applied restriction on civil activities such as lockdown mechanism (Bu et al., 2020; Callow et al., 2020) or a large-scale social restriction within such time period. Therefore, in such situation, encouraging the community movement to contribute in citizen science would be beneficial for both social and environmental aspects. Citizen science is a massive movement engaging public participation in scientific research (Silvertown, 2009;

Wang Wei et al., 2016). The citizen science movement would benefit the community in understanding the importance of home gardens to enhance urban resilience as well as building voluntary-driven data (Wang Wei et al., 2016). The emerging trends of building voluntary-driven data, however, is also in line with the development of online platforms. There are available online platforms such as iNaturalist (Gazdic and Groom, 2019) and eButterfly (Prudic et al., 2017) which can be used for butterfly monitoring. However, such platforms are all in English language which may not be suitable for a non-English country such as Indonesia. Therefore, during March 2021, we developed KupuKita, an online platform for urban butterfly monitoring which focus mainly on urban butterfly for Jakarta and its satellite cities in Indonesian language. This study explores the initial results of KupuKita which aimed to examine the butterfly species diversity and community structure across different urban gradient in Jakarta greater area. The results of this study are expected to provide an exhaustive information on the response of butterfly in urban environment as well as enhancing home gardens as additional green spaces in the cities.

## 2. Materials and Methods

We developed an initiative is called KupuKita (in Indonesian means 'our butterflies') which has been started in March 2021 as the first urban citizen science platform for butterfly watching. This platform covers the study areas which was spread within Jakarta and its satellite cities (Bogor, Depok, Tangerang, and Bekasi which are located in West Java), abbreviated as Jabodetabek (Figure 1).

The data used in this study was collected under this initiative starting from March until September 2021. The data was collected by developing the first simple online checklist form of urban butterfly in Indonesian language, so that the citizen could submit their own home garden observations as well as other areas close to their homes. Considering the ease of data collection which feature the question and its integration into the web platform, KoboToolBox (https://www.kobotoolbox.org/) was chosen as an online survey supporting platform in collecting the butterfly data. Previously, KoboToolBox have been used as data submission form for citizen science projects (Chau, 2020; Panitsa et al., 2021). We focused on easy-to-identify large species such as the species from Nymphalidae, Papilionidae, and Pieridae families to ensure correct identification by citizens. Other butterfly families such Lycaenidae and Hesperiidae were not included as they are too small to observe and can be overlooked for the untrained observers (Corbet and Pendlebury, 1992; Vann, 2008). The forms were featured with geolocations of observers, information of observers, pictorial species lists with selection number of individuals, habitat information and category (road edge, homegardens, parks, and urban green spaces), stratum of observation habitat (understory, middle story, upper story), as well as the questions on the presence of grasses and flowering plants. We defined urban green spaces as large area destined and managed specifically for urban forest or botanical gardens while parks are other green spaces including recreational area, cemetery, community playground, etc.

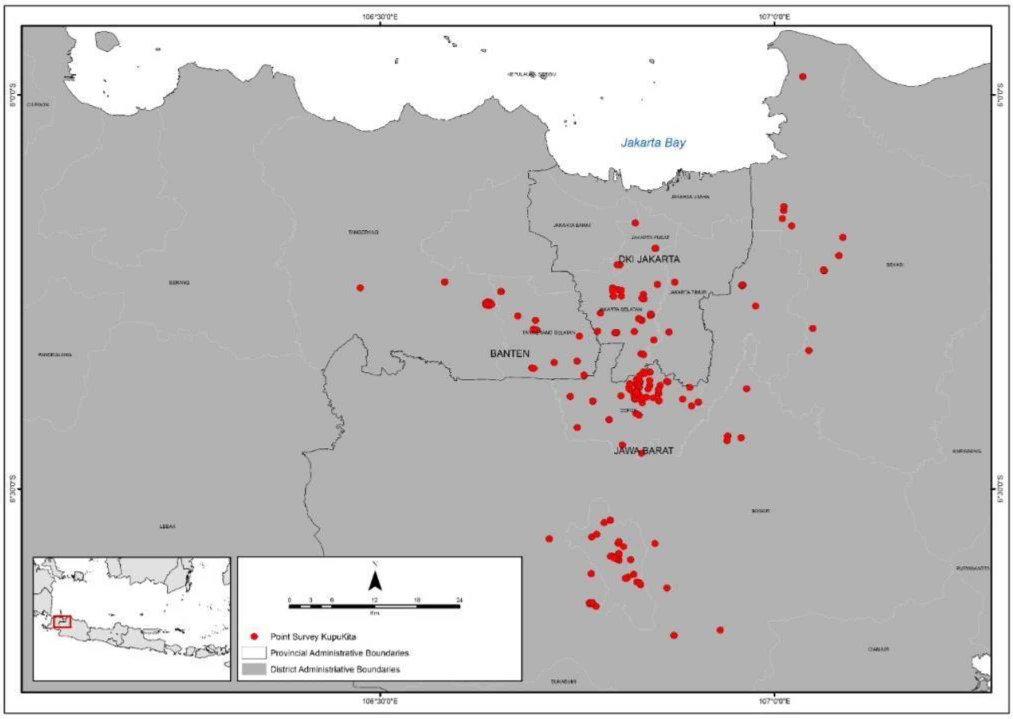


Figure 1. Range of study area in Jabodetabek with survey points

The observer was asked for supporting evidences by taking a picture of observed habitat. We also encouraged participants to take a picture of the butterflies they seen. Data were then validated by KupuKita team. The forms used in data collection can be viewed here: http://bit.ly/formkupukita. Promotion of the forms were carried out through social media and personal contacts. We also carried out several online trainings which was supported by a mentoring system through WhatsApp group. In this group, participants can share pictures of the butterflies they observed which then discussed for identification. As part of feedback and rewards, name of observers were including their efforts were listed as well as real time daily butterfly abundance and distributions were displayed in the website (http://kupukita.org).

Observation of butterfly was carried out using a combination of Pollard walk and point count methods where 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). Distance between points was approximately 50-100 m.

We then calculated the abundance of butterfly at different habitat types based on Encounter Rates (ER = total butterfly encounter/total number of observation). We analysed the species richness and species diversity using Shannon-Wiener Index Species diversity was calculated using Shannon diversity index ($H' = \Sigma P_i \ln P_i$), Simpson's Dominance Index ($D = 1/\sum_{i=1}^{S} p_i^2$), and Shannon $H_{max}$ ($H_{max} = Log_{10}\ S$) where, H = information content of sample (bits/individual) or Shannon diversity index, and Pi = proportion of total sample belonging to $i_{th}$ species, S = total number of species in habitat (species richness) (Magurran, 2004). T- tests were carried out to determine the differences between the butterfly species encounter in areas where there was no grasses vs when grasses present, as well as to test the differences between areas where there was no flowering plants vs when flowering plants present. We also carried out ANOVA to look at the differences of species encounters at different stratum of habitat (understory, middle story, upper story).

We also carried out hierarchical clustering of butterfly encounter rates at different habitat types to define the butterfly community assemblages in Jakarta and its satellite cities, and then determined the rate of misclassification of this grouping with Discriminant Function Analysis.

## 3. Results

In total, during March-September 2021 we had 93 observers with a total of 361 submissions, resulting 1275 records. Participants ranged between <18 years to > 41 years old, with 50% was <18 years old followed by 18-25 years old (25%) (Table 1). Elementary students were also joined the training and shared their butterfly pictures in the WhatsApp group (Figure 2). The majority of the submissions were taken in home gardens, followed by parks, roadside, and green spaces. Most of the submissions recorded observations at shrubs/middle story, followed by understory, and upper story. Grasses and flowering plants were present at the most of the submission points (Table 1).

Table 1. Data collected during March-September 2011

| | Count | % |
|---|---|---|
| **Number of observers** | 93 | |
| 18 - 25 years | 23 | 24,7 |
| 26 - 33 years | 10 | 10,8 |
| 34 - 41 years | 2 | 2,2 |
| > 41 years | 11 | 11,8 |
| **< 18 years** | **47** | **50,5** |
| **Number of submissions** | 361 | |
| **Home gardens** | **193** | **53,5** |
| Green spaces | 56 | 15,5 |
| Parks | 74 | 20,5 |
| Roadside | 38 | 10,5 |
| **Stratum** | | |
| Understory | 213 | 37,2 |
| **Shrubs/middle story** | **237** | **41,4** |
| Upper story | 123 | 21,5 |
| **Presence of grasses and flowering plants** | | |
| Grasses | 323 | 50,2 |
| Flowering plants | 320 | 49,8 |
| **Number of records** | 1275 | |
| **Species observed per Families** | | |
| Pieridae | 6 | 13 |
| Papilionidae | 7 | 15 |
| Nymphalidae | 34 | 72 |


Figure 2. A) An elementary student carried out butterfly watching using her smartphone, and B), Picture of *Junonia orithya* shared by parcitipants in WhatsApp group

During the time range, we recorded 47 species which was composed by Nymphalidae (72%), Papilionidae (15%), and Pieridae (13%) (Table 1, Table 2). There were 4 most common species, *Appias olferna, Leptosia nina, Eurema* sp., and *Hypolimnas bolina*. These four species were also the most common species found in the all habitat types, but the composition of species found among these type of habitats were different. For example, *Delias hyparete* was more common in home gardens but not in other habitat types (Table 2). Parks comprised the highest species richness, followed by home gardens, with the least species richness was in roadside (Table 3). Species diversity (Shannon-Wiener index) followed this patterns as well. Species dominance which gives more weight on dominant species, were likely higher in home gardens followed by roadside (Figure 3). In home gardens, only two species have encounter rates > 0.3 while in roadside there were four species. The highest evenness was in the roadside suggesting that there were more dominant species in this habitat type (Table 3, Figure 3).

Table 2. List of butterfly species with encounter rates and cluster membership (bold numbers showed the ten species with the largest abundance at each habitat type)

| Family | Species | Home gardens | Green spaces | Parks | Roadside | Cluster |
|---|---|---|---|---|---|---|
| Nymphalidae | *Acraea violae* | 0.031 | 0.089 | 0.095 | 0.158 | 3 |
| | *Amathusia phidippus* | 0.010 | 0.036 | 0.027 | | 5 |
| | *Ariadne ariadne* | 0.031 | 0.054 | 0.041 | 0.079 | 4 |
| | *Cyrestis lutea* | | | 0.014 | | 5 |
| | *Danaus chrysippus* | 0.047 | | 0.068 | **0.237** | 3 |
| | *Doleschalia bisaltide* | 0.078 | **0.339** | **0.122** | 0.079 | 2 |
| | *Elymnias hypermnestra* | **0.150** | 0.143 | **0.135** | 0.079 | 4 |
| | *Elymnias nesaea* | 0.005 | 0.018 | 0.014 | | 5 |
| | *Euploea mulciber* | 0.036 | 0.125 | **0.122** | 0.053 | 6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | *Euthalia aconthea* | 0.026 | 0.018 | 0.027 | 0.026 | 5 |
| | *Euthalia adonia* | 0.031 | 0.054 | 0.027 | | 5 |
| | *Hypolimnas bolina* | **0.244** | **0.357** | **0.378** | **0.237** | 1 |
| | *Ideopsis juventa* | 0.010 | 0.036 | 0.041 | 0.026 | 5 |
| | *Junonia almana* | | 0.036 | 0.014 | 0.053 | 5 |
| | *Junonia athlites* | 0.036 | 0.071 | 0.054 | **0.184** | 3 |
| | *Junonia erigone* | 0.010 | | 0.014 | | 5 |
| | *Junonia hedonia* | **0.088** | **0.304** | 0.095 | **0.211** | 2 |
| | *Junonia iphita* | 0.016 | 0.125 | 0.054 | | 6 |
| | *Junonia orithya* | 0.062 | 0.179 | **0.122** | **0.368** | 3 |
| | *Lethe europa* | 0.005 | 0.018 | 0.027 | 0.026 | 5 |
| | *Melanitis ieda* | 0.005 | 0.107 | 0.041 | | 6 |
| | *Moduza procris* | 0.005 | | 0.027 | | 5 |
| | *Mycalesis janardana* | 0.005 | 0.071 | 0.041 | | 5 |
| | *Mycalesis mineus* | 0.010 | 0.143 | 0.014 | | 6 |
| | *Mycalesis orseis* | 0.000 | 0.054 | 0.014 | 0.026 | 5 |
| | *Mycalesis perseus* | 0.010 | **0.250** | 0.054 | 0.053 | 2 |
| | *Neptis hylas* | 0.031 | **0.250** | 0.108 | **0.184** | 2 |
| | *Phaedyma columella* | 0.041 | 0.161 | 0.068 | 0.053 | 6 |
| | *Phalanta phalantha* | | | 0.027 | | 5 |
| | *Polyura athamas* | | | 0.014 | | 5 |
| | *Polyura hebe* | 0.005 | | 0.014 | | 5 |
| | *Ypthima baldus* | 0.041 | **0.286** | 0.108 | 0.105 | 2 |
| | *Ypthima horsfieldii* | 0.016 | | 0.014 | | 5 |
| | *Ypthima philomela* | 0.047 | 0.018 | 0.014 | | 5 |
| Papilionidae | *Graphium agamemnon* | **0.130** | **0.339** | 0.068 | 0.132 | 2 |
| | *Graphium doson* | **0.083** | 0.036 | 0.108 | | 4 |
| | *Graphium sarpedon* | 0.036 | 0.018 | | | 5 |
| | *Papilio demoleus* | **0.176** | 0.107 | **0.135** | 0.053 | 4 |
| | *Papilio demolion* | 0.021 | 0.018 | 0.027 | 0.026 | 5 |
| | *Papilio memnon* | 0.083 | 0.036 | 0.108 | 0.132 | 4 |
| | *Papilio polytes* | 0.036 | 0.179 | 0.081 | | 6 |
| Pieridae | *Appias lyncida* | 0.005 | 0.018 | 0.041 | | 5 |
| | *Appias olferna* | **0.456** | **0.304** | **0.324** | **0.526** | 1 |
| | *Catopsilia pomona* | 0.052 | 0.179 | **0.122** | **0.184** | 2 |
| | *Delias hyparete* | **0.140** | 0.125 | 0.081 | 0.053 | 4 |
| | *Eurema* sp. | **0.238** | **0.411** | **0.284** | **0.421** | 1 |
| | *Leptosia nina* | **0.394** | **0.554** | **0.284** | **0.395** | 1 |

Table 3. Diversity indices in the four habitat types

| | Homegardens | Green spaces | Parks | Roadside |
|---|---|---|---|---|
| Number of Species | 42 | 39 | 46 | 28 |
| Individuals | 576 | 317 | 274 | 158 |
| Dominance_D | 0.070 | 0.047 | 0.045 | 0.064 |
| Shannon_H | 3.066 | 3.281 | 3.406 | 2.977 |

| | | | | |
|---|---|---|---|---|
| Evenness_e^H/S | 0.511 | 0.682 | 0.655 | 0.701 |

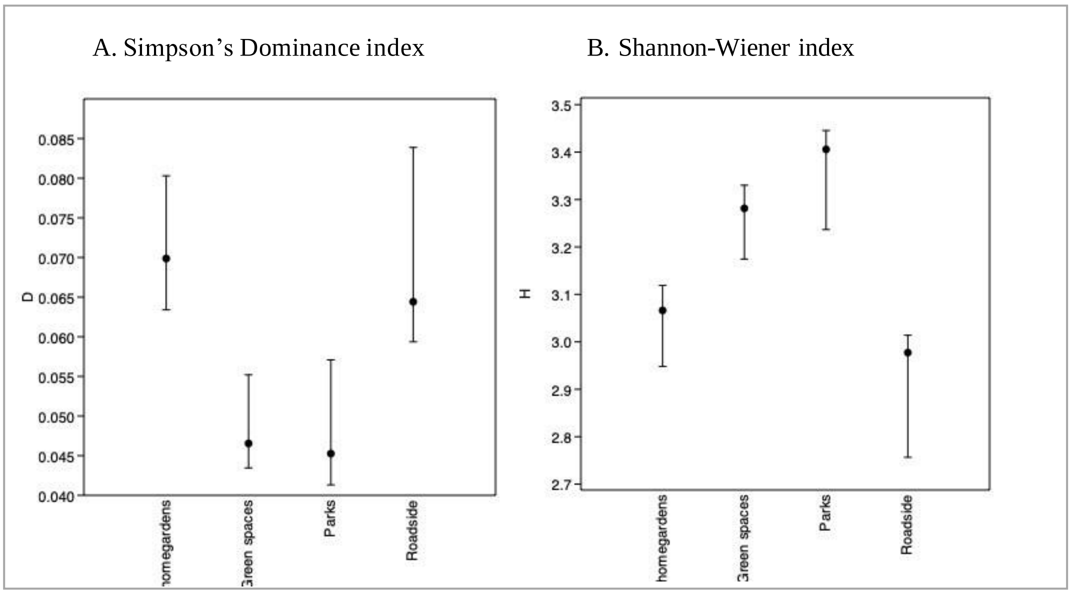


Figure 3. Simpson's dominance index and Shannon-Wiener's index of the Jakarta greater area butterfly urban community

The butterfly species occurred significantly when there were grasses (t = 5.098, P < 0.001) and flowering plants (t = 5.301, P < 0.001) in the area. Species records at different stratum of habitat were significantly different (F = 0.116, df = 2, 38; P = 0.023) with only understory-middle story was not significantly different (Duncan's multiple range test, P = 0.444).

The overall butterfly community in Jakarta and its satellite cities suggested that there were 6 cluster of butterflies, from the most common species, *Appias olferna*, *Leptosia nina*, *Eurema* sp., and *Hypolimnas bolina* (Cluster 1) which belong to the same group, to the most rare groups such as *Graphium sarpedon*, *Papilio demolion*, etc (Figure 4). Members of Cluster 1 were species with the highest ER in all habitat types. Subsequently, the rest of the cluster memberships were based on the ER in overall habitat types. Cluster 2 membership tend to be based on higher ER in green spaces. Cluster 3 was composed on species with higher ER in roadside, while members of Cluster 4 have relatively similar ER in the four habitat types. Cluster 6 with 20 species was the most rare species. These species were particularly rare in roadside but occasionally visited parks. Cluster 5 was composed of 6 species which were also rare in roadside but still frequently present in the three habitat types (Table 2, Figure 4). With discriminant analysis, this grouping was 97.87% correctly assigned to each cluster membership.

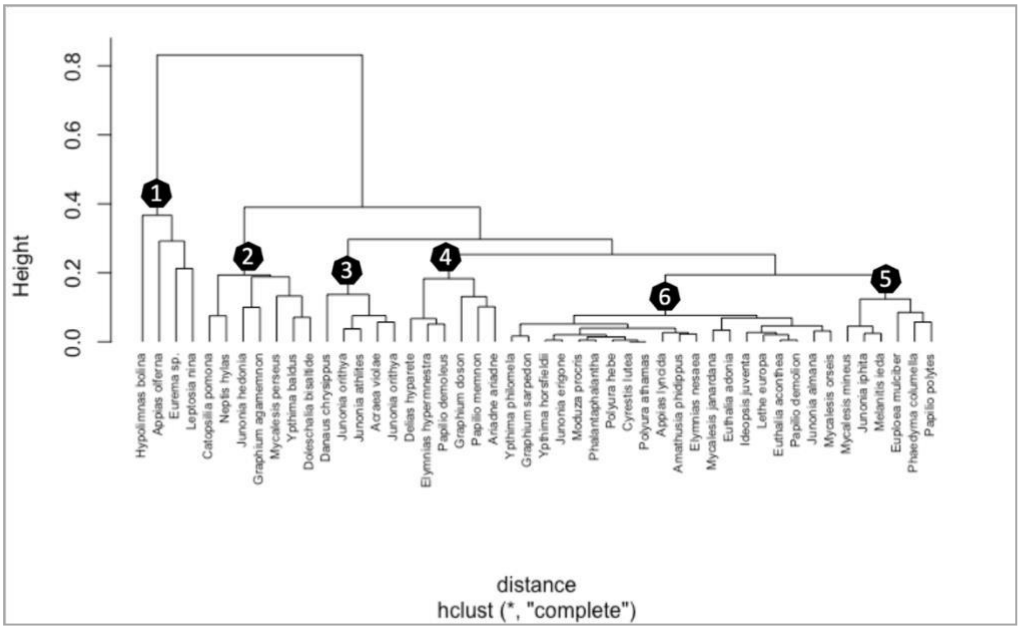


Figure 4. Dendrogram of butterfly species found in Jakarta greater areas

## 4. Discussions

### 4.1. Citizen science in urban butterfly monitoring

One of the most crucial thing in citizen science is engaging people to take interests in contributing to data collection. Citizen science is a two way process where community support scientific activities while also providing community with information on conservation issues (Lewandowski and Oberhauser, 2016). During May-September 2021, potential participants would likely to join when there was a training provided, suggesting that a non-biological background person still hesitate to participate. Half of the participants were <18 years old followed by 18-25 years suggesting that young enthusiasts are one group that showed interests and motivations. Young group is also have the capacity to drive new behaviour change in the community (García-Holgado et al., 2020; Kelemen-Finan et al., 2018). Therefore, promotion activities through trainings should be carried out regularly and reaching school students as it may gain more participants while also spreading awareness on butterfly conservation to the young generations.

Citizen science opened possibilities to cover restricted areas such as home gardens (Fontaine et al., 2016). More than 50% submissions resulted from home gardens. Data from home gardens recorded various species representing the three families, Nymphalidae Papilionidae, and Pieridae.

There were some notes on the collection of the data. Trade-offs between gathering data and reliability of the data should be taken into account (Dennis et al., 2017). First, focusing on some common species would help to ensure correct identification. The common butterflies that frequently visit participant's home garden were usually easier to identify. Citizen science tended to gather data on common, generalist species but not on threatened and specialist species (Dennis et al., 2017; Winarni et al., 2021). However, this should be supported by various methods such as providing online video on how to do butterfly watching, as well as support system such as WhatsApp group to discuss unidentified butterflies. Participants were encouraged to submit pictures of the butterflies they seen in the WhatsApp group. WhatsApp group offered possibility to carried out online focus group discussions facilitating supports and exchanging information (Colom, 2021) as well as a way to validate the data (Silvertown, 2009). We found it effective to boost an active engagement during the observation as well as to ease the assistance in the identification process, in which reducing bias of misidentified species.

Second, an eye-level observation of butterflies flying at shrubs/middle story and understory were easier to observe than upper story (Rand, 1964). Our study suggested that there was no difference between butterflies recorded at understory and middle story. Upper story which cover butterflies flying around tree canopy would be difficult to observe due to larger observation distance. There were also potential changes of observing larger species in the understory to smaller species in the canopy (Schulze et al., 2001). In the forest of Borneo, Schulze et al. (2001) noted a decrease in species abundance from understory to canopy as well as a significant shift in butterfly sizes.

4.2. Urban butterfly community and response to urbanization

Community participations helped to reveal butterfly species richness and diversity (Dennis et al., 2017; Prudic et al., 2018). *Appias olferna*, *Leptosia nina*, *Eurema* sp., and *Hypolimnas bolina* were the most common species which also can found across the different level of urbanizations, from roadside to green spaces. *Appias olferna*, *L. nina*, and *Eurema* sp. belongs to Pieridae, while *H. bolina* belong to Nymphalidae. *Leptosia nina* and *Eurema* sp. were tend to common in Asian cities such as Dacca, Metro Manila, and Kolkata (Islam et al., 2016; Nacua et al., 2020; Nair et al., 2014). Parks contains the most species richness, followed by home gardens whereas in contrary, roadside was the most poorer habitat among all although it is likely to provide refuge for pollinators because of the wildflowers diversity (Hopwood, 2013; Munguira and Thomas, 1992). Grasses were usually present in there but there was usually no specific planting along the road.

Home gardens with the highest dominance index, however, suggested that there were only few species present at high abundance such as *A. olferna* and *L. nina* while the rests of the species may present occasionally. *A. olferna* was usually found flying in open areas such as home gardens and roadside, while *L. nina* was usually observed flying restlessly close to the grounds (Nacua et al., 2020; Nair et al., 2014; Peggie and Amir, 2006). Pieridae butterflies were usually associated to plants such as Poaceae and Fabaceae (Nacua et al., 2020). Home gardens in the tropics, although usually planted by personal preference, tend to have complex vertical structures with different life-forms from vine to tall canopy trees (Huai and Hamilton, 2009; Niñez, 1987; Soemarwoto, 1987). Home gardens in Jakarta and its satellite cities may suggested different conditions such as the host plant diversity with potentially less number of plant species than in rural areas (Campera et al., 2021; Soemarwoto, 1987). They were usually grown with ornamental plants, but also contributing to food and medicinal use for the inhabitants such as various of fruiting trees and spices (Eichemberg et al., 2009; Huai and Hamilton, 2009; Soemarwoto, 1987). Interestingly, there were Papilionidae recorded in the home garden as well and can be identified by participants. *Papilio demoleus* was the most common Papilionidae in home gardens, while *Graphium agamemnon* was the most common Papilionidae in green spaces. Papilionidae is usually very selective in terms of selecting host plants for laying eggs (Corbet and Pendlebury, 1992). In fact, *Papilio demoleus* are found throughout Asia is usually associated to *Citrus* spp. plants (Corbet and Pendlebury, 1992; Guerrero et al., 2004). The presence of *P. demoleus* indicated that there were host plants in home gardens. The six clusters of butterflies present in Jakarta greater area may indicate the level of response to urban environment. Response of wildlife to urbanization has been described as urban exploiters, urban adapters, and urban avoiders (Blair, 1996; McKinney, 2006), or urban dwellers, urban utilizers, and urban avoiders based on relative importance of natural and developed areas (Fischer et al., 2015). However, the terms were usually applied to birds, mammals, and plants (Blair, 1996; Fischer et al., 2015; McKinney, 2006) and rarely on butterflies (Konvicka and Kadlec, 2011). Urban exploiters tended to be widely adapted to intensely modified urban environments and not really depend on the vegetation (McKinney, 2002). Blair (1996) suggested that urban exploiters present at high abundance in highly modified habitat. Butterflies, however, were highly related to the presence of vegetation particularly host plants and nectar sources (Bergerot et al., 2010; Corbet and Pendlebury, 1992; Han et al., 2021) and in this study, the four most common species present at the greatest abundance in all habitat types. For birds, Mardiastuti (2020) divided urban adapters to common adapters, frequent adapters, and occasional adapters. However, this classification was based on encounter probability (Mardiastuti et al., 2020). Konvicka and Kadlec (2011) used three terms for the butterfly community in Prague, i.e., urban avoider, suburban adaptable, and urban tolerant.

Our model was based on the encounter rates at different habitat within the urban area. In this study, urban exploiters were species present at highest abundance in all type of habitat indicating that they can utilize various range of urbanization. Urban adapters belong to numerous species which have ER less than the four most common species. We identified that there were urban adapters that present more frequently in urban green spaces (i.e. *Doleschalia bisaltide*, *Junonia hedonia*), urban adapters that tend to be more numerous in roadside (i.e. *Acraea violae*, *Junonia athlites*), and urban adapters that similarly adapted to all habitats (i.e. *Papilio memnon, Papilio demoleus*). We also noticed that there were two types of avoiders, first, were the uncommon species but occasionally visited parks compare to other habitats (i.e. *Papilio polytes, Melanitis ieda, Mycalesis mineus*). Second, were the species that occasionally present in the three habitat types but rare in roadside (i.e. *Junonia erigone, Euthalia aconthea*). However, this classification is likely dynamic because butterfly may show seasonality. Some species such as *A. olferna* or *L. nina* may present all year round but other species such as *M. ieda* may be related to their nectar plant source (Saikia, 2014). Braby (1995) also suggested that activity time may affect the relative abundance. *Melanitis ieda* in Australia was mostly crepuscular (Braby, 1995). Contrary to Konvicka and Kadlec (2011), we did not detect any urban avoiders. Such differences suggested that butterflies may show a more detailed response towards different environmental conditions (Ries and Debinski, 2001).

### 4.3. Home gardens to support urban butterfly

Urbanization has had a great impact on the remained green spaces due to the increasing built-up areas (Nor et al., 2017). Urbanization mostly caused negative effect to butterflies and even causing local extinction of several butterfly species (Ramírez-Restrepo et al., 2017; Ramírez-Restrepo and MacGregor-Fors, 2017). Despite the growing impact of urbanization, home gardens are important to support multipurpose agroecosystem, providing economic, ecological and social functions (Huai and Hamilton, 2009). In terms of ecological functions, home gardens contribute to biodiversity conservation such as preserving genetic materials, maintenance of soil fertility and soil structure, providing carbon storage (Huai and Hamilton, 2009; Kumar, 2006), as well as providing habitat to many wildlife species, including butterflies. Home gardens offer refuge when natural habitats are unavailable (Fontaine et al., 2016). Although diversity tends to be lower, butterfly species richness could be higher in home gardens than other habitat types in urban Jakarta and its satellite cities. The higher species richness indicated that habitat suitability characteristics such as caterpillar host plants, adult butterfly host plants, water resources, canopy opening, and interspersion of habitat components may support the species richness (Maryam and Pramukanto, 2020). Indonesian home gardens called "pekarangan" are usually enriched with diverse plants in different life forms, which include fruiting trees, vegetables, herbs, and spices (Arifin and Nakagoshi, 2011; Soemarwoto, 1987). The high butterfly species richness in home gardens proved that home gardens may function as additional urban habitats for the butterflies in the cities.

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