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Abundance assessment of Sulawesi Banded Swallowtail, *Papilio gigon gigon* and availability of resource plants in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

TAUFIQ ISMAIL[1], RISMA ILLA MAULANY[2,♥], PUTU OKA NGAKAN[2]

[1]Bantimurung Bulusaraung National Park Office. Jl. Poros Maros-Bone Km. 12, Bantimurung, Maros 90561, South Sulawesi, Indonesia
[2]Department of Forest Conservation, Faculty of Forestry, Universitas Hasanuddin. Jl. Perintis Kemerdekaan KM. 10, Makassar 90245, South Sulawesi, Indonesia. Tel./fax.: +62-411-589592, ♥email: risma.maulany@unhas.ac.id

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Abstract. *Ismail T, Maulany RI, Ngakan PO. 2024. Abundance assessment of Sulawesi Banded Swallowtail* Papilio gigon gigon *and availability of resource plants in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia. Biodiversitas 25: 673-682.* The Sulawesi Banded Swallowtail (*Papilio gigon gigon* Felder & Felder, 1864) is an endemic butterfly species of Sulawesi, Indonesia currently under threat from hunting and trade activities and habitat degradation. This study aims to examine the abundance of *P. gigon gigon* and resource plants' availability and to analyze the relationship between resource host and nectar plant density with the abundance of the butterfly species in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia. Data were collected using the line transect method in two habitat types: settlement and forest located in three observation sites (Bantimurung, Leang-leang, and Pattunuang). The data were analyzed with *Spearman's* correlation test. The results showed a significant positive correlation in Bantimurung between the host plant densities ($r = 0.258$; $p = 0.010$) and nectar plants ($r = 0.211$; $p = 0.036$) with the abundance of *P. gigon gigon*. In Pattunuang, the host plants had indicated an insignificant correlation ($r = 0.061$; $p = 0.548$) with the abundance of *P. gigon gigon*, and in contrast, the nectar plants showed a significant positive correlation ($r = 0.487$; $p = 0.000$). Only in Leang-leang the correlation between the abundance of *P. gigon gigon* showed no significant correlation with both host ($r = 0.152$; $p = 0.132$) and nectar plants ($r = 0.041$; $p = 0.686$). Differences between the observation areas were suspected to be influenced by human activities such as tourism and hunting. Therefore, management interventions by the national park are required to support the conservation of *P. gigon gigon* in the area.

Keywords: Butterfly's abundance, correlation, host and nectar plants, hunting

INTRODUCTION

Sulawesi Island (Indonesia), as part of the Wallacea Region, has been recognized as a hotspot area of biodiversity with high endemism (Myers et al. 2000; Marchese 2015; von Rintelen et al. 2017). The island has become a home for 132 species of mammals with 63% are endemic with high endemism in rats (75.7%) and fruit bats (10.7%), 1,500 bird species with 35% endemic, twenty-five amphibian species, forty species of lizards, and 52 terrestrial species of snakes (Maryanto and Higashi 2011; Harris et al. 2014; Sloan et al. 2014). Order Lepidoptera's area supports 557 species with 40% endemicity (Koneri and Maabuat 2016; Koneri et al. 2019). As one of the insect's families, butterflies provide ecosystem services, particularly in assisting pollination for many plants. In addition, butterflies also serve as bio-indicators to detect changes in the environment, including plant communities, air quality, light conditions, and metal contamination, and to indicate the quality of habitat (Ismail et al. 2020; Legal et al. 2020; Chowdhury et al. 2023; Pallottini et al. 2023).

The occurrence of butterflies in nature depends on abiotic and biotic factors (Munyuli 2013). One abiotic factor affecting butterflies' richness is climate (Zellweger et al. 2016, 2017). The host plant is one of the biotic factors that are crucial to determining both richness and survivability of butterflies as it provides shelter (host plants) and acts as a food source (nectar plants) (Navarro-Cano et al. 2015; Zellweger et al. 2016). Butterflies are insects that undergo complete metamorphosis. In the caterpillar and imago phase, butterflies need food intake. According to Artusi (2014), butterfly diets are certain leaves of host plants for the caterpillar phase and nectar from flowers when they enter the imago phase. Therefore, host and nectar plants support the stability of the butterfly population in nature.

Moreover, of 557 species of 6 orders, 372 are classified as endemic to Sulawesi (Vane-Wright and de Jong 2003). Papilionidae has been indicated to possess the least number of endemic species (26 species), including Sulawesi Banded Swallowtail *Papilio gigon gigon* Felder & Felder, (1864) (Martin 2018). The *P. gigon gigon* is the only subspecies of *P. gigon* living on the island and Sangihe Islands (satellite islands near Sulawesi). Morphologically, the subspecies has been identified to have black wings expanded to a maximum of 13 cm with greenish-yellow shades forming a straight transverse line from the upper to the lower part of the wing. On the rear wing are extensions of wings resembling a tail (Handayani et al. 2018). Another subspecies, *P. gigon neriotes*, could only be found in Sangihe and Talaud Islands, while *P. gigon mangolinus* is endemic to Banggai

and Sulu Islands (Vane-Wright and de Jong 2003). The species was known to have limited distribution and low population size, leading them to higher risks of being vulnerable to extinction (Vane-Wright and de Jong 2003; Fortini et al. 2015; Manes et al. 2021). In Bogani Nani Wartabone National Park (North Sulawesi), the number of individuals of *P. gigon* spotted was only 86 individuals in four line transects established (Koneri et al. 2023).

The *P. gigon gigon* has not yet been protected both by the Indonesian government regulations and the International Union for Conservation of Nature (IUCN). Bantimurung Bulusaraung National Park in Maros (South Sulawesi) is known as the Kingdom of Butterfly (Handayani and Ismail 2019) and is also a habitat of *P. gigon gigon*. The *P. gigon gigon* in Bantimurung Bulusaraung National Park is also inseparable from threats such as hunting, trade, and forest degradation (Putri 2016b; Aminah et al. 2020). Until now, not many studies have been conducted regarding *P. gigon gigon*. There is an urgent need to conserve as many endemic species as possible, including *P. gigon gigon* in the area. However, specific research on the species is still very limited, including knowledge of its current abundance and the abundance of potential host and nectar plants of the *P. gigon gigon*. Therefore, to support butterfly conservation, a study was conducted to portray the abundance of *P. gigon gigon*, including the relationship between resource availability and the population's abundance in Bantimurung Bulusaraung National Park. The information would become a basis for designing conservation efforts for the species and future management of the national park.

MATERIALS AND METHODS

Study area

The research was conducted in Indonesia, in three sites of Bantimurung Bulusaraung National Park (South Sulawesi) Indonesia (Bantimurung, Leang-leang, and Pattunuang). The national park was situated between 119°34'17"-119°55'13" E and 4°42'49"-5°06'42" S (Figure 1). Administratively, the research sites were located in two sub-districts, Bantimurung and Simbang of Maros Regency. In Bantimurung, the transect was laid on the national park's utilization zone, intersecting with settlement areas, roads, river bodies, and the tourism area of Bantimurung Waterfall Nature Park. The tourism area had 248,000 people visiting annually in the last 5 years. The transects encompassed habitats such as riparian areas, secondary forests, and karst forests. Meanwhile, in both Leang-leang and Pattunuang, the transects were located in specific park zones. The transect in Leang-leang was located near a newly established highway, and the distance between the transect and the settlement is approximately 260 m. Secondary forests, gardens, and rain-fed paddy fields surround Leang-leang. The transect enacted in Pattunuang was positioned in the utilization zone with a more stable environment (Figure 2). The selected sites were locally known as the main habitats for butterflies. The average temperature in the area was 29°C, ranging between 22°-35°C, with an average rainfall of 347 mm/month and humidity between 60-82%. The rainy season usually occurs in October to March, while the dry season is between April to September each year. The data were collected from September 2022 to January 2023.

The three study sites surveyed have two habitats: Forest and settlement areas. All forested areas were situated in Bantimurung Bulusaraung National Park, dominated by karst forests. In Bantimurung, the forest habitat was located between 119°68'56" 98 E and 5°01'58" 99 S at the latitude of 117 m above sea level (asl), while the settlement areas were between 119°67'89" 18 E and 5°02'06" 06 S with the elevation of 15 m above sea level.

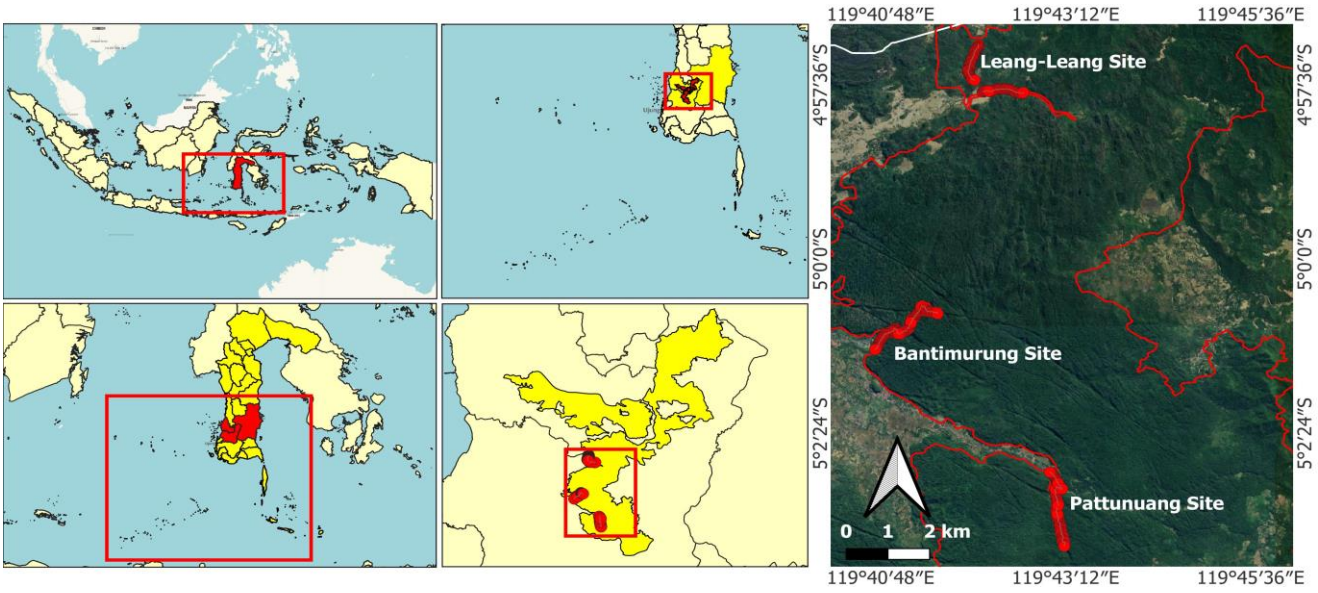

Figure 1. The study area and the three study sites, i.e. Bantimurung, Leang-Leang, and Pattunuang in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

The observation sites in Leang-leang geographically at 119°71'79" 67 E and 5°05'70" 30 S (elevation: 56 m asl) for forest habitat and settlement area were between 119°71'65" 68 E and 5°04'88" 53 S (elevation: 159 m asl). Meanwhile, for Pattunuang, the first location was between 119°71'79" 52 E and 5°05'69" 68 S at 118 m asl (forest habitat), and the second location was between 119°71'66" 01 E and 5°04'88" 48 S at 63 m asl (settlement area).

Data collection and analysis

Vegetation survey

In each study site, two purposive sampling transects of each habitat were established to collect data on host and nectar plants. The diversity and abundance of both plants associated with *P. gigon gigon* were recorded in 1 kilometer transect at each site (Koneri et al. 2023). In each transect, 50 observation plots of 20x20 meters were employed. Thus, there were 100 plots in each study site observed from morning to afternoon. The observation transect area of each research location is 4 ha. For each plot, data on species, life form, and number of individuals of plants used as host and nectar sources by *P. gigon gigon* were noted, including the coordinates of plant location. Host plants required by the species for all life stages were identified based on the results of literature studies and then surveyed at the study site. Nectar plants were identified based on field observations. Further identification by collecting samples of dry specimens (herbarium) was carried out in the Forest Conservation and Ecotourism Laboratory of Faculty Forestry, Hasanuddin University.

Population survey

Furthermore, to portray the population conditions of *P. gigon gigon*, surveys in the six predetermined transects divided into 9 replicates were carried out (Pollard and Yates 1993; UKBMS 2022; Koneri et al. 2023). The observations of individuals were made by speed walking over the transects in the morning (between 9:00-11:00 am) and afternoon (between 2:00-4:00 pm). When individuals of *P. gigon gigon* were spotted, time of occurrence, number of individuals, type of habitats (forests or settlement), and coordinates were counted. Any eggs, caterpillars, or pupae found during the survey were also noted. In addition, any butterfly hunting activities were also observed and recorded. Random interviews with butterfly hunters encountered along the observation transect were also conducted.

Data analysis

The data obtained from the field were tabulated using Microsoft Excel to determine the average, density, abundance, and frequency. The correlation between host plants and nectar plants to *P. gigon gigon* populations was analyzed using Spearman's correlation analysis with R software version 4.1.2. A Spearman's correlation was run to determine the correlation between host plant density and nectar to *P. gigon gigon*'s abundance in Bantimurung Bulusaraung National Park.

RESULTS AND DISCUSSION

Species diversity and density of host and nectar plants

In the three observation sites, 6 species of host plants of *P. gigon gigon* butterflies were found; these were *Melicope lunu-ankenda, Citrus maxima, Citrus sinensis, Citrus limon, Citrus aurantifolia,* and *Micromelum minutum* (Table 1). All six host plants are members of the Rutaceae family. All 6 species were found in Bantimurung, 2 species were found in Leang-leang, and 4 species were found in Pattunuang. The *M. lunu-ankenda* and *C. aurantifolia* were found in all locations, while *C. sinensis* and *C. limon* could only be found in Bantimurung.

Although number of host species was highest at Bantimurung, the overall density of host plants at that site was the lowest (5.5 individuals/ha). In contrast, the Leang-leang site had the highest total density (49 individuals/ha) despite having the fewest species. The *M. lunu-ankenda* was the species with the highest density at Leang-leang (48.5 individuals/ha). In line with its density, *M. lunu-ankenda* also has a high-frequency value (74%), indicating an even distribution.

There were 10 species identified as nectar plants of *P. gigon gigon* in the six observation transects spread across the three locations (Table 2). The number of nectar plant species found in Bantimurung was 6; in Leang-leang, there are as many as 4 species, and Pattunuang has 9 species. The highest total density was located in Leang-leang (85.75 individuals per ha). The species with the highest density was *Chromolaena odonata* (48.5 individuals/ha) in Leang-leang, with a frequency of 14%, indicating that the species was evenly distributed in clusters. This is in contrast to *Lantana camara*, which had a lower density (33.47 individuals/ha) but a frequency of 44%, indicating this species is evenly distributed.

The nectar plant species found in all three observation sites was *Lantana camara*. *Chromolaena odonata* was only spotted in Pattunuang and Leang-leang. *Pavetta makassarica* was only found in Leang-leang, while *Pseuderanthemum* sp. can only be seen in Pattunuang. Most of the flowers of nectar plants hade attractive and bright colors with a deep corolla. In addition, most of the nectar plants found had cylindrical flowers (6 species). Some of the activities of *P. gigon gigon* sucking flower nectar and mud puddling were captured and illustrated in Figure 3.

Abundance and occurrence of *P. gigon gigon*

Based on the survey established in the three study area sites, the number of individuals found per ha in the three surveyed areas was relatively similar (Table 3). The number of individuals found varied from 1.79 to 2.42 per ha (Table 3). The density of *P. gigon gigon* per ha was relatively similar between Bantimurung and Pattunuang but higher in Leang-leang. The abundance of *P. gigon gigon* individuals was around 2 individuals/ha in the three sites (9%).

In projecting the presence of *P. gigon gigon* in the study areas, the number of individuals encountered was monitored for 9 days and compared between morning and

afternoon (Table 4). The results show that most individuals of *P. gigon gigon* were active in the morning and higher individuals could be observed in all sites. Lesser individuals were seen during the afternoon time. However, a higher average number of individuals encountered was found in Leang-leang (19 individuals) at both times compared to Bantimurung (14 individuals) and Pattunuang (16 individuals).

Table 1. Host plant species of *Papilio gigon gigon* in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

Scientific Name	Local Name	D (Individuals/ha)	F (%)	Habitat Type	Life Form
Bantimurung					
Melicope lunu-ankenda (Gaertn.) T.G.Hartley	*Tallu raung*/euodia	1.5	2	S	Tree
Citrus maxima (Burm.) Merr.	*Jeruk bali*/pomelo	1.5	5	S; F	Tree
Citrus sinensis (Mill.) Pers., 1806	*Jeruk manis*/ sweet orange	1	2	S; F	Tree
Micromelum minutum (G.Forst.) Wight & Arn.	*Lada-lada*/red-lime berry	0.75	1	S	Shrubs
Citrus aurantifolia (Christm.) Swingle	*Jeruk nipis*/orange	0.5	1	S	Shrubs
Citrus limon (L.) Osbeck	Lemon	0.25	1	S	Shrubs
Total		5.5	12		
Leang-leang					
Melicope lunu-ankenda (Gaertn.) T.G.Hartley	*Tallu raung*/euodia	48.5	74	S; F	Tree
Citrus aurantifolia (Christm.) Swingle	*Jeruk nipis*/orange	0.5	1	S; F	Shrubs
Total		49	75		
Pattunuang					
Micromelum minutum (G.Forst.) Wight & Arn.	*Lada-lada*/red lime berry	9.75	3	S	Shrubs
Citrus maxima (Burm.) Merr.	*Jeruk bali*/pomelo	3.75	10	S; F	Tree
Melicope lunu-ankenda (Gaertn.) T.G.Hartley	*Tallu raung*/euodia	1.25	1	S	Tree
Citrus aurantifolia (Christm.) Swingle	*Jeruk nipis*/orange	0.75	3	S	Shrubs
Total		15.5	17		

Note: D: Density, F: Frequency, S: Settlement, F: Forest

Table 2. Nectar plants of *Papilio gigon gigon* in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

Scientific name	Local/english name	D (ind./ha)	F (%)	Habitat type	Life form	Flower colour	Flower Type
Bantimurung							
Clerodendrum paniculatum L.	Pagoda flower	16	17	S	Shrub	Red	Cylindrical
Hibiscus rosa-sinensis L.	Chinese hibiscus	8.5	11	S; F	Shrub	Red	Campanulate
Ixora chinensis Lam.	Asoka flower	6.25	5	S	Shrub	Red, yellow	Cylindrical
Donax canniformis (G.Forst.) K.Schum.	Common donax	6	3	F	Shrub	White	Cylindrical
Lantana camara L.	Hedge flower	3.5	5	S	Shrub	Red-orange' pink-yellow	Cylindrical
Coffea canephora Pierre ex A.Froehner	Robusta coffee	0.5	3	F	Shrub	White	Funnelform
Total		40.75					
Leang-leang							
Chromolaena odorata (L.) R.M.King & H.Rob.	Siam weed	48.5	14	S	Shrub	White	Head
Lantana camara L.	Hedge flower	33.75	44	S; F	Shrub	Red-orange' pink-yellow	Cylindrical
Syzigium aqueum (Burm.fil.) Alston	Cherry water	3.25	6	F	Tree	White	Cylindrical
Pavetta makassarica Bremek.	Kaleleng lulu	0.25	1	S	Tree	White	Salverform
Total		85.75					
Pattunuang							
Pseuderanthemum sp.	*Bunga ballung-ballung*	7	3	F	Shrub	White	Cylindrical
Ixora chinensis Lam.	Asoka flower	6.5	7	S	Shrub	Red, yellow	Cylindrical
Clerodendrum paniculatum L.	Pagoda flower	6.25	2	S	Shrub	Red	Cylindrical
Hibiscus rosa-sinensis L.	Chinese hibiscus	5	5	S	Shrub	Red	Campanulate
Coffea canephora Pierre ex A.Froehner	Robusta coffee	3.75	10	S; F	Shrub	White	Funnelform
Donax canniformis (G.Forst.) K.Schum.	Common donax	2.75	2	F	Shrub	White	Cylindrycal
Chromolaena odorata (L.) R.M.King & H.Rob.	Siam weed	2.25	3	S	Shrub	White	Head
Lantana camara L.	Hedge flower	1.5	3	S	Shrub	Red-orange' pink-yellow	Cylindrical
Syzigium aqueum (Burm.fil.) Alston	Cherry water	1.5	6	S; F	Tree	White	Cylindrical
Total		36.5					

Note: D: Density, F: Frequency, S: Settlement, F: Forest, M: Morning, A: Afternoon

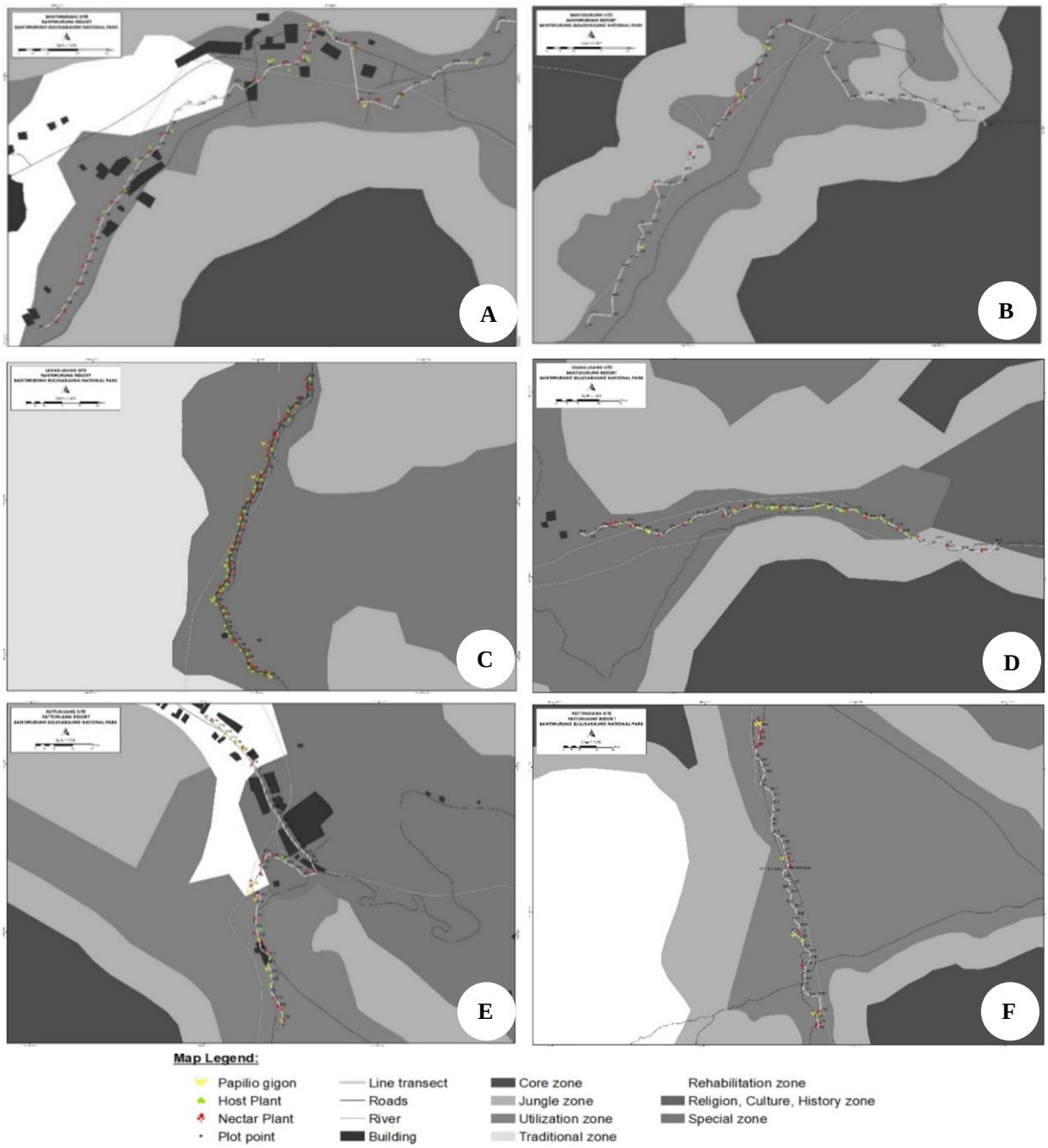

Figure 2. Map of transects and plot distributions in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia: A. Settlement areas of Bantimurung, B. Forest areas of Bantimurung, C. Settlement areas of Leang-leang, D. Forest areas of Leang-leang, E. Settlement areas of Pattunuang, F. Forest areas of Pattunuang

Butterfly hunting activities

Therefore, to record any threats faced by *P. gigon gigon* in Bantimurung Bulusaraung National Park, any hunting activities seen in the study sites for 9 observation days were noted (Table 5). The number of hunters in each site was also identified with the presence of hunters each day. The results indicated that in all study sites, hunting activities were present with 11 hunters (Table 5). The highest number of hunters was found in Leang-leang (5 hunters) with 100% frequency of hunter presences in the observation days. Meanwhile, Bantimurung had 4 hunters with only 44.4% of days with the presence of hunters. Pattunuang was found to have only 2 hunters detected, with 33.33% of observation days with hunters around.

Correlation between abundance of *P. gigon gigon* with associated plant species

It was revealed that host plants and nectar generally correlated in different sites (Table 6). The analysis results in Bantimurung showed a significant positive relationship between both host plants ($r = 0.258$; $p = 0.010$) and nectar plants ($r = 0.211$; $p = 0.036$) on *P. gigon gigon* abundance. In Leang-leang, however, there was an insignificant positive relationship between the host and nectar plants

(p>0.05). In Pattunuang, it was shown that only nectar plants (r = 487; p = 0.000) had a significant positive relationship with *P. gigon gigon*. *P. gigon* abundance and nectar plant density (r = 0.211; p = 0.036) to *P. gigon gigon* abundance. In contrast, at Leang-leang, each host and nectar plant (p>0.05) showed an insignificant positive correlation to *P. gigon gigon* abundance. Meanwhile, in Pattunuang, the results of Spearman's correlation analysis showed a significant correlation only between nectar plants and *P. gigon gigon* abundance (r = 0.487; p = 0.000), while between host plant density and *P. gigon gigon* abundance showed no significant correlation (p = 0.548).

Discussion

During the study, the study found *P. gigon gigon*, in the three different sites (Bantimurung, Leang-leang, and Pattunuang) of Bantimurung Bulusaraung National Park. It was revealed that there was a total of 6 host plant species (*M. lunu-ankenda*, *C. maxima*, *C. sinensis*, *C. aurantifolia*, *C. limon*, and *M. minutum*) and 10 nectar plant species (*Clerodendrum paniculatum*, *Hibiscus rosa-sinensis*, *Ixora chinensis*, *Donax canniformis*, *L. camara*, *Coffea canephora*, *C. odorata*, *Syzigium aqueum*, *P. makassarica*, *Pseuderanthemum* sp.). Host plants in Bantimurung (6 species) and Patunuang (4 species) were more diverse than in Leang-leang (2 species). This was also similar to the nectar plants, where in Bantimurung and Pattunuang, the number of species was higher than in Leang-leang. The *P. gigon gigon* has been known to utilize some plants of the Rutacea family, such as *Melicope* sp. *Citrus* spp. *Glycosmis* sp. and *M. minutum* as host plants (Handayani et al. 2018). The *P. gigon gigon* is an oligophagous species that uses several numbers of host plants within a single family (Muto-Fujita et al. 2017). This study also shows that *P. gigon gigon* is more abundant in the morning (Table 4). Some other researchers have also reported that butterflies are found more in the morning (Najah et al. 2023). This can be because most plants experience anthesis and produce nectar in the morning, so butterflies use the morning more than the afternoon to find food (Fowler et al. 2016; Schwarz et al. 2021). Butterflies are generally more active in sucking nectar, sunbathing, and reproducing in the morning (Vlašánek et al. 2018) and tend to rest more in the afternoon (Finkbeiner 2014).

Table 3. Abundance and Frequency of Papilio gigon gigon in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia (4 ha)

Sites	Abundance (individuals per ha)	Frequency (%)
Bantimurung	1.79	8
Leang-leang	2.42	9
Pattunuang	1.97	8

Table 4. Comparison of *Papilio gigon gigon* occurrences between morning and afternoon periods in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia (M: Morning, A: Afternoon)

Sites	Number encountered during observation days (individuals)																		Average (individuals)	
	1		2		3		4		5		6		7		8		9			
	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A	M	A
Bantimurung	10	7	10	6	4	5	7	5	6	5	6	6	7	7	11	10	10	7	8	6
Leang-leang	11	10	8	6	17	12	8	7	17	8	13	15	17	4	7	7	2	5	11	8
Pattunuang	13	12	11	9	10	5	7	6	4	4	9	6	9	5	7	9	8	8	9	7

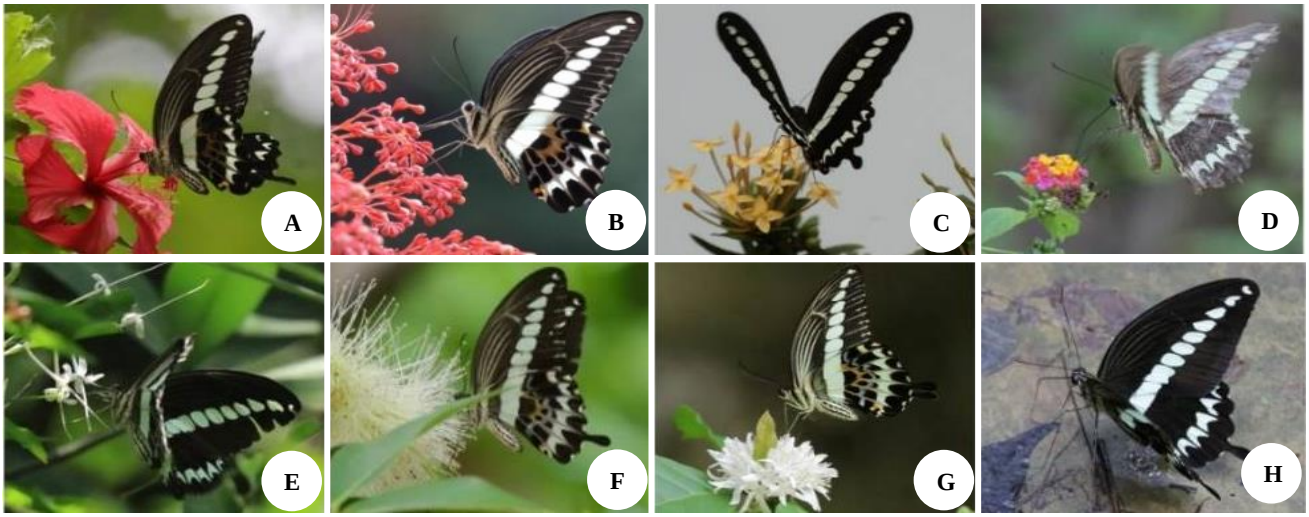

Figure 3. *Papilio gigon gigon* visited several nectar plants and mud puddling in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia: A. *Hibiscus rosa-sinensis*, B. *Clerodendrum paniculatum*, C. *Ixora chinenis*, D. *Lantana camara*, E. *Pavetta makassarica*, F. *Syzigium aqueum*, G. *Coffea canephora*, and H. Mineral sucking

Table 5. Butterfly hunting activities in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

Butterfly hunters	Observation days								
	1	2	3	4	5	6	7	8	9
Bantimurung									
Hunter A		√	√						
Hunter B		√							
Hunter C					√				
Hunter D							√		
Leang-leang									
Hunter E	√	√	√						
Hunter F	√	√	√						
Hunter C			√						
Hunter G				√	√	√	√	√	√
Hunter H								√	
Pattunuang									
Hunter I		√			√				
Hunter J				√					

Note: √: present

Table 6. Spearman's correlation analysis between host and nectar plant densities on the abundance of *P. gigon gigon* in Bantimurung Bulusaraung National Park, South Sulawesi, Indonesia

Variables observed	Abundance of *P. gigon gigon*	
	r	*p*
Bantimurung		
Host plant	0.258**	**0.010**
Nectar plant	0.211*	**0.036**
Leang-leang		
Host plant	0.152	0.132
Nectar plant	0.041	0.686
Pattunuang		
Host plant	0.061	0.548
Nectar plant	0.487**	**0.000**

Note: **: Correlation is significant at the 0.01 level, *: Correlation is significant at the 0.05 level

Even so, in terms of quantity, the number of host plants in Leang-leang (48.75 individuals/ha) was more abundant than in the other two locations. The quality of habitat was highly determined by variation in abundance between populations of a species (Tam and Bonebrake 2016; Mukherjee and Mondal 2020), which was related to the availability of food resources (Wix et al. 2019; Nursia et al. 2022). Host plant quantity could also be crucial in setting inter-site variation in population abundance, particularly for species with dietary and habitat specialists (Nidup et al. 2014; Curtis et al. 2015). Compared to the other two study sites, the host plant density of *P. gigon gigon* in Bantimurung is the lowest. In line with this, the imago population in Bantimurung was also the lowest compared to that found in the other two study sites. The results of the correlation analysis, however, showed a significant positive correlation between host plant density and *P. gigon gigon* abundance and between nectar plant density and *P. gigon gigon* abundance. This finding indicates that if the density of host and nectar plants in Bantimurung can be increased, the abundance of *P. gigon gigon* imago will also increase, considering that hosts and nectar are the basic needs of butterflies in the caterpillar and imago phases (Ariyani et al. 2018).

The low density of host and nectar plants in Bantimurung could be caused by tourism development in the tourism areas. This development has made part of the land surface covered with cement or papping blocks, which resulted in insufficient space for host plants and nectar to grow. In addition, the construction of tourist facilities by closing seepage areas, especially on sandy riverbanks, causes *P. gigon gigon* imago to lose places to obtain minerals. Putri (2016a) was also of the same opinion that developing tourist facilities and infrastructure in Bantimurung has led to the degradation of butterfly habitats.

In contrast to Bantimurung, the density of host and nectar plants in Leang-leang showed the highest value compared to other study sites. The abundance of *P. gigon gigon* at this study site was also the highest. Still, the correlation analysis did not significantly correlate between host plant density and nectar plant density on the abundance of *P. gigon gigon*. The results of this study indicated that an increase in the density of host plants and nectar plants in Leang-leang was not followed by an increase in the abundance of *P. gigon gigon*. However, other findings from this study may explain the possibility of other factors causing the absence of a correlation between the density of host plants and nectar plants and the abundance of *P. gigon gigon* butterflies in Leang-Leang. Another factor referred to was the intensive hunting activity of butterflies in the study site. Muhammadiyah (2014) also revealed that the abundance of butterflies in Bantimurung Bulusaraung National Park decreased with high hunting activity in the national park.

The high level of butterfly hunting activity in Leang-leang was suspected to be due to a lack of supervision from national park officials. Compared to Bantimurung and Pattunuang, which are tourist areas, where national park officers are always on duty, Leang-leang had no officers on duty during data collection. Butterfly hunting activities in Leang-leang were found inside the Bantimurung Bulusaraung National Park area, unlike Muhammadiyah (2014), who stated that butterfly hunting only occurs outside the national park area.

In Pattunuang, host plant density and abundance of *P. gigon* showed a positive but insignificant correlation. Compared to Bantimurung, data from Pattunuang show that the density of host plants for *P. gigon gigon* is higher, but the abundance of its imago is almost the same. This is the cause of the insignificant correlation between host plant density and *P. gigon gigon* abundance in Pattunuang. The lack of imago abundance that is not proportional to the density of host plants may be due to parasites, chrysalis predators or hunters. Unlike in Leang-leang, where hunters were brave enough to capture the imago openly, hunters in Pattunuang took the chrysalis (*pupae*) only so they were easy to hide and undetected by the officers. Nectar plant density in Pattunuang was the lowest compared to other study sites. Consistent with this, the abundance of *P. gigon*

was also low. Therefore, the correlation between nectar plant density and *P. gigon gigon* population showed a significant positive. Hence, it can be assumed that if nectar plant density increases, the abundance of *P. gigon gigon* can increase.

Host plants play an important role in the life cycle of *P. gigon gigon*. During the study, females of the species were found laying eggs on *C. sinensis* in Bantimurung and *M. lunu-ankenda* in Leang-leang. Three Genera of Rutacea (*Citrus, Melicope*, and *Glycosmis*) were identified as host plants in all life stages of *P. gigon gigon* (Igarashi and Fukuda 1997; Vane-Wright and de Jong 2003). Not only that, larvae were found on both plants. Especially in *C. sinensis*, this butterfly's prepupae and chrysalis phases were found.

The nectar plants found in Leang-leang are *C. odorata* and *L. camara*. The *L. camara* and *C. odorata* were found in almost all research locations. These plants are wild, like fairly open areas with shrub habitus, and both were found at the highest level in residential habitats. It grows in clusters along the highway that divides the national park area. The *C. odorata* and *L. camara* are invasive plants (Rindyastuti et al. 2021); the presence of invasive species in a habitat influences species interaction patterns, especially in pollination and threats to native plants (Negi et al. 2019; Poland et al. 2021). Even so, *L. camara* and *C. odorata* are nectar plants for several butterflies, especially from Heseperidae, Nymphalidae, and Papilionidae families, as well as some of the Pieridae and Lycanidae butterflies (Shihan and Kabir 2015; Negi et al. 2019).

Although host and nectar plants were abundant in Leang-leang, the relationship between host and nectar plant densities towards the abundance of the *P. gigon gigon* have shown differences. It was assumed that this was due to a high level of butterfly hunting activity in Leang-leang as shown by the frequencies of hunting activities during the observation days. Direct hunting and harvesting of butterflies occurred in the buffer zone of Bantimurung Bulusaraung National Park (Muhammadiyah 2014) to meet the demands of visitors for souvenirs and handicrafts (Putri 2016b; Ansari et al. 2019). Therefore, tourism development indirectly has also affected butterfly habitats and populations by limiting the abundance of food plants and disturbing the butterfly's home range. This aligns with the findings of Putri (2016b) that the construction of tourist facilities and infrastructure and tourist activities disturb the comfort and habitat of butterflies.

The intensity of butterfly hunting and number of hunters in Leang-leang was higher than in other sites. During field data collection, butterfly hunters, including *P. gigon gigon*, were encountered daily. There are no butterfly hunting regulations outside the Bantimurung Bulusaraung National Park area regarding restrictions on butterfly catchers, seasons, numbers, and butterfly species that can be caught, especially unprotected endemic species that have the potential for overexploitation (Muhammadiyah 2014; Putri 2016b). In addition, the high intensity of butterfly hunting occurred in forest areas of Leang-leang was also due to a lack of supervision from national park officials. Unlike Bantimurung and Pattunuang, which are tourist areas, the attendance of national park officers on duty can not be seen every weekday in Leang-leang. Apart from the trade, the lack of regulations for catching butterflies outside conservation areas also became an issue (Putri 2016a). Bonebrake et al. (2010) also reported that butterflies from the Papilionidae family, which have large sizes with beautiful patterns, like *P. gigon gigon*, are collectors' main targets, which might cause their populations to decline and threaten the species. Therefore, hunting and trading in this national park area needs more attention from the management. To preserve the butterflies in Leang-leang, national park officers must carry out forest protection and security efforts to control butterfly hunting activities in this location.

The *P. gigon gigon* has specific flower preferences to meet its nectar needs. Arnold (2016) mentioned that butterflies prefer nectar with a high amino acid content. They select flowers based on nectar composition. Subedi et al. (2021) stated that the depth of the flower corolla and the length of the butterfly's proboscis affect the preference of the visited flowers. The *P. gigon gigon* prefers cylindrical flowers (tubes). The *P. gigon gigon* is a subspecies and belongs to the Papilionidae family. Rusman et al. (2016) and Subedi et al. (2021) found that butterflies of the Papilionidae and Hesperidae family more often visit flowers that have tubular crowns. The *P. gigon gigon* frequently visits some nectar plants with deep corollas, such as cylindrical (tube) and salverform forms such as *L. camara*, *I. chinensis*, and *C. paniculatum*. Rusman et al. (2016) mentioned that butterflies from the Papilionidae family mostly prefer tube crown flowers. Some studies state that a butterfly's level of preference for plant nectar is influenced by the amino acid content, the depth of the flower corolla, and the butterfly's body size. In addition, during field observations, *P. gigon gigon* was also recorded visiting the flowers of *Phaleria capitata* and *Clerodendrum thomsonae*, but it was located out of the observation transect.

In the future, habitat development is also needed to increase the population of *P. gigon gigon* in Bantimurung and Pattunuang. Habitat development can be done by planting both host plants and nectar plants. Curtis et al. (2015) state that host plants and butterfly population abundance are closely related. Recommended host plants include *M. lunu-ankenda* in forested habitats; in settlement habitats, it is *C. sinensis* and *M. minutum*. Recommended nectar plants include *H. rosa-sinensis* and *C. paniculatum* to be planted in settlement habitat, while for forest habitat, *S. aqueum*, *Pseuderantheum sp*. and *D. canniformis*.

The availability of host and nectar plants is not the only determinant of the size of the population of a butterfly species. In Bantimurung Bulusaraung National Park, the results reveal that human activities near their habitats can impact the low abundance of *P. gigon gigon* (imago). The existence of butterfly hunters in Leang-leang has influenced the population of the species in the area and in addition, tourism activities in Bantimurung area have indirectly inhabited the availability and abundance of host and nectar plants. Although the two sites had potential number of host and nectar plants which were showed by

high diversity and abundance of resource plants. Therefore, management interventions such as zoning to regulate human activities, habitat restoration by planting local resource plants for butterflies, in particular for settlement areas, law enforcement, and community awareness through conservation education are required to support butterfly conservation. Furthermore, to fulfill the demand for butterfly stocks for souvenirs and crafts, it is important to encourage nearby communities to establish small-scale butterfly breeding that reduces hunting activities in the area.

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