

Research Article

Butterflies' Diversity and Nectar Resource Use across Altitudinal Gradients in Cibodas Resort, Mount Gede Pangrango National Park

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ABSTRACT

Butterflies are an important insect group that play a crucial role in ecosystems as pollinators and bioindicators of environmental quality. This study aimed to analyse the diversity and habitat of butterflies at the Cibodas Resort in Mount Gede Pangrango National Park (TNGGP). The Visual Encounter Survey method was modified using the Time-Constrained Count method with diversity analysis using the Shannon-Wiener Index. Data on flowering plants directly utilised by butterflies as nectar sources were collected at Cidendeng Waterfall (1390 m asl), Telaga Biru (1500 m asl), Cibeureum Waterfall (1650 m asl), and Hot Springs (2150 m asl). The highest butterfly diversity was recorded at Telaga Biru ($H' = 3.22$), Cidendeng Waterfall ($H' = 3.02$), Cibeureum Waterfall ($H' = 3.00$), and the Hot Springs area ($H' = 1.36$). This study identified ten plant species as nectar sources for butterflies, including *Impatiens platypetala*, *Impatiens javensis*, *Medinilla* sp., *Ageratum* sp., *Bartlettina sordida*, *Mussaenda* sp., *Brugmansia* sp., *Cestrum* sp., *Schima wallichii*, and *Aristolochia* sp. Furthermore, protected butterfly species listed based on the Regulation of the Minister of Environment and Forestry Number P.20 / MENLHK / SET-JEN / KUM.1 / 6/2018 and CITES Appendix II, include *Troides helena* and *Troides cuneifera*, as well as several endemic species of Java, including *Elymnias ceryx*, *Zeuxidia dohrni*, and *Papilio arjuna gedeensis*. These findings underscore the importance of butterfly conservation efforts, including planting preferred nectar-rich plant species, to support biodiversity-based ecotourism management.

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INTRODUCTION

Butterflies are insects that play a vital role in the ecosystems. In addition to functioning as environmental bioindicators, several species have been reported to respond sensitively to heavy metal contamination, making them valuable organisms for monitoring environmental health (Pallottini et al. 2023). Their sensitivity to microclimatic changes, habitat degradation, and chemical pollutants makes butterflies one of the most reliable biological indicators for assessing ecosystem integrity. Butterflies' main ecological role is as natural pollinators, where pollen sticks to their bodies when they suck nectar and is then transferred to other flowers of the same plant species, facilitating pollination (Reddi & Bai 1984; Millah et al. 2023). Through this mechanism, butterflies contribute significantly to maintaining ecosystem balance and supporting sustainable plant regeneration, which ultimately enhances forest stability and resilience, particularly in tropical landscapes (Bonebrake et al. 2010).

Butterflies are an integral component of the food chain. They serve as prey for various organisms, including birds, reptiles, spiders, and predatory insects, thus supporting higher trophic levels. This ecological interaction aligns with the findings of Bintoro et al. (2022), who noted that one attraction of natural tourism, such as birdwatching, is observing birds feeding their young with insects or butterfly imagoes. Such predator-prey interactions enrich the natural experience of visitors and highlight the importance of butterflies in maintaining ecological processes. As indicators of biodiversity and contributors to landscape greening, butterflies represent one of the most important insect groups (Paramanandham et al. 2021).

In addition to their ecological significance, butterflies have high aesthetic, educational, and economic value. Their colourful wings and graceful flight patterns make them appealing for ecotourism, nature photography, and environmental education programmes. Moreover, butterflies are often cultivated for conservation breeding, research, and hobbyist collections, contributing to local economies (Wang et al. 2023). Butterflies and moths constitute the second largest order of fauna after Coleoptera (Suhaimi et al. 2017). Globally, there are approximately 18,000 butterfly species (Graça & Solis 2018; Dantas et al. 2021), of which approximately 90 % are found in tropical regions. This high concentration underscores the crucial role of tropical ecosystems in the conservation of butterflies worldwide.

Indonesia, known as one of the world's megadiverse countries, supports more than 2200 butterfly species distributed across a wide variety of habitats, ranging from coastal zones to montane forests (Peggie et al. 2025). One important region for studying butterfly biodiversity is the Cibodas Resort, which is located within the TNGGP. The area extends from the lower submontane zone to the higher montane regions, offering a wide gradient of environmental conditions and vegetation types that serve as potential habitats for diverse butterfly assemblages to thrive. Although this region has long been a focal point for ecological research, particularly on mammals, birds, amphibians, and plants, information on butterfly diversity at higher elevations remains relatively scarce (Ario et al. 2020).

Previous research indicates that butterfly diversity tends to decline with increasing altitude due to changes in temperature, humidity, vegetation structure, host plant availability, and food resource composition (Popović et al. 2020; Ginoga et al. 2024; Leksono et al. 2025). Altitudinal gradients also influence species turnover, with certain butterflies exhibiting unique adaptations to cooler and moister montane environments. Understanding how butterfly communities respond to elevation is crucial for designing effective conservation strategies, particularly in the context of climate change, which may shift species distributions.

Butterfly diversity patterns in montane ecosystems have traditionally been examined along elevational gradients, with altitude recognised as a primary driver of species distribution and community composition. However, protected mountain landscapes increasingly function as both conservation areas and tourism destinations, creating complex socio-ecological systems where natural gradients interact with anthropogenic disturbance. Despite this reality, few studies have simultaneously evaluated elevational effects and tourism pressure in shaping butterfly diversity and habitat characteristics. Moreover, most previous assessments have relied primarily on diversity indices, with limited attention to interaction-based or habitat-resource perspectives.

Gunung Gede Pangrango National Park (TNGGP) represents a dynamic montane ecosystem where ecological heterogeneity overlaps with varying levels of visitor intensity. However, the extent to which tourism-related disturbance modifies habitat quality, nectar resource availability, and butterfly-plant interaction patterns remains insufficiently understood. This gap is particularly relevant for biodiversity-based ecotourism management, where conservation and recreation objectives must be balanced.

Therefore, this study aims to analyse butterfly diversity and habitat characteristics in the Cibodas Resort area of TNGGP by integrating ecological drivers (elevation and floral resource availability) with anthropogenic factors (tourist presence and site function).

The results are expected to contribute not only to butterfly ecology in tropical mountain ecosystems but also to the development of evidence-based conservation and sustainable tourism strategies grounded in ecological network resilience and habitat resource management.

MATERIALS AND METHODS

Study Area

Research on butterfly species diversity at Cibodas Resort, TNGGP, was conducted from November 2024 to January 2025 in Cipanas District, Cianjur Regency, West Java, Indonesia. The Cibodas Resort covers an area of 1,750.81 ha. The research was conducted at four locations: Cidendeng Waterfall (1390 m asl), Telaga Biru (1500 m asl), Cibereum Waterfall (1650 m asl), and Hot Springs (2150 m asl). Site selection was based on the availability of water and flowers for butterflies (Figure 1).

Site selection was based on the availability of water and flowers for butterflies (Figure 2). Cidendeng Waterfall (ATCIW) is located quite close to the Cibodas Resort ticket booth, nestled between cliffs that make the area quite shady. It is not specifically stated how large the Cidendeng Waterfall is. Adjacent to the waterfall, a canopy trail winds past an education centre that often hosts interpretation programs for school-aged visitors. Meanwhile, Telaga Biru (TB) lies on HM16 of the Mount Gede Pangrango hiking trail; a rest stop directly in front of the lake makes it a favoured spot for visitors before they continue their journey (with an area of approximately 500 square meters). Unlike the open canopy surroundings of the lake, the trails and rest areas are densely vegetated. Cibereum Waterfall (ATCIB) stands out as one of the main tourist attractions at Cibodas Resort, with the area around it being very open and lacking tree canopy cover. Its size is not specified. The hot springs (AP), divided into rivers with hot and cold water, offer moderate to strong currents in the hot river and strong currents in the cold river (with an area of approximately 1 hectare). Vertical cliffs and open sky surround the hot springs' canopy, limiting sunlight from reaching the area in the morning until around 10:00-11:00, when the cliff cover remains effective in limiting sunlight.

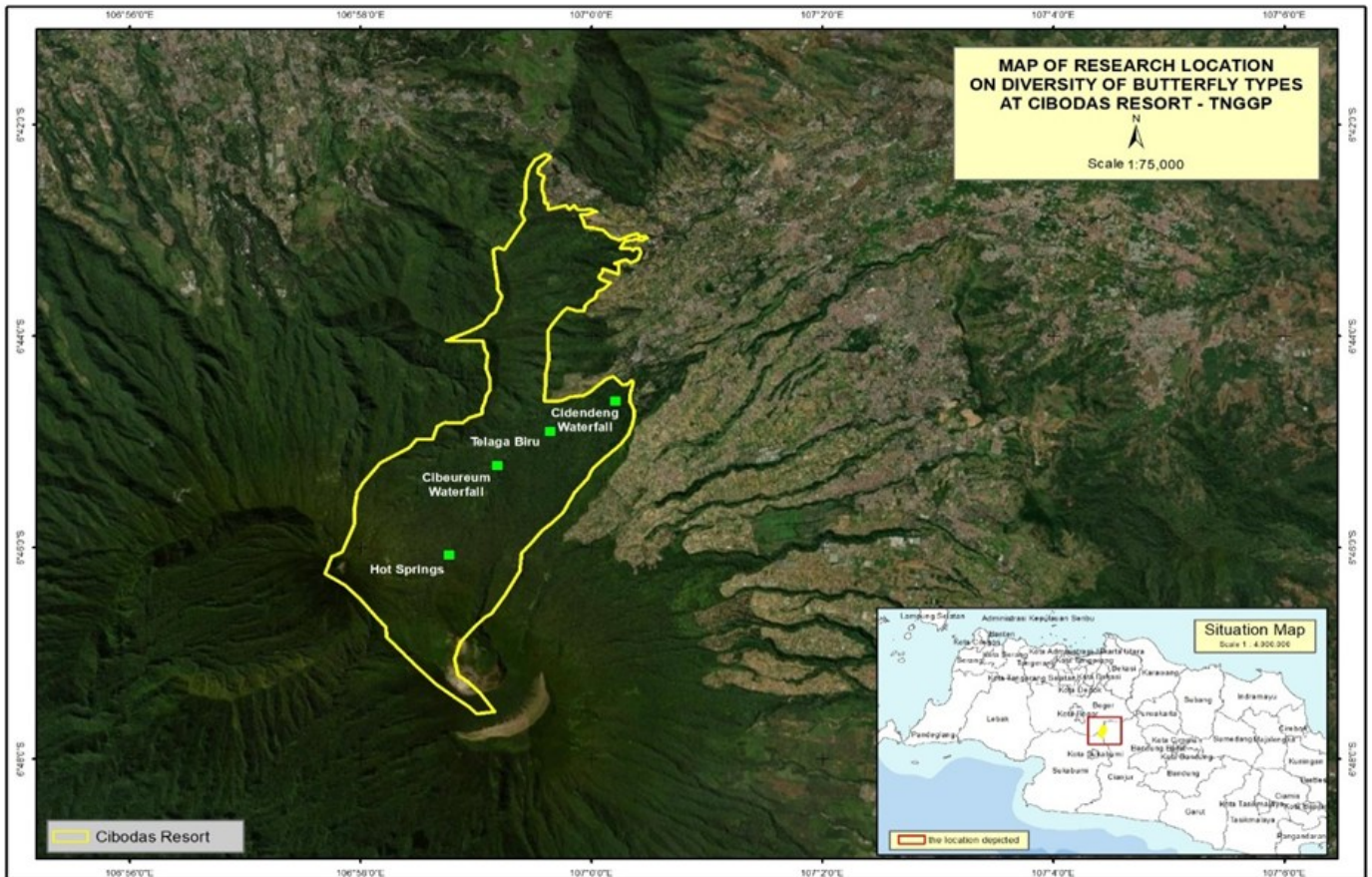


Figure 1. Map of Study Locations at the Cibodas Resort TNGGP.



Figure 2. The area around the sampling sites at various altitudes. A) Cidendeng Waterfall (ATCIW) 1390 m asl, B) Telaga Biru (TB) 1500 m asl, C) Cibereum Waterfall (ATCIB) 1650 m asl, D) Slopes around hot springs (AP) 2150 m asl.

Data Collection

Measuring butterfly diversity

The method used in this study was the Visual Encounter Survey (VES) method (Heyer et al. 1994) modified with the Time-Constrained Count method (Kadlec et al. 2011; Kral et al. 2018; Suman et al. 2021). Observations in each area were carried out along the existing climbing path with a length of 100 m from the edge of the area (waterfall, lake, and hot springs). Butterfly species were collected using catch-and-release with sweep nets. Sampling occurred from 08:00-11:00 AM and 01:00-04:00 PM at 60-minute intervals, during clear weather and sunlight. This timing allows butterflies to fly actively. If the weather is unfavourable, such as rain, butterfly data were not collected because, according to Prasetyo et al. (2017) butterfly wings will be heavy due to rainwater.

Butterfly habitat measurement

In this study, butterfly habitat was defined by the availability of flowering plants functioning as nectar resources. Observations of flowering plants were conducted concurrently with butterfly sampling at each study site. An opportunistic, non-plot-based approach recorded only plant species directly observed during butterfly nectar feeding, supplemented by secondary data. Vegetation density and structural parameters were not quantified, as the focus of the study was on trophic interaction patterns rather than plant community structure.

Each butterfly-plant interaction was documented and tabulated. Plant species were identified using Flora of Java (Steenis 2006), and verified through the PlantNet database. To examine interaction structure and resource connectivity, the dataset was analysed using ecological network analysis framework. Interactions represented link strength between butterflies and nectar plants. Network visualisation was performed using Tableau in the form of a Sankey diagram, illustrating directional flows from butterfly taxa to nectar plant species and subsequently to study sites. This visualisation enabled the identification of dominant nectar resources, highly connected species, and potential keystone interaction hubs within the system.

Data Analysis

Shannon-Wiener diversity

$$H' = -\sum \left(\frac{n_i}{N} \ln \frac{n_i}{N} \right)$$

The Shannon-Wiener Diversity Index is calculated based on the variables

n_i is the number of individuals of type i , N is the total number of individuals. An H' index value < 1 indicates low species diversity, a value of $1 - 3$ indicates moderate species diversity and a value > 3 indicates high diversity.

Evenness Index

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

The Evenness Index is calculated based on the variables H' , which is the Shannon-Wiener diversity index, and S is the number of species. A high E index value (approaching 1) indicates that individuals of each type are evenly distributed, while a low-density index value (approaching 0) indicates that a particular type dominates the community.

Dominance Index

$$D = \sum \left(\frac{n_i}{N} \right)^2$$

The dominance index is calculated based on the variables n_i is the number of individuals of type i , N is the number of individuals of all species. The dominance index value ranges from 0 to 1. A value of 0 means that the species is evenly present, while a value close to 1 means that there is a certain species that dominates the community.

Species richness

$$R_1 = \frac{S - 1}{\ln(N)}$$

Species richness is calculated based on the variables S , which is the total number of species observed, and N is the total number of individuals observed. The R_1 value < 3.5 indicates low species richness, R_1 3.5- 5.0 indicates moderate species richness, and $R_1 > 5.0$ indicates high.

Similarities of the Bray-Curtis Community

$$d_{jk} = 1 - \frac{\sum_i |x_{ji} - x_{ki}|}{\sum_i (x_{ji} + x_{ki})}$$

Bray-Curtis Community Similarity is calculated based on the variables x_{ji} is the number of i -th species in column j , x_{ki} is the Number of the i -th species in column k . The Bray-Curtis similarity index depicts the similarity of community structures between two types of habitats in the same ecosystem based on certain variables, such as species and abundance. The range of the Bray- Curtis index value is 0-1, if the index value tends to be close to 0, the similarity level of the community structure is low or has a higher difference in the community structure. Meanwhile, if the index value approaches 1, the similarity of the community structure is high or almost similar (Gupta et al. 2019).

RESULTS AND DISCUSSION

Diversity of butterfly

Based on the results of the observations, 58 butterfly species were recorded in this study. The family of butterflies found belonged to six families: Hesperiiidae (6 species), Lycaenidae (10 species), Nymphalidae (25 species), Papilionidae (8 species), Pieridae (7 species), and Riodinidae (2 species). The TB site recorded 39 species, while 33 butterfly species were recorded at the ATCIW and ATCIB sites. The AP location recorded only seven species, which is the lowest in this study. The data on the findings and documentation of the species are presented in Table 1.

Species and individual numbers are influenced by abiotic and biotic factors in each habitat. Vegetation structure at the four data collection locations tended to vary, resulting in fairly diverse butterfly species. According to Pires et al. (2020), Putri et al. (2023), and Mubarok et al. (2023), vegetation diversity in a habitat can provide a more diverse food source for butterflies, resulting in a greater number of butterfly species and individuals.

The diversity, evenness, dominance, and species richness indices of butterflies are presented in Figure 3. The highest Shannon diversity index was recorded at Telaga Biru (TB) ($H' = 3.22$), whereas the lowest value was observed at the Hot Springs site (AP) ($H' = 1.36$). The relatively high diversity

Table 1. Checklist of butterflies with number of individuals collected in each study sites.

No	Species	Study sites				
		ATCIW	TB	ATCIB	AP	total
I. Lepidoptera						
A. Hesperidae						
1	<i>Ancistroides nigrita</i>	2	1			3
2	<i>Coladenia cf. agni</i>	1	2			3
3	<i>Koruthaialos sindu</i>	1		1		2
4	<i>Notocrypta curvifasciata</i>	1	2			3
5	<i>Tagiades japedus</i>		1	2		3
6	<i>Telicota</i> sp.			1		1
B. Lycaenidae						
1	<i>Acytolepis puspa</i>		1			1
2	<i>Celastrina lavendularis</i>	4	1	1		6
3	<i>Heliophorus epicles</i>		3	4		7
4	<i>Prosotas nora</i>	1	2			3
5	<i>Rapala varuna</i>		1			1
6	<i>Udara akasa</i>	6	1	3		10
7	<i>Udara aristinus</i>				3	3
8	<i>Udara ceyx</i>				2	2
9	<i>Udara dilecta</i>	2	5	2	1	10
10	<i>Zeltus amasa</i>			1		1
C. Nymphalidae						
1	<i>Amnosia decora</i>	2	1	1		4
2	<i>Cupha erymanthis</i>	1				1
3	<i>Cynitia iapis</i>	1	2	1		4
4	<i>Cyrestis lutea*</i>	1	1	1		3
5	<i>Elymnias ceryx*</i>		2			2
6	<i>Euploea mulciber</i>			1		1
7	<i>Euploea radamanthus</i>	1	1			2
8	<i>Faunis canens</i>	3	10	4		17
9	<i>Hypolimnas bolina</i>	1	1	1		3
10	<i>Junonia iphita</i>		1			1
11	<i>Lethe confusa</i>	1	2			3
12	<i>Lethe minerva</i>	1				1
13	<i>Mycalesis sudra*</i>	1	2	3		6
14	<i>Neptis hylas</i>	1	1	1		3
15	<i>Nymphalis canacea</i>			3		3
16	<i>Pantoporia hordonia</i>		1			1
17	<i>Parantica albata*</i>		4	3	2	9
18	<i>Pseudocoladenia eacus</i>		1			1
19	<i>Ragadia makuta</i>			1		1
20	<i>Symbrenthia lillaea</i>		3	1		4
21	<i>Taenaris horsfieldi</i>	1				1
22	<i>Thaumantis odana</i>	1	2	1		4
23	<i>Vagrans sinha</i>	1				1
24	<i>Ypthima pandocus</i>		1	8		9
25	<i>Zeuxidia dohrni*</i>		1			1

Table 1. Contd.

No	Species	Study sites				total
		ATCIW	TB	ATCIB	AP	
D. Papilionidae						
1	<i>Graphium agamemnon</i>	1				1
2	<i>Graphium sarpedon</i>		1	2		3
3	<i>Losaria coon</i>			1		1
4	<i>Papilio arjuna gedeensis*</i>	1	5	5	2	13
5	<i>Papilio helenus</i>	2	2	3		7
6	<i>Papilio memnon</i>	1	1			2
7	<i>Troides cuneifera#</i>				1	1
8	<i>Troides helena#</i>	1	2	1		4
E. Pieridae						
1	<i>Delias belisama</i>	1	1	2		4
2	<i>Delias crithoe</i>		3	3		6
3	<i>Delias momea</i>			4	1	5
4	<i>Eurema blanda</i>	2	1	2		5
5	<i>Eurema cf. lacteola</i>	1		2		3
6	<i>Eurema hecabe</i>	1	4			5
7	<i>Leptosia nina</i>	1				1
F. Riodinidae						
1	<i>Taxila haquinus</i>	1				1
2	<i>Zemeros flegyas</i>		1	2		3
TOTAL						210

Note: AP (Hot Springs), ATCIB (Cibeureum Waterfall), ATCIW (Cidendeng Waterfall), TB (Telaga Biru). The asterisk '*' is an endemic species, while asterisk '#' is a protected species.

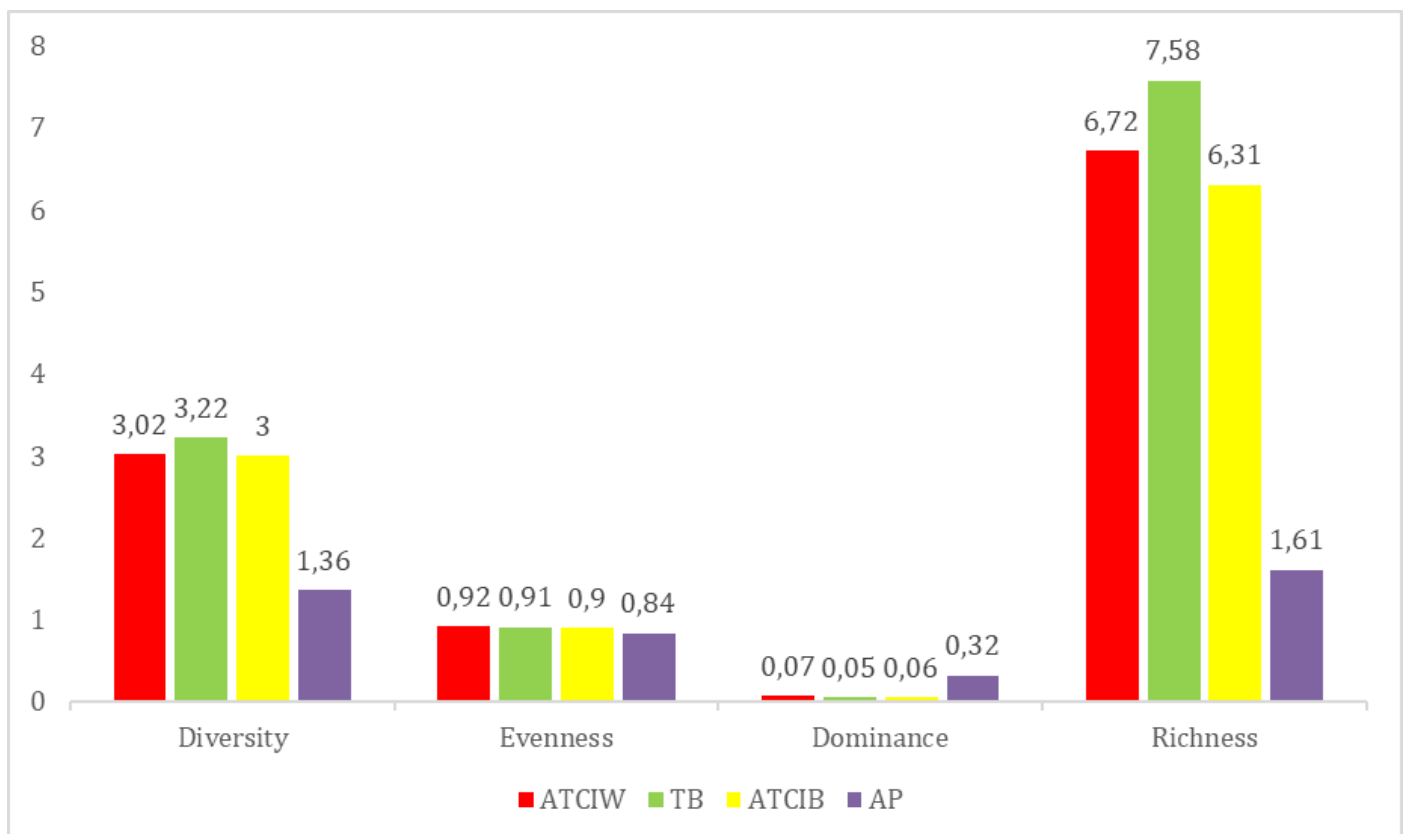


Figure 3. Diversity index, evenness, dominance and richness of butterfly species in four study locations. AP (Hot Springs), ATCIB (Cibeureum Waterfall), ATCIW (Cidendeng Waterfall), TB (Telaga Biru).

at TB may be attributed to its limited anthropogenic disturbance, as the site primarily functions as a temporary resting area for visitors on their route to Cibereum Waterfall. Reduced pressure maintains habitat quality and nectar, supporting diversity.

Conversely, the low diversity observed at AP may reflect the combined effects of intensive tourism activities and elevational differences. From a disturbance ecology perspective, high levels of anthropogenic activity can alter vegetation structure, reduce floral abundance, and disrupt butterfly foraging behaviour. Although moderate disturbance may enhance diversity, excessive tourism simplifies habitats and reduces richness. The observed pattern also aligns with the elevational diversity gradient theory, which predicts a decline in species diversity at higher elevations due to harsher abiotic conditions and reduced resource availability. Consistent with Aditya et al. (2024), butterfly diversity at 1700–1900 m asl ($H' = 2.39$) was lower than at 1500–1700 m asl ($H' = 2.56$), with the highest diversity recorded at 1300–1500 m asl ($H' = 2.63$). This trend suggests that mid-elevation zones may provide optimal microclimatic conditions and resource heterogeneity that support higher species coexistence.

Furthermore, vegetation diversity tends to decrease with increasing elevation, indirectly constraining butterfly diversity through reduced nectar and host plant availability. Putri et al. (2024) reported the highest number of vegetation species at 1500 m asl (16 species) and the lowest at 1900 m asl (13 species). Increasing environmental harshness—characterized by lower temperatures, higher humidity variability, and potentially stronger winds—limits plant growth and survival, thereby narrowing ecological niches available for butterflies. As butterflies are highly sensitive to microclimatic variation and resource distribution, elevational changes can significantly influence their distribution patterns and community structure. Overall, the interaction between anthropogenic disturbance and elevational gradients appears to play a critical role in shaping butterfly diversity patterns within the study area.

According to Dar et al. (2022), diversity indices showed that butterfly communities were more diverse at lower elevations and decreased significantly with increasing elevation. Overall, butterfly abundance and diversity were higher at lower elevations and gradually decreased towards higher elevations because floristic diversity, on which butterflies rely for survival and propagation, decreased. Low temperatures negatively influence the number of butterfly species (Molina-Martínez et al. 2013). Butterflies are heterothermic animals that require heat to regulate their body temperature and allow their wing muscles to function. Low environmental temperatures slow down the life cycle (metamorphosis), preventing new populations from emerging quickly. Furthermore, as temperatures drop, food availability also decreases.

The species evenness value at each location tended to approach 1, indicating that butterfly species were evenly distributed and that no particular species was dominant. This was confirmed by the dominance index values at each location, which were nearly zero. Only the AP location had a slightly higher value (0.32). The significant dominance value at the AP location was influenced by the presence of *Udara* sp., which was more frequently encountered than the other species. The butterfly species richness index values at the three locations tended to be high, with the highest values occurring at the TB location (7.58), followed by the ATCIW (6.72) and ATCIB (6.31) locations. The lowest species richness index was observed at AP (1.61). The high species richness index at the three locations corresponds to their habitat characteristics, located at elevations of approximately 1390–1650 m asl. According to Pires et al. (2020), butterfly richness and abundance decrease with altitude, and species composition changes with altitude.

Based on Figure 4, the Bray-Curtis similarity index divided the four locations into two clusters: ATCIW, which was similar to the ATCIB and TB

locations. The AP location had the lowest similarity to the other locations. Based on the Bray-Curtis similarity index, the first cluster consisted of ATCIB and TB, with a similarity value of 0.63. This reflects similar elevations and abiotic conditions. These two locations are quite close together; if a straight line is drawn on the map, the distance between the two locations is approximately 1 km. This condition may have caused the two locations to have similar butterfly communities. The ATCIW location tended to be similar to the ATCIB and TB locations compared to the AP location. The Bray-Curtis index value at the ATCIW location was greater than that at the TB location (0.56). This condition is related to the characteristics of the habitat, which has a canopy cover that tends to be closed, unlike the more open ATCIB; therefore, the ATCIW butterfly community is more similar to that of the TB location.

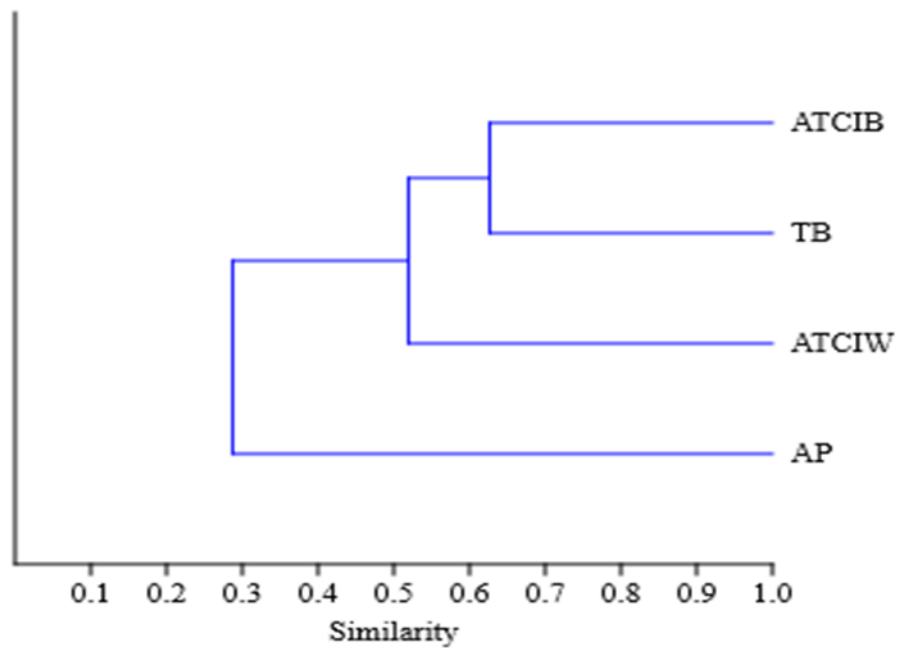


Figure 4. Bray-Curtis similarity index between study sites.

The second cluster, the AP location, was separated from the other three locations with a distance of 0.3. According to Gupta et al. (2019), the Bray-Curtis index range is 0-1. If the index value approaches 0, the level of community structure similarity is low, or there is a higher community structure difference. The AP location had a distinct butterfly community compared to the other three locations. This is related to the discovery of *Udara ceyx*, *Udara aristinus*, and *Troides cuneifera*, which were found only at the AP site. These three species were not found in the ATCIB, ATCIW, or TB sites. Information on *U. ceyx* and *U. aristinus* butterflies is still very limited, based on data from the citizen-science-based website, iNaturalist. The *U. ceyx* species was only found in four locations on the island of Java, whereas the *U. aristinus* species was not discovered. However, based on the location of the discovery, *U. ceyx* species can still be found at altitudes below 1500 m asl (Desertnaturalist 2022).

Butterfly Habitat

According to Subedi et al. (2021), flower attributes often influence the foraging choices of nectar-feeding butterflies, given the close relationship between plants and their pollinators. Based on the research results (Table 2), ten flowering plant species were used by butterflies to meet their nutritional needs

Table 2. List of flowering plants used by butterflies.

No	Family	Scientific Name	Survey Location			
			AP	ATCIB	ATCIW	TB
1	Asteraceae	<i>Ageratum</i> sp.		√	√	√
2	Asteraceae	<i>Bartlettina sordida</i>		√	√	√
3	Balsaminaceae	<i>Impatiens javensis</i>	√	√		√
4	Balsaminaceae	<i>Impatiens platypetala</i>	√	√	√	√
5	Melastomataceae	<i>Medinilla</i> sp.		√	√	
6	Rubiaceae	<i>Mussaenda</i> sp.			√	√
7	Solanaceae	<i>Brugmansia</i> sp.	√	√	√	√
8	Solanaceae	<i>Cestrum</i> sp.			√	
9	Theaceae	<i>Schima wallichii</i>	√	√	√	√
10	Aristolochiaceae	<i>Aristolochia</i> sp.	√	√	√	√

Note: AP (Hot Springs), ATCIB (Cibeureum Waterfall), ATCIW (Cidendeng Waterfall), TB (Telaga Biru).

through nectar feeding. These species include Asteraceae (2 species), Balsaminaceae (2 species), Melastomataceae (1 species), Rubiaceae (1 species), Solanaceae (2 species), Theaceae (1 species), and Aristolochiaceae (1 species). Several plants found as nectar plants for butterflies were also found by Hidayat and Kurniawati (2021) in plant exploration research at various altitudes, such as the Melastomataceae family at an altitude of 1377 m asl and Theaceae at an altitude of 1187 m asl.

Butterflies significantly preferred the flowers of herbaceous plants over woody plants, and tubular flowers over nontubular flowers (Subedi et al. 2021). Therefore, to conserve butterflies, a variety of flowers with various colour should be planted. Host plants that may be utilized by butterflies at the Cibodas Resort, especially for the Nymphalidae family, include those in the Melastomataceae and Rubiaceae families, namely Acanthaceae, Anacardiaceae, Euphorbiaceae, Leguminosae, Loranthaceae, Malvaceae, Melastomataceae, Moraceae, Annonaceae, Passifloraceae, Rubiaceae, Rutaceae, Sapindaceae, Tiliaceae and Aristolochiaceae. The Nymphalidae family was the most frequently observed during the study. According to Nurhayati et al. (2025) and Millah et al. (2023), this is because the Nymphalidae family is a polyphagous family, enabling them to survive even when their primary host plant is unavailable.

The TB site had the most flowering plants compared to the other locations. This pattern may be attributed to lower anthropogenic disturbance, as TB serves mainly as a transit corridor for visitors en route to Cibeureum Waterfall and the hot springs rather than as a primary tourism destination. Reduced human activity likely minimises trampling, vegetation alteration, and habitat modification, thereby maintaining floral resource availability and supporting butterfly habitat quality.

The butterfly species that utilise flowering plants are most numerous in the Hesperidae and Papilionidae families. Other families that utilise flowering plants including Lycaenidae, Nymphalidae, and Pieridae. Butterfly species that utilise flowering plants include *Notocrypta curvifasciata*, *Telicota* sp., *Papilio arjuna gedeensis*, *Papilio helenus*, and *Papilio* sp. Butterflies have been recorded utilising the flowers of *Impatiens* sp., *Mussaenda* sp., *Ageratum* sp., *Bartlettina sordida*, *Telicota* sp., *Brugmansia* sp., *Notocrypta curvifasciata* (Figure 5A), and *Medinilla* sp. (Figure 5B). However, according to Subedi et al. (2021), the abundance of Hesperidae was found to be significantly influenced by flower colour (with more butterflies observed on yellow than purple flowers) and flower type (with more butterflies observed on tubular than non-tubular flowers).

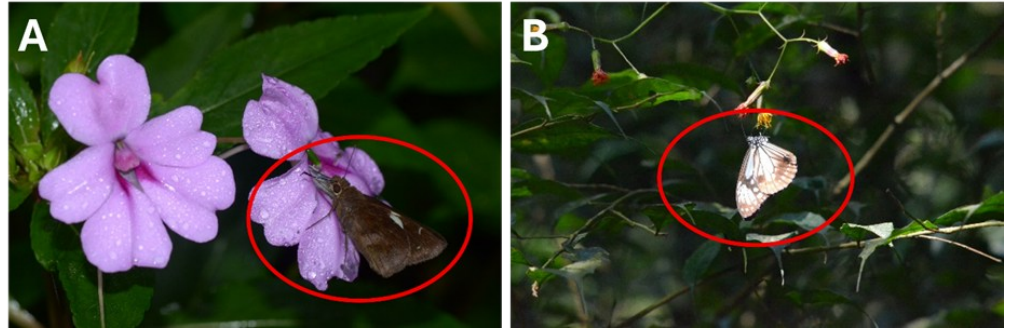


Figure 5. Butterflies feeding on nectar: (A) *Notocrypta curvifasciata* feeding on *Impatiens platypetala* flowers; (B) *Parantica albata* feeding on *Medinilla* sp.

The flowering plants of the species *Schima wallichii* are utilised by butterflies in the Nymphalidae family, namely *Delias momea* and *Delias crithoe*. Other Nymphalidae butterflies, such as *Zeuxidia dohrni*, utilize *Cestrum* sp. (Figure 6A). During the data collection, several species of butterflies were found which are species with limited distribution or endemic, and two species of butterflies were found which are included in the CITES Appendix II list (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and are protected based on the Regulation of the Minister of Environment and Forestry Number P.20 / MENLHK / SETJEN / KUM.1 / 6/2018 concerning protected plant and animal species. The types of butterflies included in the CITES Appendix II list include *Troides helena* and *Troides cuneifera*. *Troides helena* and *Troides cuneifera* are protected due to the increasing extinction of the Forest Betel (*Aristolochia* sp.), which is the primary food source and habitat for the larvae of these two butterflies. Forest Betel (*Aristolochia* sp.) is a climbing plant that often considered a weed by the community (Hamid et al. 2025).



Figure 6. Resource utilization by butterflies: (A) *Zeuxidia dohrni* utilizing *Cestrum* sp.; (B) *Papilio arjuna gedeensis* obtaining minerals through puddling on wet soil or shallow water.

Furthermore, the adult population of the Nymphalidae family depends not only on the availability of nectar from flowering plants (their nutritional source) but also on decaying plants, fruits, and animal urine. In addition to feeding on flowering plants, butterflies meet their mineral needs through mud puddling. During data collection, several butterfly species were observed engaging in mud-puddling activities, including *Cyrestis lutea*, *Faunis canens*, *Graphium sarpedon*, *Parantica albata*, *Thaumantis odana*, *Udara dilecta*, and *Papilio arjuna gedeensis*. Figure 6B *Papilio arjuna gedeensis* fulfils its mineral requirements through puddling behaviour by imbibing fluids from water puddles or moist soil to obtain essential inorganic nutrients, particularly sodium and other minerals.

To further elucidate the interaction patterns among butterflies, nectar and host plants, and study sites, these relationships were visualised using a

Sankey diagram (Figure 7). The diagram illustrates the three-level linkage between butterfly species, plant taxa, and survey locations, where the width of each flow represents the relative frequency of occurrence and interaction intensity.

The visualisation highlights several key resource plants, such as *Impatiens platypetala*, *Impatiens javensis*, and species within the genus *Aristolochia*, which connect multiple butterfly taxa across study sites. These plants function as central nodes within the ecological network, supporting both generalist and specialist species, including protected butterflies such as *Troides helena*, *Troides cuneifera*, and *Papilio arjuna gedeensis*.

Furthermore, the Sankey structure reveals spatial variation in interaction intensity among survey locations, indicating that certain microhabitats contribute disproportionately to butterfly resource availability. This pattern reinforces the importance of maintaining habitat heterogeneity, including nectar-rich flowering plants and mineral-rich puddling sites, as essential components of sustainable butterfly conservation strategies.

The information obtained in this study provides a crucial basis for effective and sustainable conservation efforts for butterflies and their preferred nectar plants. The presence of protected and endemic butterfly species, such as *Troides helena*, *Troides cuneifera*, and *Papilio arjuna gedeensis*, underscores the urgency of protecting the natural habitats of the Cibodas Resort of Mount Gede Pangrango National Park. Given that butterflies serve as sensitive bio-indicators of changes in environmental quality, the collected data on species diversity, habitat preferences, and host and nectar plant availability can be used as scientific instruments for periodic evaluation of ecosystem conditions.

Based on these findings, the formulation of more targeted conservation policies is needed, including the establishment of microhabitat protection zones rich in host plants such as *Impatiens platypetala*, *Impatiens javensis*, and *Medinilla* sp, as well as the planting of year-round flowering nectar-loving species such as *Lantana camara*, *Bidens pilosa*, *Clerodendrum japonicum*, and *Ixora javanica* and also the planting of climbing plants such as *Aristolochia* sp. from the Aristolochiaceae family to support the food needs of butterflies. These efforts need to be integrated with tourism activity regulations to avoid disturbing sensitive areas and involve the community and tourists in the par-

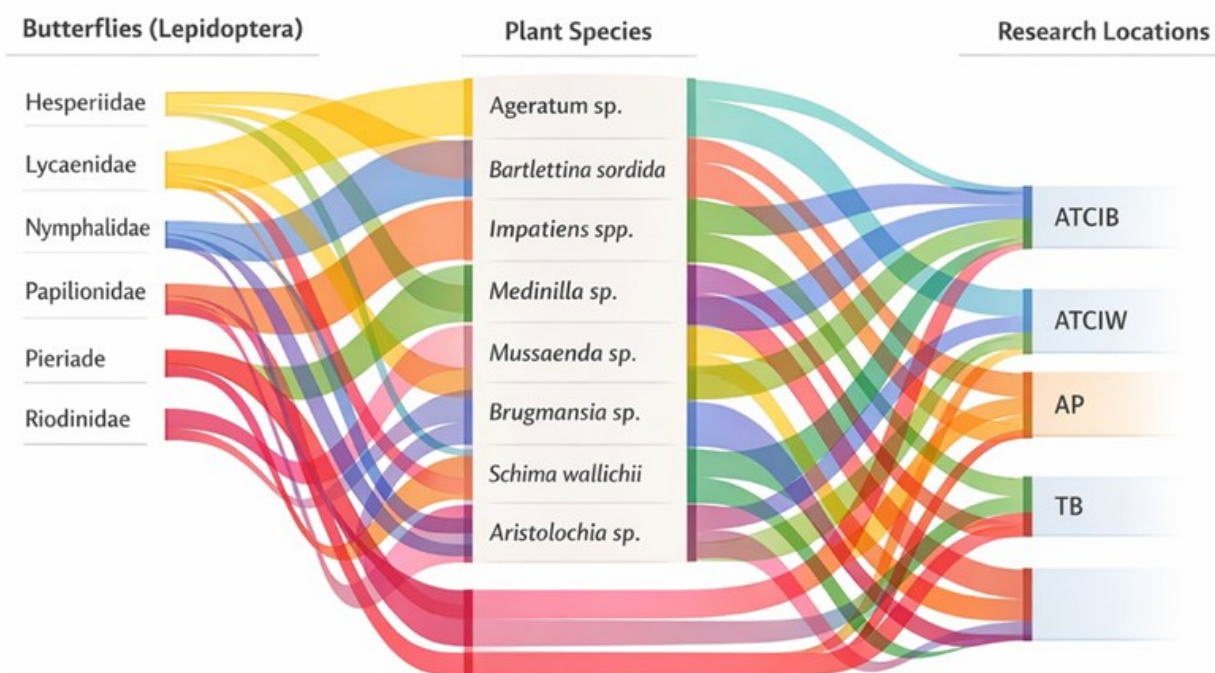


Figure 7. Sankey diagram among butterflies, host plants, and study sites.

ticipatory monitoring. Thus, butterfly conservation in this area will be not only ecological and adaptive but also sustainable and based on multi-stakeholder involvement to maintain the stability of the Mount Gede Pangrango National Park ecosystem.

CONCLUSION

Several plant species serve as primary nectar resources for diverse butterfly taxa, including *Impatiens* spp. (Balsaminaceae), *Brugmansia* sp. (Solanaceae), *Schima wallichii* (Theaceae), and *Aristolochia* sp. (Aristolochiaceae). These species function as shared resource nodes within the ecological interaction network, supporting multiple butterfly families such as Nymphalidae, Papilionidae, and Lycaenidae. Their role highlights the importance of maintaining plant–pollinator interaction integrity in sustaining butterfly community structure.

Network visualisation revealed that sites with higher flow connectivity exhibited greater interaction density and species richness. Telaga Biru (TB) showed a more complex butterfly–plant interaction network (39 species) compared to the Hot Springs site (AP), which displayed substantially lower interaction flow (7 species). This pattern indicates that habitat disturbance and site function significantly influence ecological connectivity and community resilience.

The occurrence of protected and endemic species such as *Troides helena*, *Troides cuneifera*, and *Papilio arjuna gedeensis*, listed under the Indonesian Ministry of Environment and Forestry Regulation No. P.20/MENLHK/SETJEN/KUM.1/6/2018 and Appendix II of CITES, further strengthens the conservation value of the study area. In particular, the preservation of the host plant *Aristolochia* sp. is critical for maintaining viable populations of these conservation-priority butterflies.

From a management perspective, conservation strategies should prioritise the protection and enrichment of key nectar and host plants, especially in areas subjected to intensive tourism activities. Incorporating ecological network-based indicators into habitat monitoring frameworks can enhance biodiversity-sensitive tourism management and support long-term ecosystem sustainability.

AUTHORS CONTRIBUTION

R.S.H: supervision, funding acquisition, conceptualisation, methodology, investigation, validation, reviewing and editing, data curation. R.R.H: resources, data curation, writing original draft preparation; S.I: conceptualisation, data curation, reviewing and editing.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in any part of this research.

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