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RESEARCH ARTICLE

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The effect of altitude on the butterfly diversity in the Gunung Gede Pangrango National Park, West Java, Indonesia

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ABSTRACT

Altitude is one of the factors that decrease butterfly diversity due to the different types of habitats. Gunung Gede Pangrango National Park is one of the places at different altitudes, such as Situgunung Resort. This study aimed to investigate butterfly species' diversity, richness, and evenness at three altitude levels. This study was completed in October 2019 at altitudes 750, 850, and 950 meters above sea level (masl). Butterfly inventory (diversity) data were collected using the transect method, and data on habitat characteristics were acquired through direct observation. The richness, diversity, evenness, and community similarity of butterfly species and the biotic and abiotic habitat characteristics were then analyzed. The result showed 51 butterfly species at Situgunung Resort, Gunung Gede Pangrango National Park. The highest diversity index and richness index were found at an altitude of 750 masl (3.22 and 7.91) and the lowest at 950 masl (2.46 and 3.98). The highest evenness index was found at 750 masl, while the highest similarity community index was found at altitudes 750 and 850 masl. The relation between altitude and butterfly diversity is that the higher the altitude, the lower the butterfly diversity.

Introduction

Gunung Gede Pangrango National Park is a natural conservation area with topography varying from sloping to mountainous. The Gunung Gede Pangrango National Park is a mountainous tropical rainforest. Mountain rain forests consist of three vegetation zones, namely the sub-montane zone (800–1,500 masl) as the research site, which is included in the utilization zone, the montane zone (1,500–2,400 masl), and the sub-alpine zone (above 2,400 masl). Gunung Gede Pangrango National Park is a place where protected and unprotected animals live. The environment, including height, determines the structure and composition of forest communities, flora, and fauna [1]. In mountainous regions, altitude is the dominant control of air temperature; therefore, any systematic changes in altitude will affect air temperature [2].

Butterflies are insects from the Order Lepidoptera with beautiful colors on their wings. According to Amir et al. [3], pollinators are one of the functions of butterflies in nature. Butterflies act as pollinators while pollinating flowers to help naturally propagate plants in an ecosystem. The more diverse the host plants, the more diverse the butterfly diversity in the area [4]. Butterfly diversity in one place is different from that in other places. The factors that play a role in the existence and diversity of butterflies are environmental factors, such as air temperature, rainfall, sunlight, humidity, vegetation, predators, and parasites.

The biotic and abiotic factors that support butterfly survival also change. According to Khan et al. [5] stated that abiotic and biotic factors in a habitat could affect butterfly diversity because butterflies are very sensitive to habitat changes. Temperature, one of the abiotic factors, decreased with increasing altitude. The greater the change in altitude, the lower the diversity of the vegetation types [6]. An increase in altitude can decrease

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butterfly diversity [7]. This study aimed to examine the diversity, richness, and evenness of butterfly species at three altitudes.

Materials and Methods

Study Area

The study was conducted from October to November 2019 in the Situgunung Resort area, Gunung Gede Pangrango National Park, at three altitudes: 750, 850, and 950 masl. The Gunung Gede Pangrango National Park is geographically located between 106°51'–107°02' east longitude and 6°41'–6°51' south latitude, with a total area of 24,270.80 ha. The Situgunung area is located at the foot of Mount Gede Pangrango, an eco-tourism area of 100 ha in the Sukabumi Regency. It has a hilly topography with a type A climate, high rainfall, and a latosol-dominant soil type. A map of the study area is presented in Figure 1.

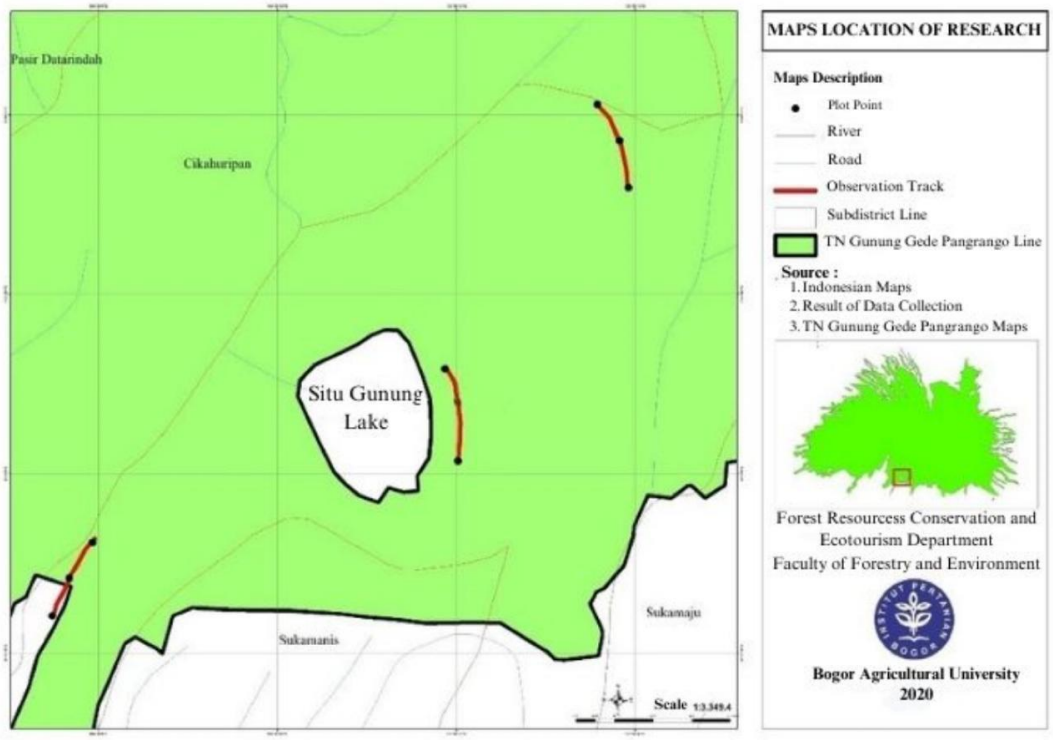

Figure 1. Study area map.

Data Collection

The data collection tools used in this study were a butterfly net, dry-wet thermometer, measuring device, syringe, specimen box, butterfly field guide (Butterfly Practical Guide in the Bogor Botanical Gardens compiled [8]), identification guide for butterflies of West Java [9], stationery, Global Positioning System (GPS), altimeter, measuring tape, compass, 70% alcohol, papilot paper, and camphor. The habitat characteristic data for food availability were observed directly when the observations took place in each location. Water source observations were conducted by observing the existence, form (flowing or stagnant), and water quality as seen from the pH level of water. Micro-climate measurements were conducted by measuring the temperature and humidity at each observation location using a dry-wet thermometer placed 120 cm above ground level.

Sunlight measurements were manually performed under the forest canopy using the threshold method by increasing or lowering the threshold value until a match was found between the classified image and the original image to obtain a clear boundary between the part covered by the canopy and the open part [10]. Data were collected by capturing photos identified using Hemiview 2.1 canopy analysis software, generating the Leaf Area Index (LAI) output. The conditions of vegetation inhabited by butterflies were obtained using the vegetation analysis method. For vegetation analysis, five 20 × 20 m sample plots were constructed and divided into three subplots of 10 × 10 m, 5 × 5 m, and 2 × 2 m [11].

A butterfly inventory was conducted using the transect method [12]. The number of transects made at each altitude was one transect with a length of 1,000 m, a width of 20 m, and a distance between plots of 10 m. Catching butterflies was carried out by following the direction and length of the transect when the butterflies were active, namely 08.00–11.00 WIB and 12.00–15.00 WIB in clear weather, with three repetitions of butterfly catching at each altitude. The identification of butterflies was carried out directly during observation and indirectly by bringing the butterflies caught in a butterfly net into papilot paper to be identified later by referring to the field guidebook. The field guidebooks used were the Practical Guide to Butterflies in the Bogor Botanical Gardens, compiled by Peggie and Amir [8], and the Identification Guide for Butterflies in West Java [9].

Data Analysis

The butterfly species diversity was calculated using the Shannon-Wiener Diversity Index [13] with the formula $\mathbf{H' = -\Sigma pi\ ln\ pi}$. The value of butterfly species richness was calculated using the Margalef Richness Index [13] with the formula $Dmg = (\mathbf{S-1})/\mathbf{l}$. The value of species evenness was calculated using the evenness index Shannon formula [13] with the formula E = H'/ln S. Community similarity (ISJ) was assessed using the Jaccard community similarity index with the formula ISJ = c/(a+b+c) [14]. The influence of environmental factors was analyzed using a Biplot Analysis. A biplot is an attempt to visualize data in a two-dimensional chart. Biplot analysis is descriptive in nature and can visually present a group of objects and variables in a flat chart [15].

Results and Discussion

Results

General Conditions of the Research Location

Situgunung Resort is located at an altitude between 650 to 1,036 masl. Its temperature ranges from 16 °C to 28 °C, with an average humidity of 84% [15]. The abiotic condition of the habitat that distinguishes the three altitudes is the presence of a water source that can affect the existence of butterfly species. At an altitude of 750 m, there was a water source in the form of water flowing from Lake Situgunung. At an altitude of 850 m, there was a water source in the form of Lake Situgunung; at an altitude of 950 masl, there was no water source. The general conditions (abiotic components) of the research location, including air temperature, humidity, and LAI, are listed in Table 1.

Table 1. Abiotic components of the three altitudes.

Altitude (masl)	Temperature (°C)	Humidity (%)	LAI
750	26.7	57	1.21
850	24.1	63	0.63
950	22.1	75	1.88

Vegetation

Based on vegetation analysis at the Situgunung Resort's three altitudes, 47 vegetation types with 39 families were identified. Table 2 shows eleven vegetation species that became food for larvae and butterflies at the three altitudes.

Table 2. Vegetation species as foods for larvae and butterflies at the three altitudes.

Vegetation species	Family	Altitude			Function		Butterfly species which consume it
		750	850	950	Foods for larvae	Foods for butterflies	
Ageratum conizoides	*Asteraceae*	✓	✓		✓	✓	*All butterflies*
Macaranga tanarius	*Euphorbiaceae*	✓	✓	✓	✓		*Graphium sp.*
Chromolaena odorata	*Asteraceae*	✓	✓			✓	*Delias sp.*
Sida rhombifolia	*Malvaceae*	✓				✓	*Eurema blanda*
Melastoma malabathricum	*Melastomataceae*	✓	✓	✓		✓	*All butterflies*
Leucaena leucocephala	*Fabaceae*	✓		✓	✓		*Melanitis leda*
Impatiens platypetala	*Balsaminaceae*	✓		✓		✓	*Eurema sp.*

Vegetation species	Family	Altitude			Function		Butterfly species which consume it
		750	850	950	Foods for larvae	Foods for butterflies	
Tibouchina urvilleana	*Melastomaceae*	✓				✓	*All butterflies*
Piper betle	*Piperaceae*		✓		✓	✓	*Troides sp.*
Pinus merkusii	*Pinaceae*	✓	✓	✓	✓		*All butterflies*
Datura Suaveolens	*Solanaceae*	✓	✓	✓	✓		*Eurema sp.*

Butterfly Population

Research at three altitudes conducted at the Situgunung Resort, Gunung Gede Pangrango National Park, found 955 individual butterflies with 51 species and five families. The dominant family was Nymphalidae. The altitude of 850 masl had the highest number of individuals, namely 456 butterflies, whereas the altitude of 950 masl had the smallest number of butterflies (119) (Figure 2).

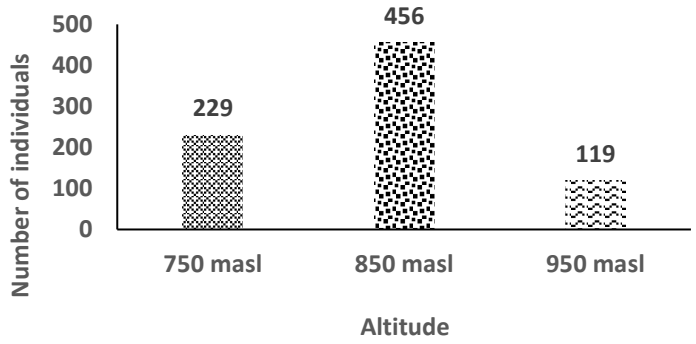

Figure 2. Number of individual butterflies at three altitudes of Situgunung Resort Gunung Gede Pangrango National Park.

Nymphalidae dominated at the three altitudes, with as many as 21 species at an altitude of 850 masl from 53 species obtained from the three altitudes. Meanwhile, Hesperidae was the family with the least number of species, namely zero at an altitude of 950 masl from 5 species obtained from overall altitudes, as shown in Figure 3. Among the 51-butterfly species found at the three altitudes, butterfly species with conservation status or were included as protected animals based on the Ministry of Environment and Forestry No. 106 of 2018, CITES Appendix and IUCN Red List are presented in Table 3. *Troides sp.* flies above Lake Situgunung at an altitude of 850 masl to 950 masl.

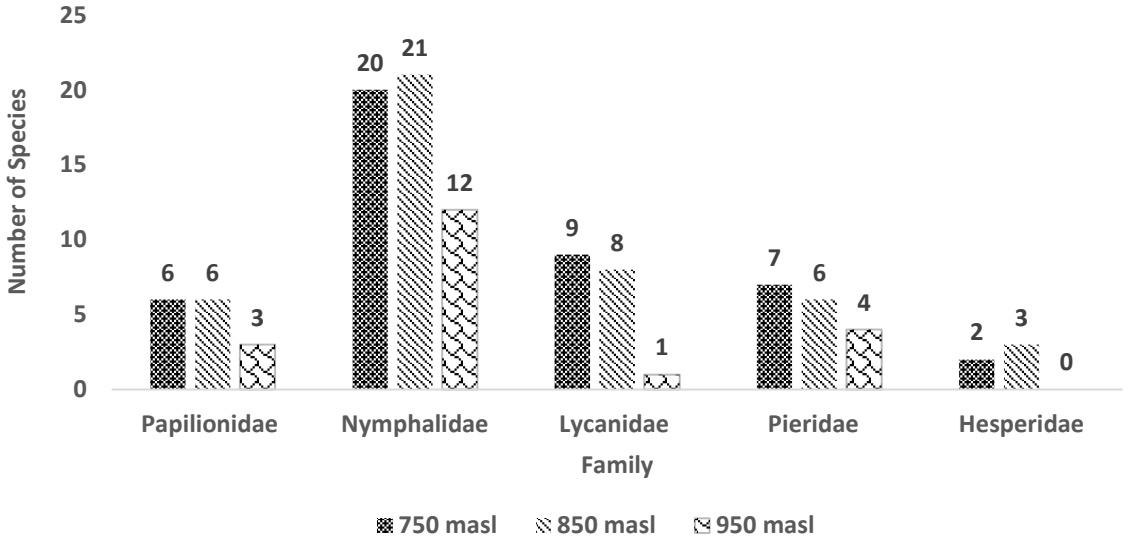

Figure 3. Comparison of the number of butterfly species at the three altitudes of Situgunung Resort Gunung Gede Pangrango National Park according to family.

Table 3. Vegetation species as foods for larvae and butterflies at the three altitudes.

Species names	Family	LHK Ministerial Decree No. 106/2018	CITES	IUCN red list
Troides sp.	Papilionidae	Protected	Appendix II	Least concern
Delias belisama	Pieridae			Least concern
Danaus sp.	Nymphalidae			Least concern
Junonia atlites	Nymphalidae			Least concern

Butterfly Species Diversity, Richness, and Evenness

Butterfly species diversity (H'), richness (Dmg), and evenness (E) can be seen in Table 4. The butterfly with the highest diversity index value was found at an altitude of 750 masl, with a value of 3.22. The altitude of 750 masl had an area with a canopy cover that was not too tight and was a water source. The lowest butterfly diversity value was found at an altitude of 950 m with a value of 2.46. The research location with the highest species richness was at an altitude of 750 masl at 7.91, and the lowest species richness was at an altitude of 950 masl at 3.98. The evenness values of the species at the three altitudes ranged from 0.80 to 0.85. The three evenness figures at the three altitudes were close to one, indicating that the evenness of the species at the three altitudes was quite high. The lowest species' evenness was at an altitude of 850 masl (0.80), and the highest was at an altitude of 750 masl (0.85).

Table 4. Diversity, richness, and evenness of butterfly species at Resort Situgunung Gunung Gede Pangrango National Park.

Altitude (masl)	Diversity (H')	Richness (Dmg)	Evenness (E)
750	3.22	7.91	0.85
850	3.02	7.02	0.80
950	2.46	3.98	0.82

Butterfly Community Similarity

The community similarity coefficient presented in Table 5 was used to determine the level of community similarity when using the habitat. The altitude with the highest similarity coefficient was between 750 masl and 850 masl, with an index value of 0.76. There were 38 butterfly types at both altitudes. The smallest similarity index was between altitudes of 750 and 950 masl at 0.36. There were 17 butterfly types at both altitudes.

Table 5. Coefficient of community at three altitudes at Resort Situgunung Gunung Gede Pangrango National Park.

Community Similarity Index	750	850	950
750	1	0.76	0.36
850		1	0.42
950			1

The Relations between Environmental Factors and Butterfly Diversity

The results of the biplot analysis illustrated the relationships between environmental factors and butterfly diversity at each altitude, showing that at an altitude of 750 masl, butterfly diversity was influenced by the existence of a water source. At an altitude of 850 masl, the environmental factors that affected butterfly diversity were availability of food for larvae, air temperature, and food for butterflies. At an altitude of 950 m above sea level, butterfly diversity is influenced by air humidity and LAI.

Discussion

The results of this study at three altitudes obtained five families of butterflies: Lycanidae, Nymphalidae, Papilionidae, Pieridae, and Hesperidae. The Nymphalidae family has the highest number of species and individuals. It follows [16] statement that the Nymphalidae family has approximately 7,200 species spread across continents, except for Antartica. A study on the elevational distribution of butterflies in the Himalayas, Langtang National Park, Nepal, reported that Nymphalidae are significantly distributed across high, mid, and low elevation zones [17]. According to Rohman et al. [18], Nymphalidae is a cosmopolite butterfly family. Cosmopolite butterflies are spread over many areas of the world, such as bright places, farms, forests, rotten fruits, and animal waste, and have high survival ability in various habitats as they are polyphagous. The family with the lowest number of species was Hesperidae. According to Shalihah et al. [19], butterflies that belong

to this family are usually active at night or when the sun is still dim in the morning, called crepuscular. Scott [20] stated that this type of butterfly rarely flies far away, and only a few migrate.

Based on the results at an altitude of 750 masl, the diversity value was the highest among the three altitudes. This aligns with the statement by Öztürk et al. [21] that varying altitudes will determine biodiversity. The highest biodiversity index at an altitude of 750 m above sea level was attributed to sufficient supporting factors for butterfly life, such as water sources (water flowing from Lake Situgunung), canopy cover, temperature, humidity, and vegetation, which can be utilized as diverse food sources. This aligns with the statement of [22]. Riparian habitat types (habitats located on the banks of rivers or lakes) have high potential as a place for butterflies to live because of the availability of water sources, open vegetation, and high sun intensity. Butterflies are sensitive to air temperature, and an open area with higher sun intensity and relative air temperature is considered a favorable environment for butterflies [23]. Species respond to environmental conditions through changes in morphology and behavior, phenology, and geographic range shifts [24]. Oktorina [25] stated that a fairly open area causes many flowering plants to grow. Based on the results of the biplot analysis, this altitude is supported by environmental factors, such as water sources, temperature, humidity, and food vegetation for larvae and butterflies.

Based on the results obtained at an altitude of 850 masl, the diversity value obtained was the second highest among the three altitudes after 850 masl. This is because the supporting factors for butterfly life are sufficiently fulfilled, such as temperature, humidity, vegetation, and water sources, in the form of Lake Situgunung and open canopy cover. The richness value at this altitude is the second highest after 750 masl because, at this altitude, the level of adaptation and competition in foraging tends to be lower because of the relatively lower number of species and individuals. This is in line with the statement of Ferrer-Paris et al. and Despland et al. [26,27] that the diversity of caterpillar and butterfly food plants in a habitat is related to the richness of butterfly species in that habitat. Diversity at altitude is supported by environmental factors, such as water sources, temperature, humidity, open canopy cover, and adequate forage plants for caterpillars and butterflies.

Based on the results at an altitude of 950 masl, the diversity value obtained was the smallest compared to other altitudes because at this altitude, the supporting factors for butterfly life were not met, such as the absence of a water source and dense canopy cover. The richness value at this altitude was the lowest among the three altitudes because, at this altitude, the level of adaptation and competition in looking for food tended to be higher because of the relatively higher number of species and individuals. The biplot analysis results showed that there was no water source at this altitude, but it had high temperature and humidity, a lack of forage plants, and a fairly dense canopy cover. According to Koneri et al. [28] stated that butterflies prefer habitats with moderate temperature. This is in line with Alarape et al. [29], who reported that temperature can affect oviposition, mating behavior, larval development, and butterfly food plants.

In line with this, Sumi et al. [22] stated that butterflies are influenced in various aspects by climate change as they are sensitive to temperature and rising temperatures due to global warming on butterfly wings. The evenness values obtained at the three altitudes were evenly distributed because the evenness index value obtained at each altitude was close to the maximum evenness (E was close to 1). According to Efendi et al. [4], the greater the evenness value of butterfly species, the more evenly distributed butterfly species are, and certain types of butterflies are not dominant. The smaller the value of evenness of species, the less evenly distributed the species, and there is dominance by certain types of butterflies.

Troides sp. is one of the butterfly species listed in the Ministry of Environment and Forestry Regulation No. 106 of 2018 about the Second Amendment to The Minister of Environment and Forestry Regulation Number P.20/Menlhk/Setjen/Kum.1/6/2018 Regarding Protected Plant and Animal Species. This butterfly is seen flying over Lake Situgunung at an altitude of 850 m and 950 masl. It is also proven that the presence of forage plants found at the observation site, namely *Aristolochia sp.* There is a positive correlation between the length of butterfly wings and average temperature, as the average temperature change affects the length of butterfly wings. Bladon et al. [30] also stated that there was a significant difference in the buffering ability of butterflies against climate change. The longer the butterfly wings, the higher its ability to adapt to climate change. Hence, larger butterflies may be better at increasing and decreasing their thorax temperatures using thermoregulation. This is in line with the findings of *Troides helena* butterfly species, which have quite long wings at 850 masl toward 950 masl altitudes. Butterflies with quite long wings are mostly from the Papilionidae Family, which have a large body with wings of more than 50 mm [16].

The altitude with the highest similarity coefficient is between 750 masl and 850 masl, with an index value of 0.76. There were 38 butterfly types at both the altitudes. The smallest similarity index is between altitudes

of 750 and 950 masl at 0.36. The number of butterfly types at both altitudes was 17. The highest similarity of butterfly communities was at altitudes of 750 masl and 850 masl at 0.76. This is because of the similarity of vegetation types and the availability of caterpillars and butterfly food, which are almost the same at both altitudes. The community similarity is at least 750 masl and 950 masl at an altitude of 0.36, because the availability of food and water at an altitude of 950 masl is less than that at an altitude of 750 masl. According to Alikodra [31], habitat suitability, which includes environmental adaptation, vegetation strata, food availability, natural selection, and other natural factors, affects the opportunity for community similarities between different habitats and is closely related to the distribution of butterflies.

Based on these results, it is known that there is a difference between butterfly diversity and altitude, indicating that increasing altitude lowers butterfly diversity. The results of this analysis align with the research of Mihoci et al. [7], which showed that the number of butterfly species decreases with increasing altitude. Supported by Panjaitan [32], significant differences occur in the high number of individuals and diversity of butterfly species at low altitudes, which decrease with increasing altitude. This is in line with Dar et al. [33], who stated that the diversity index shows that butterfly communities are more diverse at lower altitudes and decline significantly with increasing altitude. Overall, butterflies and their diversity are stronger at lower elevations and gradually decline at higher elevations because floristic diversity declines when they rely on to survive and reproduce. Butterfly richness and abundance decline with altitudes, and species composition changes along the altitudes [34–37].

The lower the rainfall and altitude, the higher the abundance of butterfly species [4]. This is because an increase in altitude causes the environmental conditions to change. The increase in altitude affects the composition and structure of existing forest vegetation. Altitude changes also cause changes in the microclimate in the place, such as light intensity, temperature, and humidity. Changes in environmental conditions, including air temperature, will determine the patterns of species distribution and composition of the local butterfly community [38]. In accordance with Habel et al. [38], Kovacevich et al. [39] also stated that microclimate variability in tropical forests plays a key role in shaping species distribution and their ability to cope with environmental change [39]. According to Lee et al. [40] stated that butterflies serve as effective indicators of temperature change, and butterfly distribution can be utilized to determine their adaptive abilities to climate patterns.

Butterflies are poikilothermic [41,42], and their body temperature is affected by environmental temperature [43,44]. Butterflies are cold-blooded animals that do not generate sufficient heat from their metabolism to provide them with the heat and energy they need to fly. Therefore, butterflies rely on heat absorbed from the sun, so they often bask in the sun in the morning to help increase their body heat. Altitude changes reduce plant species diversity [6] because butterflies and caterpillars have fewer types of food at each altitude.

The highest diversity and richness were observed at an altitude of 750 m above sea level. This can be attributed to the availability of food sources and water and favorable air temperature conditions, enabling butterflies from higher altitudes to migrate to this location. Consequently, the diversity and richness were higher at 750 m above sea level. According to Al Baraj and Ögür [45], air temperature influences the migration of insects, particularly butterflies. Researchers who conducted a study in The Qinling Mountains in China stated that the environment and other factors collaboratively shape and influence butterfly diversity [46].

Conclusions

The butterfly population at Resort Situgunung Gunung Gede Pangrango National Park included as many as 51 species, comprising 955 individuals. Diversity and richness had a value range of 2.46 to 3.22 and 3.98 to 7.91. The types of butterflies at each altitude were evenly spread because they had a species evenness value close to 1. The highest community similarity index was at an altitude of 750 masl and 850 masl of 0.85; this value decreased with increasing altitude. The research location with the most optimal characteristics for butterfly life is at an altitude of 850 m, as seen from temperature, humidity, sunlight intensity (LAI), water sources, and food vegetation that support butterfly life, as seen from species diversity and species richness.

Author Contributions

LNG: Conceptualization, Methodology, Investigation, Writing; **SBR**: Conceptualization, Writing, Review & Editing; **IFH**: Investigation, Writing.

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References

1. Sinha, S.; Badola, H.K.; Chhetri, B.; Gaira, K.S.; Lepcha, J.; Dhyani, P.P. Effect of altitude and climate in shaping the forest compositions of Singalila National Park in Khangchendzonga Landscape, Eastern Himalaya, India. *Journal of Asia-Pacific Biodiversity* **2018**, *11,* 267–275, doi:10.1016/j.japb.2018.01.012.
2. Pepin, N.C.; Arnone, E.; Gobiet, A.; Haslinger, K.; Kotlarski, S.; Notarnicola, C.; Palazzi, E.; Seibert, P.; Serafin, S.; Schöner, W.; et al. Climate Changes and Their Elevational Patterns in the Mountains of the World. *Reviews of Geophysics* **2022**, *60*, 1–40, doi:10.1029/2020RG000730.
3. Amir, M.; Wono, A.N.; Sih, K. *Insects of Halimun Mount National Park, Western Java: Butterflies (Lepidoptera)* (in Indonesian language); BCP-JICA: Bogor, ID, 2003; ISBN 979-328-512-5.
4. Efendi, M.A. Butterfly diversity (*Lepidoptera ditrysia*) in the "corridor forest" area of Halimun Salak Mount National Park, West Java (in Indonesian language). Thesis, Institut Pertanian Bogor, Bogor, ID, 2009.
5. Khan, Z.H.; Raina, R.H.; Dar, M.A.; Ramamurthy, V.V. Diversity and distribution of butterflies from Kashmir Himalayas. *Journal of Insect Sciences* **2011**, *24*, 45–55.
6. Ganesid, M.A.P.; Burhanuddin; Manurung. Diversity of Vegetation Tupes in Nature Reserves Lho Fat Pin Pie Monterado, Bengkayang. *Journal Sustainable Forest* **2019**, *7*, 86–96.
7. Mihoci, I.; Hrsak, V.; Kucinic, M.; Stankovic, M.; Delic, M. Butterfly diversity and biogeography on the Croatian karst mountain Biokovo: vertical distribution and preference for altitude and aspect? *Eur J Entomol.* **2011**, *108*, 623–633.
8. Peggie, D.; Amir, M. *Practical Guide to The Butterflies of Bogor Botanic Garden*; LIPI Press: Bogor, ID, 2006; ISBN 979-579-094-3.
9. Schulze, C.H. 2011. Identification Guide for Butterflies of West Java.
10. Pujiastuti, A.; Harjoko, A. Long Calculation System of Solar Irradiation with Otsu Threshold Method (Case Study: St. Barongan Climatology). *Journal Klimatology* **2016**, *5*, 11–20.
11. Suharjo, B.H. *Indonesian Forest and/or Land Fire Control* (in Indonesian language); IPB Press: Bogor, ID, 2016; ISBN 978-602-440-581-6.
12. Noerdjito, W.A.; Puji, A. *Animal Survey Method and Population Monitoring: The Fourth Series of Papilionidae Butterflies* (in Indonesian language); Pusat Penelitian dan Pengembangan Biologi-LIPI Cibinong: Bogor, ID, 2003; ISBN 979-579-048.
13. Magurran, A.E. *Ecological Diversity and Its Measurement*. Croom-Helm: London, UK, 2004; ISBN 069-108-485-8.
14. Krebs, C.J. *Ecological Methodology*, 2nd ed; Harper and Row Pub: New York, USA, 1989; ISBN 006-043-784-4.
15. Gabriel, K.R. The biplot graphic display of matrices with application to principal component analysis. *Biometrika* **1971**, *58*, 453–467, doi:10.2307/2334381.
16. Ruslan, H. *Butterfly Diversity* (in Indonesian language); LPU-UNAS: Jakarta, ID, 2015; ISBN 978-602-081-902-0.
17. Pandey, R.; Khadka, K.K.; Ghimire, A.; Jha, P.; Pathak, U. Elevational distribution of butterflies in the Himalayas: a case study from Langtang National Park, Nepal. *Journal of Mountain Science* **2017**, *14*, 1384–1390.
18. Rohman, F.; Efendi, L.; Andrini, L.R. *Butterfly Bioecology* (in Indonesian language); Universitas Negeri Malang: Malang, ID, 2019; ISBN 978-602-470-160-4.
19. Shalihah, A.; Gemi, P.; Cindy, R.; Rizkawati, V.; Anwar, Z.I. *Butterflies in Padjadjaran University Jatinangor* (in Indonesian language); Departemen Keilmuan Divisi Entomologi HIMBIO Unpad: Bandung, ID, 2012;

20. Scott, J.A. *Butterflies of North America: A Natural History and Fieldguide*; Stanford University Press: London, UK, 1986; ISBN 080-472-013-4.
21. Öztürk, M.; Hakeem, K.R.; Hanum, F.; Efe, R. *Climate Change Impacts on High-Altitude Ecosystems*; Springer International Publishing: Cham, Switzerland, 2016; ISBN 978-331-912-859-7.
22. Mustari, A.H.; Pramana, Y.; Nurlinda, R. Butterfly diversity in Bantimurung Bulusaraung National Park (in Indonesian language). *Jurnal Media Konservasi* **2013**, *18,* 63–68.
23. Sumi, N.; Lee, E.; Kim, H.; Choi, S.; Yi, H. The relationship of mean temperature and 9 collected butterfly species' wingspan as the response of global warming. *Journal of Ecology and Environment* **2021**, *45*, 1–8, doi:10.1186/s41610-021-00193-y.
24. Weiskopf, S.R.; Rubenstein, M.A.; Crozier, L.G.; Gaichas, S.; Griffis, R.; Halofsky, J.E.; Hyde, K.J.W.; Morelli, T.L.; Morisette, J.T.; Muñoz, R.C.; et al. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. *Science of The Total Environment* **2020**, *733*, 1–18, doi:10.1016/j.scitotenv.2020.137782.
25. Oktorina, P. Butterfly Diversity In Dramaga Research Forest and Its Development as A Tourism Object (in Indonesian language). Undergraduate Thesis, Institut Pertanian Bogor, Bogor, ID, 2017.
26. Ferrer-Paris, J.R.; Sanchez-Mercado, A.; Viloria, A.L.; Donaldson, J. Congruence and diversity of butterfly-host plant associations at higher taxonomic levels. *PloS One* **2013**, *8*, 1–15.
27. Despland, E.; Humire, R.; Martin, S.S. Species richness and phenology of butterflies along an altitude gradient in the desert of Northern Chile. *Arctic, Antarctic, and Alpine Research* **2012**, *44*, 423–431.
28. Koneri, R.; Nangoy, M.J.; Maabuat, P.V.; Saroyo; Wakhid. Diversity and composition of butterflies in three habitats around Rayow Waterfall, Minahasa District, North Sulawesi, Indonesia. *Journal of Biological Diversity* **2022**, *23*, 1091–1098.
29. Alarape, A.A.; Omifolaji, J.K.; Mwansat, G.S. Butterfly species diversity and abundance in University of Ibadan Botanical Garden, Nigeria. *Open J Ecol*. **2015**, *5*, 352–360.
30. 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.; et al. How butterflies keep their cool: Physical and ecological traits influence thermoregulatory ability and population trends. *Journal of Animal Ecology* **2020**, *89*, 2440–2450.
31. Alikodra, H.S. *Wild Animal Management* (in Indonesian language), 1st ed; Institut Pertanian Bogor: Bogor, ID, 2002; ISBN 979-933-707-9.
32. Panjaitan, R. Papilionide (lepidoptera) Superfamily Butterfly Community in Gunung Meja Natural Tourism Forest area, Manokwari, West Papua (in Indonesian language). Thesis, Institut Pertanian Bogor, Bogor, ID, 2011.
33. Dar, A.A.; Jamal, K.J.; Shah, M.S.; Ali, M.; Sayed, S.; Gaber, A.; Kesba, H.; Salah, M. Species richness, abundance, distributional pattern and trait composition of butterfly assemblage change along an altitudinal gradient in the Gulmarg region of Jammu & Kashmir, India. *Saudi Journal of Biological Sciences* **2022**, *29*, 2262–2269.
34. Pires, A.C.V.; Barbosa, M.; Beiroz, W.; Beirao, M.D.V.; Marini-Filho, O.J.; Duarte, M.; Mielke, O.H.H.; Ladeira, F.A.; Nunes, Y.R.F.; Negreiros, D.; et al. Altitudinal variation in butterfly community associated with climate and vegetation. *An. Acad. Bras. Ciênc.* **2020**, *92*, 1–13.
35. Jemal, A.; Getu, E. Diversity of butterfly communities at different altitudes of Menagesha-suba state forest, Ethiopia. *Journal of Entomology and Zoology Studies* **2018**, *6*, 2197–2202.
36. Popović, M.; Micevski, B.; Verovnik, R. Effects of elevation gradient and aspect on butterfly diversity on Galičica Mountain in the Republic of Macedonia (south–eastern Europe). *Animal Biodiversity and Conservation* **2021**, *44*, 67–79.
37. Artusi, S. New Study of Altitude and Butterfly Diversity Evaluation of butterfly diversity in La Hesperia and influence of altitude on diversity. 2014. Available online: https://digitalcollections.sit.edu/isp_collection/2017 (accessed on 15 December 2024).
38. Habel, J.C.; Ulrich, W.; Gros, P.; Teucher, M.; Schmitt, T. Butterfly species respond differently to climate warming and land use change in the northern Alps. *Science of the Total Environment* **2023**, *890*, 1–7, doi:10.1016/j.scitotenv.2023.164268.

39. Montejo-Kovacevich, G.; Martin, S.H.; Meier, J.I.; Bacquet, C.N.; Monllor, M.; Jiggins, C.D.; Nadeau, N.J. Microclimate buffering and thermal tolerance across elevations in a tropical butterfly. *J Exp Biol.* **2020**, *223*, 220426, doi:10.1101/2019.12.19.882357.
40. Lee, S.; Jeon, H.; Kim, M. Spatial distribution of butterflies in accordance with climate change in the Korean Peninsula. *Sustainability* **2020**, *12*, 1–18, doi:10.3390/su12051995.
41. Smetacek, P. The study of butterflies. *Resonance* **2000**, *5*, 8–14.
42. Stefanescu; Constantí; Peñuelas, J.; Filella, I. Effects of climatic change on the phenology of butterflies in the northwest Mediterranean Basin. *Global Change Biology* **2003**, *9*, 1494–1506.
43. Choi, S.W. The relationship between local distribution and abundance of butterflies and weather factors. *The Korean Journal of Ecology* **2003**, *26*, 199–202.
44. Saastamoinen, M.; Hanski, I. Genotypic and environmental effects on flight activity and oviposition in the Glanville fritillary butterfly. *The American Naturalist* **2008**, *171*, 701–712.
45. Al Baraj, D.H.; Ögür, E. The Effect of Global Warming on Migration of Butterflies. *Selcuk Journal of Agricultural and Food Sciences* **2022**, *36*, 79–82, doi:10.15316/sjafs.2022.082.
46. Ren, J.; Li, S.; He, M.; Zhang, Y. Butterfly Community Diversity in the Qinling Mountains. *Diversity* **2022**, *14*, 1–13, doi:10.3390/d14010027.