https://doi.org/10.17576/serangga-2026-3102-05

SPECIES COMPOSITION OF FRUIT-FEEDING BUTTERFLIES (LEPIDOPTERA: NYMPHALIDAE) IN THE DUKU PLANTATION AREA, SOUTH SUMATRA, INDONESIA

Astrid Sri Wahyuni Sumah[1]* & Ali Alamsyah Kusumadinata[2]
[1]Graduate Program of Biology Education,
Muhammadiyah University Palembang, Indonesia
[2]Science of Communication,
Djuanda University of Bogor, Indonesia
*Corresponding author email: *astrid.sumah@gmail.com*

Received: 10 November 2025; Accepted: 23 June 2026; Published: 23 August 2026

ABSTRACT

Duku (*Lansium domesticum* Corr.) is an important fruit crop in South Sumatra, where farmers frequently observe fruit-feeding butterflies during the fruiting season. Because butterflies respond sensitively to environmental changes, they are often used as indicators of plantation health. However, despite the crop's economic importance, the diversity of fruit-feeding butterflies in duku plantations remains poorly documented. Fruit-feeding butterflies, particularly members of the family Nymphalidae, are often observed in duku plantations during the fruiting season. Therefore, this study aimed to determine the diversity of fruit-feeding butterflies in duku plantation areas and examine the relationship between butterfly diversity and environmental factors, including temperature, light intensity, humidity, and wind speed. Observations were conducted using the scan sampling method at various observation periods, specifically before, during, and after the harvest period. The results showed that 33 species and 284 individual butterflies were recorded in the duku plantation. The highest numbers of species and individuals were recorded during the third observation period (25 species and 84 individuals), which occurred after the harvest period and at the beginning of the dry season. The butterfly diversity value ($H' = 3.26$) in the plantation was high ($H' > 3$), and the species evenness value was below 1, indicating an uneven distribution of individuals among species, particularly *Mycalesis janardana* (35 individuals). Statistically, temperature ($P = 0.661$) and light intensity ($P = 0.565$) showed the strongest relationships with butterfly abundance among the environmental parameters examined, although the relationships were not statistically significant. The results of this study provide baseline information on fruit-feeding butterfly diversity in duku plantations and contribute to understanding their potential role in maintaining the ecological balance of duku plantation ecosystems.

Keywords: Species richness; species evenness; biodiversity assessment; environmental variables; agroecosystem

ABSTRAK

Duku (*Lansium domesticum* Corr.) merupakan tanaman buah-buahan penting di Sumatera Selatan, di mana kupu-kupu pemakan buah sering diperhatikan oleh petani semasa musim berbuah. Oleh sebab kupu-kupu memberikan tindak balas yang sensitif terhadap perubahan persekitaran, serangga ini sering digunakan sebagai penunjuk keadaan ekosistem ladang. Walau bagaimanapun, meskipun tanaman duku mempunyai kepentingan ekonomi, kepelbagaian kupu-kupu pemakan buah di kawasan tanaman duku masih kurang didokumentasikan. Kupu-kupu pemakan buah, khususnya daripada famili Nymphalidae, sering diperhatikan di kawasan tanaman duku semasa musim berbuah. Oleh itu, kajian ini bertujuan untuk menentukan kepelbagaian kupu-kupu pemakan buah di kawasan tanaman duku serta mengkaji hubungan antara kepelbagaian kupu-kupu dengan faktor persekitaran, termasuk suhu, keamatan cahaya, kelembapan dan kelajuan angin. Pemerhatian telah dijalankan menggunakan kaedah persampelan imbasan (*scan sampling*) pada tiga tempoh pemerhatian, iaitu sebelum, semasa dan selepas tempoh penuaian. Hasil kajian menunjukkan bahawa sebanyak 33 spesies yang terdiri daripada 284 individu kupu-kupu telah direkodkan di kawasan tanaman duku. Bilangan spesies dan individu tertinggi direkodkan pada tempoh pemerhatian ketiga (25 spesies dan 84 individu), iaitu selepas tempoh penuaian dan pada awal musim kering. Nilai indeks kepelbagaian kupu-kupu ($H' = 3.26$) di kawasan tanaman duku adalah tinggi ($H' > 3$), manakala nilai kesamarataan spesies adalah kurang daripada 1, menunjukkan taburan individu yang tidak sekata antara spesies, dengan *Mycalesis janardana* merupakan spesies yang paling banyak direkodkan (35 individu). Secara statistik, suhu ($P = 0.661$) dan keamatan cahaya ($P = 0.565$) menunjukkan hubungan yang paling kuat dengan kelimpahan kupu-kupu berbanding parameter persekitaran lain yang dikaji, walaupun hubungan tersebut tidak signifikan secara statistik. Hasil kajian ini menyediakan maklumat asas mengenai kepelbagaian kupu-kupu pemakan buah di kawasan tanaman duku serta menyumbang kepada pemahaman tentang potensi peranannya dalam mengekalkan keseimbangan ekologi ekosistem tanaman duku.

Kata kunci: Kekayaan spesies; kesamarataan spesies; penilaian biodiversiti; pemboleh ubah persekitaran; agroekosistem

INTRODUCTION

Duku (*Lansium domesticum* Corr.) is closely related to langsat and exhibits similar morphological characteristics. However, the two fruit types can be distinguished by differences in fruit characteristics, particularly fruit diameter (Paull 2014). The diameter of duku fruit is smaller than that of langsat fruit. Duku is a typical fruit of Southeast Asia. In South Sumatra Province, duku is one of the superior fruit crops, while outside the province, it is regarded as a fruit characteristic of South Sumatra (Mayanti 2009). The duku-producing area in South Sumatra Province is Komering, which includes the regencies of Ogan Komering Ilir (OKI), East Ogan Komering Ulu (OKU), and South Ogan Komering Ulu (OKU). Currently, East OKU Regency holds a Geographical Indication (GI) certificate for duku, known as the Duku Komering Certificate (Marisa & Sugiarto 2018).

Pollination of duku flowers typically occurs through cross-pollination by pollinating insects, such as butterflies. Butterflies are among the insects with the most striking wing colours (Sumah 2019) and are typically active in the morning under bright environmental conditions. Butterflies are also among the insects that can be used as bioindicators of certain habitats (Koneri & Maabuat 2016). The level of butterfly diversity and their actual geographical distribution can provide valuable information in environmental studies as indicators of environmental conditions, as well as insights into potential changes that may occur (Bibi et al. 2022; Kwon et al. 2021). Environmental conditions can facilitate or inhibit species formation (Rosch et al. 2013). Environmental parameters, which serve as indicators of environmental structure (García-Robledo et al. 2016), function as filters in community structuring by preventing the establishment of certain species (Weerakoon et al. 2015). Ecological relationships, such as those involving insect pollinators, may represent an important mechanism of biological community structuring and potentially affect the distribution of species along environmental gradients (Houlihan et al. 2013).

Butterflies can be divided into two groups based on their feeding habits, namely nectar-feeding and fruit-feeding species, the latter of which feed on fermented fruits, excrement, and decaying plant and animal exudates (Silva et al. 2015). All fruit-feeding butterflies belong to the family Nymphalidae and represent approximately 20% of Neotropical butterflies (Fordyce & DeVries 2016; Lamas 2004). Little research has been conducted on the diversity of fruit-feeding butterflies. The composition and diversity of Nymphalidae butterflies in South Sumatra have previously been documented by Lamin et al. (2024), providing baseline information on butterfly communities in the region. The diversity of fruit-feeding butterflies in oil palm plantations has been reported previously. Mutmainnah and Santosa (2019) found 73 species in two different oil palm plantation areas in Ketapang, West Kalimantan, while Kwatrina et al. (2018) recorded 57 species in an oil palm plantation in West Kotawaringin, Central Kalimantan. Meanwhile, Muhelni et al. (2016) found 25 species of fruit-feeding butterflies in oil palm plantations in West Sumatra. Although several studies have provided information on the diversity of fruit-feeding butterflies, the diversity of fruit-feeding butterflies in the duku plantations of East OKU Regency has not yet been reported. Therefore, this study aims to analyse the diversity of fruit-feeding butterflies and their relationship with environmental factors in the duku plantation area of Gunung Batu Village, East OKU Regency, South Sumatra Province, Indonesia.

MATERIALS AND METHODS

Research Sites

The research location was established in a duku plantation in Gunung Batu Village (3°40′19.54″ S, 104°42′05.92″ E), East OKU Regency, South Sumatra Province, Indonesia, based on direct field observations to identify a site considered representative. Butterfly sampling was conducted using a survey method with scan sampling (Martin & Bateson 1993), which involved recording species directly along established routes. One method of sampling fruit-feeding butterflies is the use of traps containing fermented fruit as bait, which has been widely applied in tropical regions (DeVries 1987).

Observations were conducted from January to May 2023 between 09:00–11:00 and 13:00–15:00 WIB (Western Indonesian Time). Butterfly observations included the identification of species and the number of individuals recorded. The observations were divided into three sampling periods, with a one-month interval between each period to minimise the likelihood of recounting butterflies that had already been recorded during previous survey days and repeated visits. Butterfly specimens were captured using insect nets and placed in papilot paper for subsequent identification in the laboratory. The specimens were stored for two weeks before identification. Environmental parameters measured during the observations included relative humidity, air temperature, light intensity, and wind speed. Butterfly species were identified using the identification guide by Peggie and Amir (2006).

Data Analysis
Butterfly diversity was analysed using the Shannon–Wiener diversity index (Magurran 2004) according to the following formula:

$$H' = -\sum\left[\frac{ni}{N}\right]\log\left[\frac{ni}{N}\right]$$
$$-\sum \text{Pi} \log \text{Pi}$$

with:
H' = Shannon-Wiener Index
ni = Number of individuals of each species
N = Total number of individuals
Pi = Probability of importance for each species = ni / N
log = Natural log

The evenness of butterfly species in a habitat can be calculated using the species evenness index formula (Magurran 2004), with the following formula:

$$E = \frac{\mathrm{H}'}{\ln S}$$

with:
H' = Shannon-Wiener diversity index
S = Number of species found

If the species evenness index is close to one, it indicates that butterfly species are evenly distributed. Conversely, if the index value is close to zero, it indicates an uneven distribution of butterfly species within the habitat. In addition, the relationship between butterfly diversity and environmental factors was analysed using Principal Component Analysis (PCA) with the R software (version 2.11.0) (Everitt & Hothorn 2006; R Development Core Team 2015).

RESULTS AND DISCUSSION

Butterfly Diversity
Based on the identification results and sample calculations in the duku plantation area, 33 species and 284 individual butterflies belonging to the family Nymphalidae were recorded (Table 1). The family Nymphalidae was the largest butterfly family found during the observations. Butterflies from the family Nymphalidae have the highest number of species and the widest distribution (Chahyadi & Bibas 2016; Panjaitan et al. 2020). They also exhibit cosmopolitan characteristics and have a high ability to survive in various types of habitats due to their polyphagous feeding behaviour (Chandekar et al. 2014).

Table 1. Number of species and individuals of butterflies in the duku plantation area of Gunung Batu Village

Family	Species	Number of Individual			Total
		First	Second	Third	
Nymphalidae	*Acraea violae*	8	2	-	10
	Danaus chrysippus	3	-	1	4
	Ideopsis juventa	-	-	3	3
	Tanaecia munda	-	3	2	5
	Charaxes solon	2	-	2	4
	Junonia almana	-	2	2	4
	Lexias canescens	5	-	3	8
	Lexias pardalis	4	3	-	7
	Neptis hylas	-	6	3	9
	Polyura schreiberi	2	5	-	7
	Thaumantis klugius	5	3	2	10
	Ypthima huebneri	3	1	-	4
	Euploea eunice	5	-	-	5
	Euploea mulciber	2	-	-	2
	Hypolimnas bolina	2	7	5	14
	Junonia orithya	-	5	3	8
	Junonia atlites	4	5	3	12
	Junonia hedonia	5	3	2	10
	Doleschallia bisaltide	-	10	5	15
	Athyma reta	-	-	7	7
	Ypthima baldus	3	17	8	28
	Mycalesis janardana	5	20	10	35
	Mycalesis horsfieldi	-	15	-	15
	Discophora timora	-	-	5	5
	Elymnias hypermnestra	-	-	3	3
	Faunis canens	2	5	2	9
	Amathusia phidippus	-	4	2	6
	Charaxes bernardus	1	-	2	3
	Melanitis leda	2	5	2	9
	Melanitis phedima	3	1	4	8
	Charaxes solon	1	2	-	3
	Hypolimnas misippus	-	3	1	4
	Agatasa calydonia	1	5	2	8
Total of individual		**68**	**132**	**84**	**284**
Total of species		**11**	**23**	**25**	**33**
H’		**2.90**	**2.83**	**3.04**	**3.26**
E		**0.69**	**0.58**	**0.69**	**0.58**

Polyphagous are a group of animals that live and feed on various types of plants from different families (Muhelni et al. 2016; Putri et al. 2016). Fruit-feeding butterflies are easily identifiable because they can be easily trapped, and their identification is relatively straightforward compared to other groups of butterflies (Liseki & Vane-Wright 2016). Butterflies from this family are fruit-feeding species; therefore, they are often found flying in the lower canopy and around the base of duku trees during the day. The most abundant species was *Mycalesis janardana* (35 individuals), which was found flying in both the canopy and lower parts of the trees. Nine butterfly species were recorded throughout the observation period, namely *Hypolimnas bolina*, *Junonia atlites*, *Junonia hedonia*, *Ypthima baldus*, *Mycalesis janardana*, *Faunis canens*, *Melanitis leda*, *Melanitis phedima*, and *Agatasa calydonia*. The discovery and addition of butterfly species were consistently observed during each observation period (Figure 1). This was because the species accumulation curve did not reach an asymptote, indicating that additional sampling effort would likely record more species. The curve continued to show an upward trend, suggesting that the number of butterfly species would likely continue to increase if the observation period were extended. Butterflies can be found in greater numbers in larger habitat fragments (Triplehorn & Johnson 2005) and areas with higher connectivity (Brito et al. 2014). Large areas of rainforest in Indonesia have been converted into agricultural systems (Panjaitan et al. 2020). In Sumatra, rainforests have been largely converted into monoculture plantations, particularly oil palm plantations (Drescher et al. 2016), which have had a significant impact on butterfly diversity (Gray et al. 2019; Teuscher et al. 2016).

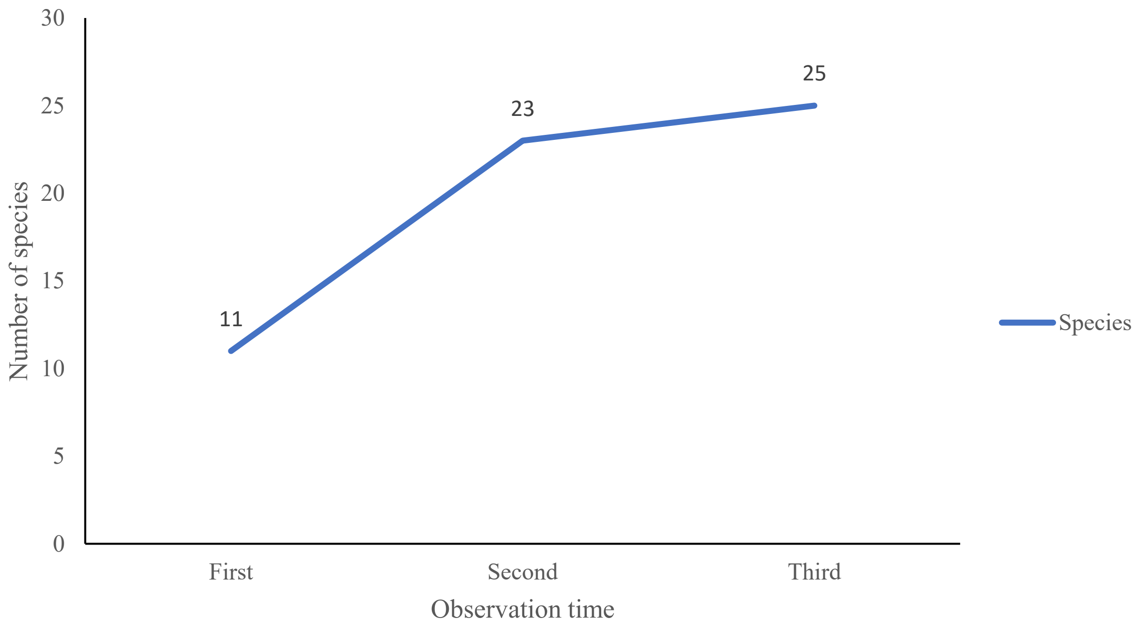

Figure 1. Number of butterfly species recorded during each observation period

The species diversity index value (H') in the third observation period (3.04) was higher than that in the first observation period (2.90) and the second observation period (2.83). According to Magurran (2004), in all environments (both tropical and temperate), a large proportion of species are rare, while a small number of common species represent approximately 90% of the total abundance. Consistent with the results of this study, two species accounted for 71% of the total abundance, namely *Mycalesis janardana* (35 individuals) and *Ypthima baldus* (28 individuals) (Table 1).

Both butterfly species are small in size and able to survive in small habitat fragments (Silva et al. 2015). This may be because the third observation period (May) coincided with the beginning of the dry season and occurred after the harvesting period. During this period, butterflies were observed sunbathing and flying more frequently as the day became brighter.

This behaviour was also considered to be related to favourable abiotic factors and the availability of plants that began to bloom. Meanwhile, the evenness index value (E) in the first and third observation periods was 0.69, which was higher than that in the second observation period (0.58). Both index values were close to 1, indicating a relatively even distribution of butterfly species. However, during the observation period, several butterfly species dominated the community (Table 1). The results reported by Rembold et al. (2017) and Brown and Crone (2016) suggested that high butterfly diversity is associated with more heterogeneous habitat structures, greater plant diversity, and favourable abiotic factors. Silva et al. (2020) also recorded 45 species of fruit-feeding butterflies in habitats with heterogeneous structures and sufficient light intensity. Generally, the presence of butterflies is highly correlated with the availability of host plants, and changes in plant communities can also affect butterfly biodiversity (Goncalves-Souza et al. 2015; Ruhi et al. 2017). Butterflies select plants as food sources and are attracted to flowers as sources of nectar or other food resources (Suthar et al. 2019). The selection of host plants by butterflies, particularly fruit-feeding butterflies, depends on various factors, including innate colour preferences (Ravikanthachari Nitin et al. 2018), crown depth, flower arrangement from which nectar can be extracted, and chemical compounds present in plant leaves (Patel et al. 2017; Sharma & Sharma 2013).

The number of butterfly species recorded was higher during the third observation period (25 species) compared to the other observation periods because, at this time, the duku fruits were ripe and ready to be harvested by the community for sale or personal consumption. Seasonality can be recognised as a strong driver of butterfly diversity (Ghosh & Saha 2016; Zellweger et al. 2016). This is because seasonal changes significantly influence plant phenology, and butterfly diversity is closely associated with the availability of these resources (Ribeiro et al. 2012; Sagwe et al. 2015). Pereira et al. (2017) also found that butterfly diversity was higher during the rainy season (27 species) than during the dry season (20 species). Environmental conditions, such as forest habitats with transitional seasons (lower temperature and higher humidity), are more favourable than dry-season conditions (Baudier et al. 2015). However, the greatest abundance of butterflies can be found in open areas with high light intensity, as many butterfly species are adapted to exposure to strong sunlight (Valtonen et al. 2017). Several species recorded during the third observation period (May) showed higher abundance (25 species and 284 individuals), likely due to larger canopy openings, as these species possess natural tolerance to low humidity, high temperatures, and strong light intensity (Brito et al. 2014). Similar results were reported by Uwizelimana et al. (2022), who found that higher species richness and abundance (56 species) were recorded during the dry season in Nyungwe National Park, Rwanda.

The Influence of Environmental Factors on Butterfly Diversity

Environmental factors, such as canopy openings and light intensity, can affect the distribution of butterflies (Meijide et al. 2018). Observations revealed that the duku plantation habitat exhibited varying environmental conditions during each observation period, which influenced the presence of butterflies recorded at the study site (Table 2). The canopy cover of duku trees ranged from 20% to 70%, allowing sunlight to penetrate the plantation floor and supporting the presence of butterflies within the plantation. Based on the PCA analysis, butterfly occurrence was generally influenced by temperature and light intensity (Figure 2). During the first observation period, temperature was the most influential environmental factor. During the second observation period, butterfly occurrence was influenced by wind speed and humidity. During the third observation period, the number of individuals and species was strongly influenced by light intensity.

The temperature recorded during the second observation period was higher (33°C) because temperatures in March were influenced by a combination of cooler conditions from the rainy season and warmer conditions from the transition towards the dry season. Meanwhile, the temperatures recorded in January and May represented two different conditions, namely cooler temperatures in January and warmer temperatures in May. Butterfly body temperature is affected by the temperature of the surrounding environment (Barton et al. 2014). Butterflies rely heavily on flight for most activities; however, insect flight requires considerable energy, and the thoracic muscles of flying insects exhibit the highest metabolic rates (Luo et al. 2014), exceeding resting metabolism by up to twofold (Mattila & Hanski 2014). Therefore, butterflies must bask for 5–10 minutes before initiating flight, depending on the surrounding environmental conditions.

Table 2. Observational data on environmental factors and butterfly diversity in the duku plantation area

Observation Time	**Sp**	**Ind**	**Tempt (°C)**	**RH (%)**	**IC (Lux)**	**KA (Knot)**
First	11	68	32.50	75.50	31250000	0.10
Second	23	132	33.00	77.83	37750000	0.63
Third	25	84	30.83	76.33	43866667	0.18

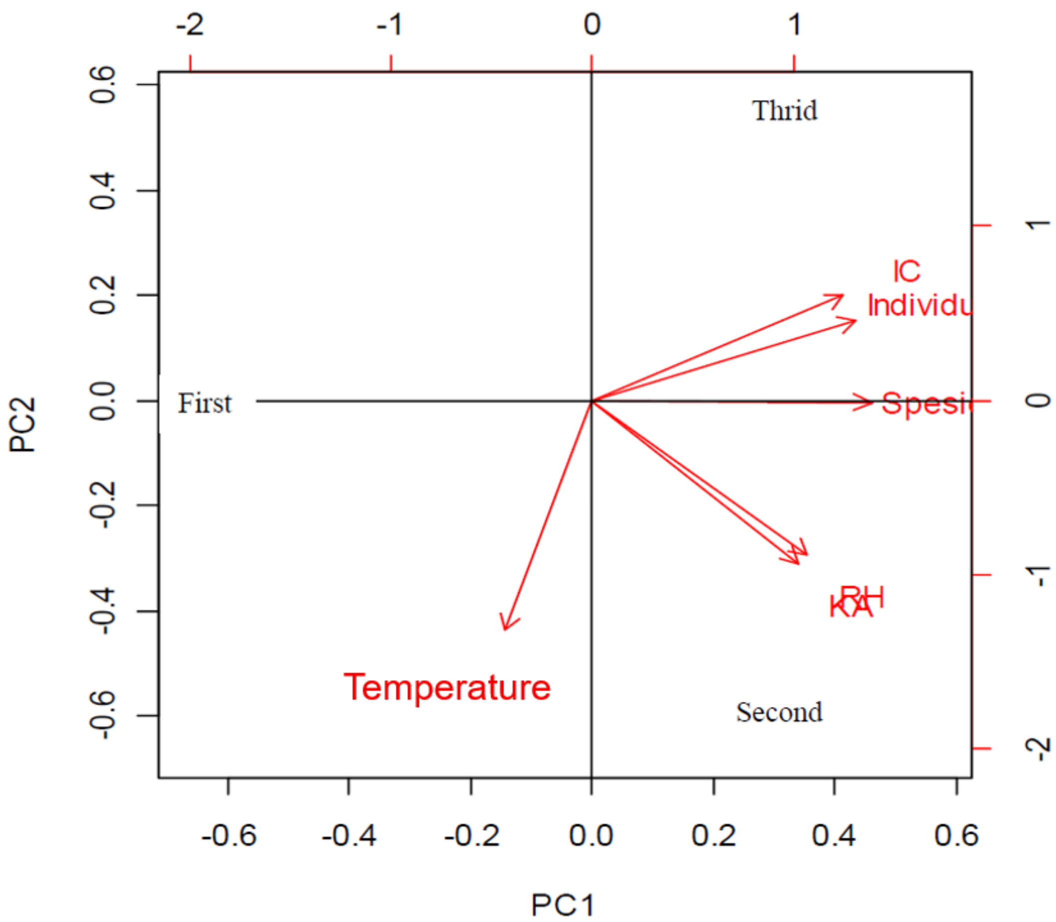

Figure 2. Correlation between environmental factors and butterfly diversity in the duku plantation area (refer to Table 2 for description)

As a result, butterflies require a muscle temperature of approximately 30–38°C to initiate flight (Niitepold & Hanski 2013; Tsai et al. 2020), and flight activity is strongly influenced by thermoregulation processes occurring in the wings (Sumah 2019). The optimum temperature for butterflies to begin their activities is approximately 20–35°C (Franzen et al. 2022; Wong et al. 2016). Sumah and Apriniarti (2019) found that the air temperature range recorded for butterfly diversity studies at CIFOR, Bogor, was 26°C. During the transitional season (between the rainy and dry seasons), butterfly body temperature is determined by the balance between heat gained from external sources, such as solar radiation (Ma et al. 2021), and heat loss caused by increased cooling mechanisms (Bladon et al. 2020; Wong et al. 2016), for example through wind speed (Mattila 2015). This may also explain the higher humidity and wind speed values recorded during the second observation period (March), as well as the higher light intensity values recorded during the third observation period (May). Environmental conditions with relatively high humidity and wind speed are more favourable during the transitional season than during the dry season (Diamond & Chick 2018; Fernandes et al. 2014). A similar pattern occurs in rupestrian grasslands, which are characterised by high humidity during the dry season (Coelho et al. 2017; Nobre et al. 2012).

Light intensity has a direct impact on butterfly occurrence, especially for species that prefer to forage in the lower canopy (Muhelni et al. 2016), such as butterfly species from the family Nymphalidae (Christharina & Abang 2014). The air conditions in plantations during the morning remain warm and relatively humid, causing butterflies to frequently move within the tree canopy (Francesconi et al. 2013), allowing them to regulate their body temperature according to the surrounding environment. Open tree canopies positively affect butterfly diversity, particularly during the dry season (Loos et al. 2014), and reveal important structural factors influencing fruit-feeding butterflies that are currently being studied (Pardonnet et al. 2013; Valtonen et al. 2017).

Butterflies play important roles in plantations, namely pollination and the maintenance of prey–predator relationships. These roles provide important ecosystem services that contribute to human well-being (Keerthika & Parthiban 2022). The identification and management of pollinating insect diversity in plantations have a direct effect on increasing plantation productivity (Goded et al. 2019; Mannaf et al. 2022). Plantation areas have undergone changes over the past decade, including the increased use of pesticides and synthetic fertilisers (Kusumadinata et al. 2020). The use of pesticides has indirect negative effects on pollinating insects by disrupting community structure (Campera et al. 2021). This differs from the duku plantation at the research site, where pesticides and synthetic fertilisers are not applied. Farmers still rely on natural bioindicators available in the environment to manage pests that may damage these plants, improve soil fertility around duku trees, and respond to environmental changes associated with seasonal variation. Information on plant fertility and harvest readiness provided by nature can reduce the risk of crop failure among farmers (Misganaw et al. 2017; Kusumadinata et al. 2020). Fruit-feeding butterflies are often used by duku farmers to determine the condition of duku fruits that are ready for harvest. In addition, several other organisms used as bioindicators in plantation areas include Coleoptera insects (Ruslan & Sumah 2021), ants (Anjos et al. 2022; Offenberg 2015), bees (Ruiz et al. 2013; Skorbilowicz et al. 2018), birds (Ayat & Tata 2015; Mekonen 2017), and other mammal species (Barros et al. 2014; Misganaw et al. 2017).

CONCLUSION

The results of this study represent the first assessment of fruit-feeding butterfly diversity in duku plantations. A total of 33 species comprising 284 individual butterflies were recorded in the duku plantation of Gunung Batu Village, East OKU Regency, South Sumatra Province, Indonesia. The high butterfly diversity indicates that duku plantations can provide suitable habitats and resources for fruit-feeding butterflies. Temperature and light intensity were identified as important environmental factors influencing butterfly abundance and diversity during the observation period. Therefore, maintaining suitable plantation conditions, including vegetation structure and natural environmental characteristics, is essential for supporting butterfly diversity and ecosystem balance in duku plantations.

ACKNOWLEDGEMENTS

The researchers would like to thank the Head of Gunung Batu Village, East OKU Regency, for granting the research permit, as well as the duku farmers who provided information on the factors determining duku fruit harvest readiness.

AUTHORS DECLARATIONS

Funding Statement
This research did not receive any specific grant from funding agencies in the public, commercial, or not for profit sectors.

Conflicts of Interest
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

Ethics Declarations
Ethics declarations are not applicable for this research.

Data Availability Statement
The datasets generated during and/or analysed during the present study are available from the corresponding author.

Authors' Contributions
ASWS conceived, designed, and identified the sample; AAK participated in data analysis; ASWS and AAK wrote the script and revised it. All authors have read and approved the manuscript.

REFERENCES

Anjos, D.V., Tena, A., Viana-Junior, A.B., Carvalho, R.L., Torezan-Silingardi, H., Del-Claro, K. & Perfecto, I. 2022. The effects of ants on pest control: A meta-analysis. *Proceedings of the Royal Society B: Biological Sciences* 289(1981): 20221316.

Ayat, A. & Tata, H.L. 2015. Diversity of birds across land use and habitat gradientsinforests, rubber agroforests and rubber plantations of North Sumatra. *Indonesian Journal of Forestry Research* 2(2): 103-120.

Barros, M.A.S., Pessoa, D.M.A. & Rui, A.M. 2014. Habitat use and seasonal activity of insectivorous bats (Mammalia: Chiroptera) in the grasslands of southern Brazil. *Zoologia* 31 (2): 153–161.

Barton, M., Sunnucks, P., Norgate, M., Murray, N. & Kearney M. 2014. Co-gradient variation in growth rate and development time of a broadly distributed butterfly. *PLoS ONE* 9(4): e95258.

Baudier, K.M., Mudd, A.E., Erickson, S.C. & O'donnell, S. 2015. Microhabitat and body size efects on heat tolerance: Implications for responses to climate change (army ants: Formicidae, Ecitoninae). *Journal of Animal Ecology* 84: 1322–1330.

Bibi, M., Bibi, S., Akhtar, N., Ullah, Z,. Khan, M.F. & Qureshi, I.Z. 2022. Butterfly (Order: Lepidoptera) species Richness, diversity and distribution in different localities of Battagram, Pakistan. *Saudi Journal of Biological Sciences* 29: 1853–1857.

Bladon, A.J., Lewis, M., Bladon, E.K., Buckton, S.J., Corbett, S., Ewing, S.R., Hayes, M.P., Hitchcock, G.E., Knock, R., Lucas, C., McVeigh, A., Menendez, R., Walker, J.M., Fayle, T.M. & Turner, E.C. 2020. How butterflies keep their cool: Physical and ecological traits influence thermoregulatory ability and population trends. *Journal of Animal Ecology* 89: 2440–2450.

Brito, M.M., Ribeiro, D.B., Raniero, M., Hasui, E´., Ramos, F.N. & Arab, A. 2014. Functional composition and phenology of fruit-feeding butterflies in a fragmented landscape: Variation of seasonality between habitat specialists. *Journal of Insect Conservation* 18: 547–560.

Brown, L.M. & Crone, E.E. 2016. Individual variation changes dispersal distance and area requirements of a checkerspot butterfly. *Ecology* 97(1): 106-115.

Campera, M., Balestri, M., Manson, S., Hedger, K., Ahmad, N., Adinda, E., Nijman, V., Budiadi, B., Imron, M.A. & Nekaris, K.A.I. 2021. Shade trees and agrochemical use affect butterfly assemblages in coffee home gardens. *Agriculture, Ecosystems & Environment* 319: 107547.

Chahyadi, E. & Bibas, E. 2016. Jenis-jenis kupu-kupu (Sub Ordo Rhopalocera) yang terdapat di kawasan Hapanasan, Kabupaten Rokan Hulu, Provinsi Riau. *Jurnal Riau Biologia* 1(1): 50-56.

Chandekar, S.K., Nimbalkar R.K. & Kuvalekar, A.A. 2014. The seasonal pattern in the abundance of Butterflies, their biotopes and nectar food plants from Maval Tahsil, Pune District, Maharastra, India. *International Journal of Plant, Animal and Environmental Sciences* 4(1): 50-64.

Christharina, S.G. & Abang, F. 2014. Taxonomic diversity of the fruit-feeding butterflies (Lepidoptera: Nymphalidae) in Kubah National Park, Sarawak, Southwest Borneo. *Tropical Natural History* 14(1): 7-20.

Coelho, M.S., Carlos, P.P., Pinto, V.D., Meireles, A., Negreiros, D., Morellato, L.P.C & Fernandes, G.W. 2017. Connection between tree functional traits and environmental parameters in an archipelago of montane forests surrounded by rupestrian grasslands. *Flora* 238: 51-59.

DeVries, P.J. 1987. *Butterflies of Costa Rica: Their Natural History. Papilionidae, Pieridae, Nymphalidae*. Princeton University Press, Princeton, New Jersey, USA.

Diamond, S.E. & Chick, L.D. 2018. Thermal specialist ant species have restricted, equatorial geographic ranges: Implications for climate change vulnerability and risk of extinction. *Ecography* 41: 1507–1509.

Drescher, J., Rembold, K., Allen, K., Beckschäfer, P., Buchori, D., Clough, Y., Faust, H., Fauzi, A.M., Gunawan, D. & Hertel, D. 2016. Ecological and socio-economic functions across tropical land-use systems after rainforest conversion *Philosophical Transactions of the Royal Society B: Biological Sciences* 371(1694): 20150275.

Everitt, B.S. & Hothorn, T. 2006. *A Handbook of Statistical Analyzes Using R.* Chapman & Hall/CRC, Boca Raton, Florida, USA.

Fernandes, G.W., Barbosa, N.P.U., Negreiros, D. & Paglia, A.P. 2014. Challenges for the conservation of vanishing megadiverse rupestrian grasslands. *Natureza & Conservação* 12(2): 162–165.

Fordyce, J. & Devries, P. A. 2016. Tale of two communities: Neotropical butterfly assemblages show higher beta diversity in the canopy compared to the understory. *Oecologia* 181: 235-243.

Francesconi, W., Nair, P.K.R., Levey, D.J., Daniels, J. & Cullen, L. 2013. Butterfly distribution in fragmented landscapes containing agroforestry practices in Southeastern Brazil. *Agroforestry Systems* 87: 1321-1338.

Franzen, M., Francioli, Y., Askling, J., Kindvall, O., Johansson, V. & Forsman, A. 2022. Differences in phenology, daily timing of activity, and associations of temperature utilization with survival in three threatened butterflies. *Scientific Reports* 12: 7534.

García-Robledo, C., Kuprewicz, E.K., Staines, C.L., Erwin, T.L. & Kress, W.J. 2016. Limited tolerance by insects to high temperatures across tropical elevational gradients and the implications of global warming for extinction. *Proceedings of the National Academy of Sciences of the United States of America* 113: 680–685.

Goded, S., Ekroos, J., Azcarate, J.G., Guitian, J.A. & Smith, H.G. 2019. Effects of organic farming on plant and butterfly functional diversity in mosaic landscapes. *Agriculture, Ecosystems & Environment* 284: 106600.

Goncalves-Souza, T., ArauÂ jo, M.S., Barbosa, E.P., Lopes, S.M., Kaminski, L.A., Shimizu, G.H., Santos, A.J. & Romero, G.Q. 2015. Fine-scale beta-diversity patterns across multiple arthropod taxa over a Neotropical latitudinal gradient. *Biotropica* 47: 588-594.

Ghosh, S. & Saha, S. 2016. Seasonal diversity of butterflies with reference to habitat heterogeneity, larval host plants and nectar plants at Taki, North 24 Parganas, West Bengal, India. *World Scientific News* 50: 197-238.

Gray, R.E., Slade, E.M., Chung, A.Y. & Lewis, O.T. 2019. Movement of moths through riparian reserves within oil palm plantations. *Front. For. Glob. Change* 2:68.

Houlihan, P.R., Harrison, M.E. & Cheyne, S.M. 2013. Impacts of forest gaps on butterfly diversity in a Bornean peatswamp forest. *Journal of Asia Pacific Entomology* 16: 67–73.

Keerthika, A. & Parthiban, K.T. 2022. Multifunctional agroforestry landscapes: Augmenting butterfly biodiversity at foot hills of Nilgiris, India. *International Journal of Tropical Insect Science* 42: 545–556.

Koneri, R. & Maabuat, P.V. 2016. Diversity of Butterflies (Lepidoptera) in Manembo-Nembo Wildlife Reserve, North Sulawesi, Indonesia. *Pakistan Journal of Biological Sciences* 19(5): 202.

Kusumadinata, A.A., Sumardjo, Sadono, D. & Burhanuddin. 2020. Effect of farmers' characteristics, information sources, and information quality on agriculture risk communication. *International Journal of Sciences: Basic and Applied Research* 54(2): 67-83.

Kwatrina, R.Z., Santosa, Y., Bismark, M. & Santoso, N. 2018. Ecological impacts of oil-palm plantation on butterfly and bird species diversity. *Journal of Tropical Forest Management* 24 (1): 23-31.

Kwon, T-S., Lee, C.M., Kim, E-S., Won, M., Kim, S-S. & Park, Y-S. 2021. Habitat change has greater effects than climate change on butterfly occurrence in South Korea. *Global Ecology and Conservation* 26: e01464.

Lamas, G. 2004. *Atlas of Neotropical Lepidoptera: Checklist*. *Part 4A – Hesperioidea and Papilionoidea*. Scientific Publishers, Gainesville, Florida, USA.

Lamin, S., Claudia, E., Rasidin, J., & Pratama, R. 2024. Composition and diversity of the nymphalid butterfly (Lepidoptera: Nymphalidae) in South Sumatra, Indonesia. *Serangga* 29(1): 138–155.

Liseki, S.D. & Vane-Wright, R.I. 2016. Butterflies (Lepidoptera: Papilionoidea) of Mount Kilimanjaro: Nymphalidae Subfamilies Libytheinae, Danainae, Satyrinae and Charaxinae. *Journal of Natural History* 50: 865-904.

Loos, J., Dorresteijn, I., Hanspach, J., Fust, P., Rakosy, L. & Fischer, J. 2014. Low-intensity agricultural landscapes in Transylvania support high butterfly diversity: Implications for conservation. *PLoS ONE* 9(7): e103256.

Luo, S., Chong Wong, S., Xu, C., Hanski, I., Wang, R. & Lehtonen, R. 2014. Phenotypic plasticity in thermal tolerance in the Glanville fritillary butterfly. *Journal of Thermal Biology* 42: 33–39.

Ma, C.S., Ma, G. & Pincebourde, S. 2021. Survive a warming climate: Insect responses to extreme high temperatures. *Annual Review of Entomology* 66: 163–84.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing, Oxford, UK.

Mannaf, M., Zuo, A. & Wheeler, S.A. 2022. The spatial influences of organic farming and environmental heterogeneity on biodiversity in South Australian landscapes. *Journal of Environmental Management* 324: 116414.

Marisa, H. & Sugiarto, A. 2018. *Ekologi Duku Komering*. Universitas Sriwijaya: Palembang.

Martin, P. & Bateson, P.P.G. 1993. *Measuring Behavior: An Introductory Guide.* 2nd Edition. Cambridge: Cambridge University Press.

Mattila, A.L.K. & Hanski, I. 2014. Heritability of flight and resting metabolic rates in the Glanville fritillary butterfly. *Journal of Evolutionary Biology* 27: 1733–1743.

Mattila, A.L.K. 2015. Thermal biology of flight in a butterfly: genotype, flight metabolism, and environmental conditions. *Ecology Evolution* 5(23): 5539–5551.

Mayanti, T. 2009. *Kandungan Kimia dan Bioaktivitas Tanaman Duku*. Bandung: UNPAD Press.

Meijide, A., Badu, C.S., Moyano, F., Tiralla, N., Gunawan, D. & Knohl, A. 2018. Impact of forest conversion to oil palm and rubber plantations on microclimate and the role of the 2015 ENSO event. *Agricultural and Forest Meteorology* 252: 208-219.

Mekonen, S. 2017. Birds as biodiversity and environmental indicator. *Journal of Natural Science Research* 7(21): 28-34.

Misganaw, M., Mengesha, G. & Awas, T. 2017. Perception of farmers on importance of insect pollinators in gozamin district of Amhara Region, Ethiopia. *Biodiversity International Journal* 1(5): 54–60.

Muhelni, L., Herwina, H. & Dahelmi. 2016. Stratification of fruit feeding butterflies at a conservation forest of oil palm plantation in West Sumatra, Indonesia. *Journal of Entomology and Zoology Studies* 4(4): 535-540.

Mutmainnah, A.R. & Santosa, Y. 2019. Impact of oil palm plantation on the butterfly diversity: A Case study in KGP & CNG, Ketapang, West Kalimantan. *IOP Conference Series: Earth and Environmental Science* 336: 012032.

Niitepold, K. & Hanski, I. 2013. A long life in the fast lane: Positive association between peak metabolic rate and lifespan in a butterfly. *Journal of Experimental Biology* 216: 1388–1397.

Nobre, C.E.B., Iannuzzi, L. & Schlindwein, C. 2012. Seasonality of fruit-feeding butterflies (Lepidoptera, Nymphalidae) in a Brazilian Semiarid Area. *ISRN Zoology* 2012: Article ID 268159.

Offenberg, J. 2015. Ants as tools in sustainable agriculture. *Journal of Applied Ecology* 52: 1197–1205.

Panjaitan, R., Drescher, J., Buchori, D., Peggie, D., Harahap, I.S., Scheu, S. & Hidayat, P. 2020. Diversity of butterflies (Lepidoptera) across rainforest transformation systems in Jambi, Sumatra, Indonesia. *Biodiversitas* 21(11): 5119-5127.

Pardonnet, S., Beck, H., Milberg, P. & Bergman, K.O. 2013. Effect of tree-fall gaps on fruit-feeding nymphalid butterfly assemblages in a Peruvian rain forest. *Biotropica* 45: 612-619.

Patel, P.P., Patel, S.M., Pandya, H.V. & Amlani, M.H. 2017. Survey on host plants and host plant preference by lemon butterfly *Papilio demoleus* Linnaeus (Lepidoptera: Papilionidae). *Journal of Entomology and Zoology Studies* 5(6): 792-794.

Paull, R.E. 2014. *Longkong, Duku, and Langsat: Postharvest Quality-Maintenance Guidelines*. College of Tropical Agriculture and Human Resources, University of Hawai‘i, Honolulu, Hawai‘i, USA.

Peggie, D. & Amir, M. 2006. *Practical Guide to Butterflies of Bogor Botanic Garden*. LIPI, Cibinong, Indonesia.

Pereira, G.C.N., Coelho, M.S., Beirao, M.dV., Braga, R.F. & Fernandes, G.W. 2017. Diversity of fruit-feeding butterflies in a mountaintop archipelago of rainforest. *PLoS ONE* 12(6): e0180007.

Putri, D., Henny, H., Ardinis, A. & Alan, H. 2016. Ant species composition in Macaranga spp. trees at a conservation forest of palm oil plantation in West Sumatra, Indonesia. *Journal of Entomology and Zoology Studies* 4(1): 342-348.

R Development Core Team. 2015. *R: A Language and Environment For Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing , Vienna, Austria.

Ravikanthachari, N., Balakrishan, V.V., Churi, P.V., Kalesh Satyaprakash, S. & Kunte K. 2018. Larval host plants of butterflies of the Western Ghats, India. *Journal of Threatened Taxa* 10(4): 11495-44550.

Rembold, K., Mangopo, H., Tjitrosoedirdjo, S.S. & Kreft, H. 2017. Plant diversity, forest dependency, and alien plant invasions in tropical agricultural landscapes. *Biological Conservation* 213: 234-242.

Ribeiro, D.B., Batista, R., Prado, P.I., Brown, K.S. & Freitas, A.V.L. 2012. The importance of small scales to the fruitfeeding butterfly assemblages in a fragmented landscape. *Biodiversity and Conservation* 21: 811–827.

Rosch, V., Tscharntke, T., Scherber, C. & Batary, P. 2013. Landscape composition, connectivity and fragment size drive effects of grassland fragmentation on insect communities. *Journal of Applied Ecology* 50: 387–394.

Ruhi, A., Datry, T. & Sabo, J.L. 2017. Interpreting beta diversity components over time to conserve metacommunities in highly-dynamic ecosystems. *Conservation Biology* 31(6): 1459-1468.

Ruslan, H & Sumah, A.S.W. 2021. Keanekaragaman Coleoptera di sekitar kawasan cagar biosfer Giam Siak Kecil Bukit Batu Riau. *Bioma* 17(1): 1-8.

Ruiz, J.A., Gutierrez, M. & Porrini, C. 2013. Biomonitoring of bees as bioindicators. *Bee World* 90(3): 61-63.

Sagwe, R.N., Muya, S.M. & Maranga, R. 2015. Effects of land use patterns on the diversity and conservation status of butterflies in Kisii highlands, Kenya. *Journal of Insect Conservations*19: 1119–1127.

Sharma, M. & Sharma, N. 2013. Nectar resource use by Butterflies in Gir Wildlife Sanctuary, Sasan, Gujarat. *Biological Forum – An International Journal* 5(2): 56-63.

Silva, A.R.M., Pontes, D.V., Guimaraes, M.P., de Oliveira, M.V., de Assis, L.T. & Uehara-Prado, M. 2015. Fruit-feeding butterflies (Lepidoptera: Nymphalidae) of the A´ rea de Protec¸a˜o Especial Manancial Mutuca, Nova Lima and Species list for the Region of Belo Horizonte, Minas Gerais, Brazil. *Biota Neotropica* 15(3): e20140118.

Silva, V.De., Beirao, M.V. & Cardoso, D.C. 2020. Thermal tolerance of fruit-feeding butterflies (Lepidoptera: Nymphalidae) in contrasting mountaintop environments. *Insects* 11(5): 278.

Skorbilowicz, E., Skorbilowicz, M. & Ciesluk, I. 2018. Bees as bioindicators of environmental pollution with metals in an urban area. *Journal of Ecological Engineering* 19 (3): 229–234.

Sumah, A.S.W. 2019. Struktur sisik sayap kupu-kupu Superfamili Papilionoidea (Lepidoptera). *Jurnal Ilmu Alam dan Lingkungan* 10(1): 8–14.

Sumah, A.S.W. & Apriniarti, M.S. 2019. Kupu-kupu Superfamili Papilionoidea (Lepidoptera) di kawasan CIFOR, Bogor, Indonesia. *Jurnal Biologi Tropis* 19(2): 197–204.

Suthar, A.R., Sankhwai, A.O., Rathod, J.Y. & Gavali, D.J. 2019. Rapid assessment of butterfly diversity and host plants at Piplaidevi Forest Range, Dangs, Gujarat. *Biology Bulletin* 5(1): 25-31.

Teuscher, M., Gérard, A., Brose, U., Buchori, D., Clough, Y., Ehbrecht, M., Hölscher, D., Irawan, B., Sundawati, L. & Wollni, M. 2016. Experimental biodiversity enrichment in oil-palm-dominated landscapes in Indonesia. *Frontiers in Plant Science* 7: 1538.

Triplehorn, CA. & Johnson, N.F. 2005. *Borror and Delong's Introduction to The Study of Insect.* 7th Edition. Thomson Brooks/Cole, Belmont, California, USA.

Tsai, C.C., Childers, R.A., Nan Shi, N., Ren C., Pelaez, J.N., Bernard, G.D., Pierce, N.E. & Yu, N. 2020. Physical and behavioral adaptations to prevent overheating of the living wings of butterflies. *Nature Communications* 11: 551.

Uwizelimana, J.dD., Nsabimana, D. & Wagner, T. 2022. Diversity and distribution of Fruit-feeding butterflies (Lepidoptera: Nymphalidae) in Nyungwe National Park, Rwanda. *African Journal of Ecology* 60: 621–632.

Valtonen, A., Malinga, G.M., Nyafwono, M., Nyeko, P., Owiny, A. & Roininen, H. 2017. The successional pathway of the tree community and how it shapes the fruit-feeding butterfly community in an Afrotropical forest. *Journal of Tropical Ecology* 33(1): 12-21.

Weerakoon, B.M.B., Bandara, A.M.R.S. & Ranawana, K.B. 2015. Impact of canopy cover on butterfly abundance and diversity in intermediate zone forest of Sri Lanka. *Journal of Tropical Forestry and Environment* 5(1): 41–46.

Wong, S.C., Oksanen, A., Mattila, A.L.K., Lehtonen, R., Niitepold, K. & Hanski, I. 2016. Effects of ambient and preceding temperatures and metabolic genes on flight metabolism in the Glanville fritillary butterfly. *Journal of Insect Physiology* 85: 23–31.

Zellweger, F., Baltensweiler, A., Ginzler, C., Roth, T., Braunisch, V., Bugmann, H. & Bollman, K. 2016. Environmental predictors of species richness in forest landscapes: Abiotic factors versus vegetation structure. *Journal of Biogeography* 43(6): 1080-1090.