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Research Article

Diversity of Butterfly in The Segenter Waterfall Eco-Tourism Area, Lombok Island Forest Park, Indonesia

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ABSTRACT

Segenter Waterfall (SWF) is one of the ecotourism spots in the Nuraksa Forest Park, Lombok, Indonesia that requires conservation efforts to be optimally and sustainably utilised. This necessitates data related to the synecology of important ecosystem components, namely butterflies. Butterflies play an important role in pollinating plants for ecosystem sustainability. This research aims to analyse the diversity of Lepidoptera suborder Rhopalocera at SWF. The research was conducted during January-June 2024 using direct survey techniques with sweeping net. Sampling locations included the downstream watercourse, around the SWF, and the upstream watercourse. The collected data consisted of species richness and the number of individuals per butterfly species. The data obtained were analysed using the Shannon-Wiener diversity index, Evenness index, and Simpson's dominance index. During the observations, we found a total of 24 butterfly species represented by 5 families. The total number of specimens successfully collected was 84 individuals, *with Jamides celeno* being the most predominant species. The ecological index analysis results showed that H' = 3.115, E = 0.980, and C = 0.047. This indicated that the diversity of Lepidoptera from the suborder Rhopalocera is considered high. SWF has important value for the community as a source of clean water, tourist destination, conservation centre, cultural ritual site, and environmental education facility. This needs to be maintained so that the SWF area can become a sustainable ecotourism area.

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INTRODUCTION

Segenter Waterfall (SWF) is one of the spots in the Nuraksa Forest Park area. Administratively, this area is located in Kumbi village, Narmada subdistrict, West Lombok regency (DISLHK 2018). Ecologically, the environmental conditions at SWF allow it to support insect life such as butterflies. Natural conditions that are still sustainable have been used as tourist attractions on the island of Lombok, Indonesia. Therefore, Segenter Waterfall has the potential to be used as an ecotourism spot (Rahayu & Hidayah 2018; Putri et al. 2020). Apart from the natural conditions that are still relatively natural with clear water and beautiful views, Segenter Waterfall also has facilities and infrastructure such as changing rooms, information boards, photo spots and stairs and the location can be accessed using two-wheeled and four-wheeled vehicles. Ecological processes must be managed with good conservation management for the SWF area to be used sustainably as a tourist spot.

Conservation of the area's ecological processes means taking concrete actions to preserve important ecological components. One of these components is Lepidoptera from the suborder Rhopalocera Conservation. Butterfly conservation is important because this group of insects has an important role for humans. Efforts to conserve ecological processes in this area include concrete actions to maintain important components of the ecosystem. One component that plays an important role is the Lepidoptera insects of the Rhopalocera suborder. Butterfly conservation has significant value because these insects provide great benefits to humans. Ecologically, butterflies contribute to maintaining ecosystem balance through their herbivory activities, both at the larval and adult stages (Knerl & Bowers 2013; Soule et al. 2020), which support the flow of energy and matter from producers to insect consumer. In terms of tourism, butterflies are rich in colour variations and can make them an object of ecotourism (Jensen & Langergaard 2020; Lemelin & Jaramillo-López 2020; Benjamin et al. 2021). As one of the ecotourism spots, SWF has an interest in the preservation of butterflies. Butterfly conservation efforts focus on protecting various species and their habitats, which are essential for biodiversity. By implementing habitat restoration initiatives, SWF can enhance the natural environments that support butterfly populations, ensuring their survival and promoting species diversity. Although in the larval phase it can be detrimental because it uses cultivated plants as a source of nutrition (Bhat et al. 2020), but in the imago phase it acts as a pollinator (Cutter et al. 2022). This causes the butterfly to have a mutually beneficial interaction with its host plant. In addition to this role, butterflies can also be used as bioindicators of environmental conditions (Miller III et al. 2011; Ismail et al. 2020; Legal et al. 2020; Pacheco et al. 2021). This can be used to monitor environmental health in SWF, especially parts that become tourist attractions.

The data needed so that conservation efforts can be carried out optimally are species richness and population size estimation of each species. However, until now, the management does not have data related to the Lepidoptera suborder Rhopalocera community in SWF, both from observations by the authorities and from non-area management researchers. Given the potential for habitat disturbance by physical development activities and tourists, which can have a negative impact on the butterfly community (Mecenero et al. 2015), scientific investigations are urgently needed. Therefore, we conducted a study in SWF to analyse the diversity of Lepidoptera suborder Rhopalocera. Some benefits of the research results include: (1) having a better database of the formulation and implementation for better conservation management, (2) adding to the repertoire of aspects of scientific products, especially regarding the diversity of Lepidoptera suborder Rhopalocera and (3) adding references for further research, especially those related to with the diversity of Lepidoptera suborder Rhopalocera in SWF.

MATERIALS AND METHODS

Study site

This research utilizes some tools such as hand nets to collect the specimens; the specimens are stored in clear zip-lock plastic bags with size 18 x 29 cm. In further identification the specimen needs to be preserved, we used 70 % alcohol as a preserver (Marquina et al. 2021). The location of this research is in the great forest area of Lombok Island (Figure 1).

Methods

This research was conducted at SWF (Figure 1) during the interval from January to June 2024, with 12 repetitions. The field survey was carried out on a transect line which was divided into three points, namely the water flow to the downstream area, the waterfall and the water flow to the upstream area. The search for butterflies focused on the various microhabitat SWF found at these three points. This microhabitat includes areas with flowering plants, standing water around watersheds, litter and rocks. Identification of was carried out in the Biology Laboratory at Mataram University refers to the key books of determination from Peggie and Amir (2006) and Wahyuni (2015), as well as several research articles on butterflies in several locations on the island of Lombok, especially the results of research in Pusuk and Senaru, Lombok Forest Park, and Nuraksa Forest Park (Matsumoto et al. 2012; Ilhamdi et al. 2023; Ilhamdi et al. 2024).

The species richness data and the number of individuals of each species were then analysed using the Shanon-Wiener diversity index with formula $H' = -\sum p_i \ln p_i$, the Eveness evenness index with formula $E = H'/lnS$ and the

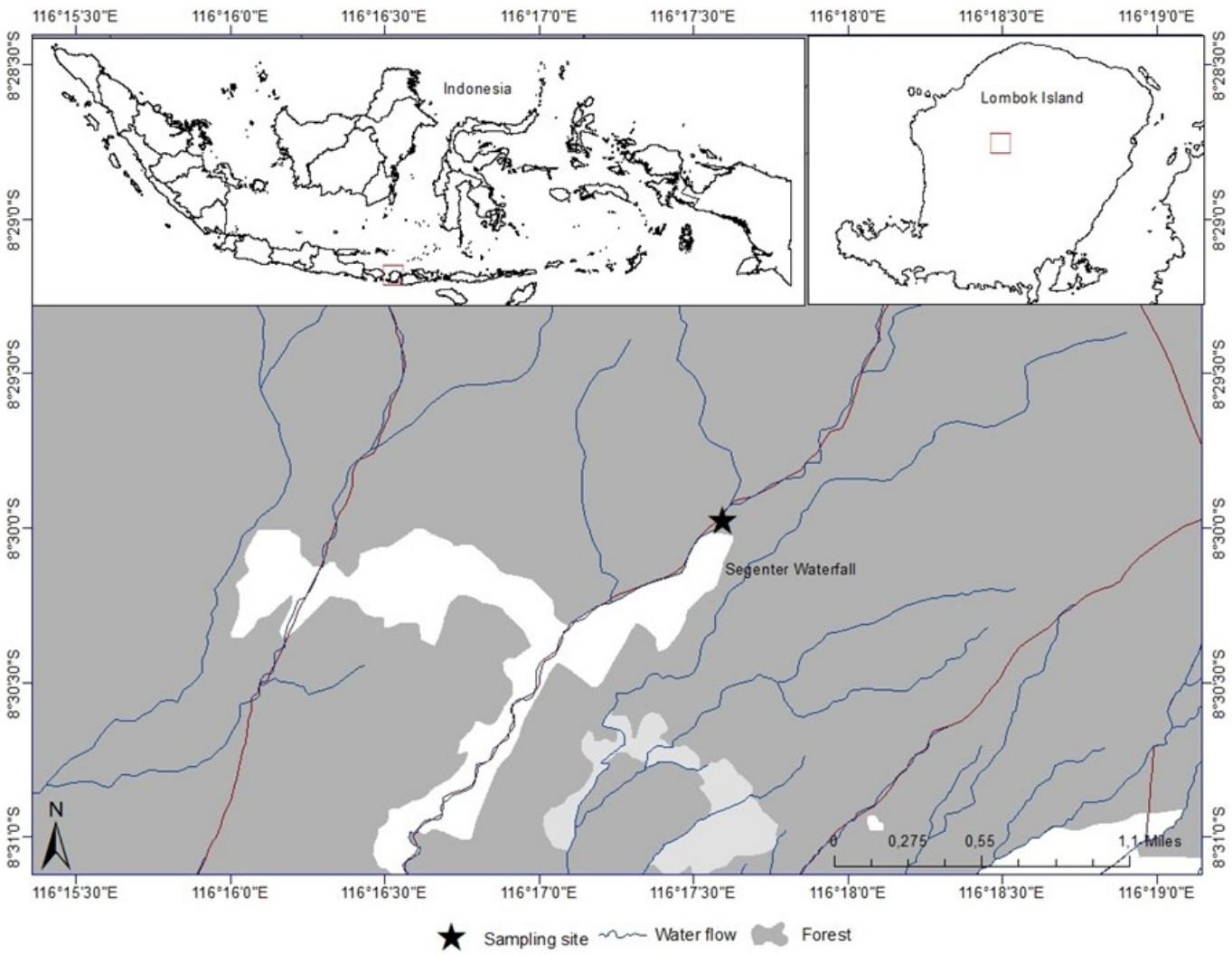

Figure 1. Map of Segenter Waterfall Eco-Tourism Area, Lombok Island Forest Park, Indonesia.

Simpson dominance index with formula $C = \sum(p_i)^2$. Where H' is Shanon-Wiener diversity index, p_i is the ratio of the number of individuals of species i to the total number of individuals of all species, E is evenness index, S is number of species, and C is Simpson dominance index.

RESULTS AND DISCUSSION

Species composition

The butterfly species found in SWF consist of 5 families, namely Hesperiidae, Pieridae, Papilionidae, Nymphalidae and Lycaenidae. The family Nymphalidae, with a total of 38 specimens, was the most abundant taxon, while the taxon with the lowest abundance was the family Hesperidae (Figure 2). This is a general finding reported from the results of studies in several other areas on the islands of Lombok and Wallace. In Sesaot, West Lombok, 4 families of butterflies have been reported, namely Papilionidae, Nympha lidae, Pieridae and Lycanidae, and the most abundant family is Nymphalidae (Hapsari et al. 2022). In the Kembang Kuning Protected Forest, East Lombok, 4 families were found similar to those reported in Sesaot, Nimphalidae being the predominant family with a total of 326 individuals (Sumiati et al. 2018). In Suranadi Tourism Park, located in Narmada sub-district, West Lombok, the families found are the same as the findings from this study, and the Nymphalidae family is the most abundant taxon, with a proportion of 45 % (Ilhamdi et al. 2018). On Talaud Island, North Sulawesi, the Nymphalidae family has an abundance percentage of 41.27 % while other families range from 0.20-29.46 % (Koneri et al. 2019). Similarly, those found on Sangihe Island (Koneri & Nangoy 2019) and in North Minahasa (Koneri et al. 2020).

Figure 2 shows that the taxon with the highest species richness is the family Nymphalidae (11 species), while the taxon with the lowest species representation is the families Hesperiidae and Lycaenidae (2 species each). The predominance of the Nymphalidae family in terms of species richness and abundance is due to its high adaptability to physical, chemical and biological environmental conditions. This is evidenced by the highest species richness of Nymphalidae compared to other families around the world. On the other hand, the species belonging to the taxon family are cosmopolitan. Nymphalidae can be easily found all year round / regardless of the season because of their generalist nature (Ghosh & Saha 2019). Although it has a tendency to host plants such as Asteraceae, Annonaceae, Fabaceae, and Poaceae (Peggie & Amir 2006), the Nymphalidae community can use other plants as a source of nutrition. So that if there is no host plant in their environment, they can sur-

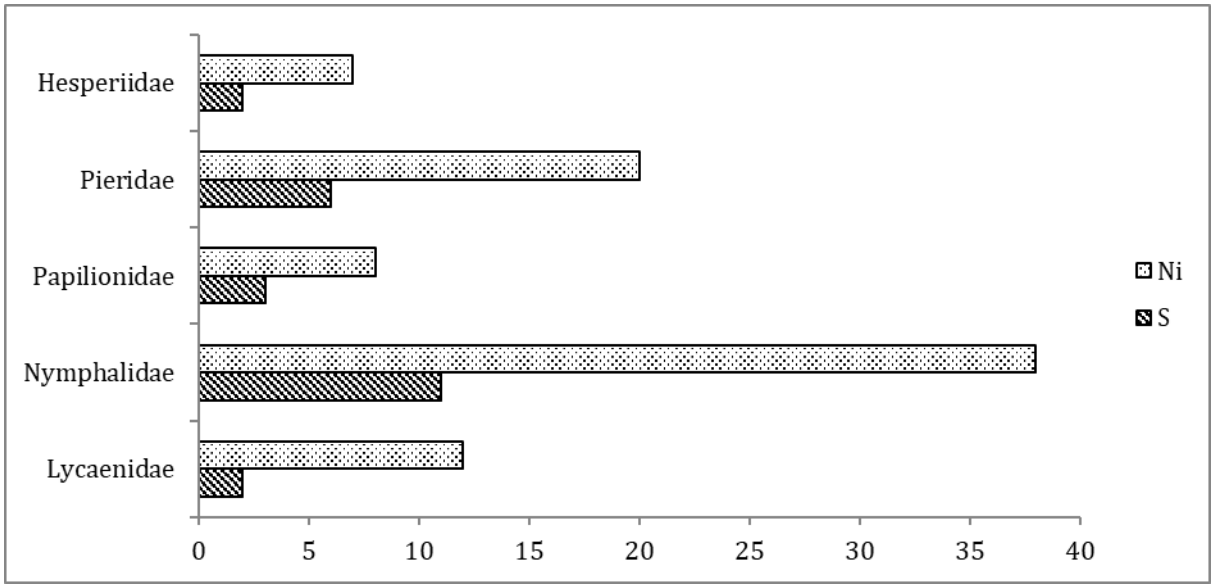

Figure 2. Comparison of species richness (S) and abundance (Ni) of each family.

vive by utilising other available feed sources. Several other species of this family not only depend on flower nectar, but can also utilise the energy and nutrients stored in rotting fruit and urine of other animals (Sarma et al. 2013).

When they are viewed from the taxon, the most dominant family is Nymphalidae and the most dominant species is Jamides celeno from the Lycaenidae family. If it is viewed from the taxon of the most predominant family, it is Nymphalidae, then viewed from the taxon of the most predominant species is *Jamides celeno*, then from the family is Lycaenidae. The total specimens were 7 individuals, while the other species only ranged from 2–5 individuals (Table 1).

One advantage of this species is that its morphometry is relatively smaller when compared to other butterfly species found in SWF. This makes it have better adaptability to the availability of feed resources because it does not need an abundant amount to meet its nutritional needs. The availability of natural food in the habitat itself has a direct impact on the population size of the butterfly species (Curtis et al. 2015). The more feed available, the higher the species abundance. The *J. celeno* species also has a variety of host plans (Cleary & Grill 2004), so it will have no problem finding sources of nutrients. During observations in the SWF, the activity of many *J. celeno* was sucking nectar on the understorey which was abundantly available along the left and right of the SWF, namely *Eupatorium odoratum*. In addition to these advantages, *J. celeno* also has a good survival strategy as a form of response to biotic factors that threaten him. These strategies include: (1) *J. celeno* forms mutually beneficial interactions with ants on the host plant and (2) the larvae can camouflage against the substrate and hide behind the leaves of the host plant (Eastwood et al. 2005). This strategy provides the advantage of being difficult to detect by predators.

Table 1. Species composition of Lepidoptera suborder Rhopalocera in SWF.

No	Famili	English Name	Spesies	Ni (individu)
1	Lycaenidae	Common Cerulean	*Jamides celeno* (Cramer, 1775)	7
2	Lycaenidae	Australian Leafwing	*Doleschallia bisaltide*	5
3	Nymphalidae	Chocolate Argus	*Junonia hedonia*	4
4	Nymphalidae	Common Evening Brown	*Melanitis leda*	5
5	Nymphalidae	Horsfield's Bushbrown	*Mycalesis horsfieldii*	4
6	Nymphalidae	Suffused Snow Flat	*Tagiades gana*	2
7	Nymphalidae	Common Sailer	*Neptis hylas*	6
8	Nymphalidae	Gray Glassy Tiger	*Idiopsis juventa*	3
9	Nymphalidae	African Queen butterfly	*Danaus chrysippus*	3
10	Nymphalidae	Common Lascar	*Pantoporia hordonia*	2
11	Nymphaliade	Dried-leaf Palmfly	*Elymnias casiphone*	3
12	Nymphalidae	Blue Tiger, Blue Wanderer	*Tirumala hamata*	3
13	Nymphalidae	Common Five-Ring	*Ypthima baldus*	3
14	Papilionidae	Great Mormon	*Papilio memnon*	3
15	Papilionidae	The Common Mormon	*Papilio polites*	3
16	Papilionidae	Tailed Jay	*Graphium agamemnon*	2
17	Pieridae	Common Emigrant	*Catopsila pamona*	4
18	Pieridae	Three-Spot Grass Yellow	*Eurema blanda*	5
19	Pieridae	The Wandering Psyche	*Leptosia nina*	4
20	Pieridae	Orange Gull	*Cepora iudith*	2
21	Pieridae	The Knight	*Lebadea Martha*	2
22	Pieridae	The Continental Swift	*Parnara ganga*	3
23	Hesperiidae	Banana Skipper	*Erionota torus*	3
24	Hesperiidae	Fulvous Pied Flat	*Pseudocoladenia dan*	4
Total (Σ)				85

The species list in Table 1 shows that there are several species that have not been reported in several areas on the island of Lombok and relatively close to SWF such as the Suranadi and Sesaot Nature Tourism Parks. The species are *Junonia hedonia*, *Tagiades gana*, *Danaus chrysippus*, *Elymnias casiphone*, *Ypthima baldus*, *Lebadea Martha*, *Parnara ganga*, *Erionota torus* and *Pseudo coladenia*. Photos in nature of these species are presented in Figure 3. From the aspect of abundance, these species are not the dominant species. During the observation, the number of individuals found ranged from 2-4 individuals.

The species list in Table 1 shows that there are several species that have not been reported in several areas on the island of Lombok and relatively close to SWF such as the Suranadi and Sesaot Nature Tourism Parks (Ilhamdi et al. 2018; Ilhamdi et al. 2023). The species are *Junonia hedonia*, *Tagiades gana*, *Danaus chrysippus*, *Elymnias casiphone*, *Ypthima baldus*, *Lebadea Martha*, *Parnara ganga*, *Erionota torus* and *Pseudo coladenia*. Pictures of these species taken from the study site are presented in Figure 3. From the aspect of abundance, these species are not the dominant species. During the observation, the number of individuals found ranged from 2-4 individuals.

Based on their distribution in Indonesia, these 9 species have been reported to survive in several habitat types in many Asian countries such as Southeast Asia, the Asian region with tropical and non-tropical climates, and some are even distributed on the continents of Africa and Australia (Ndatimana et al. 2022; Panettieri et al. 2018; Rahman & Maryati 2021; Reddy & Hemadri 2018; Vikas 2020). This shows that the environmental carrying capacity provided by the SWF area is more suitable for them compared to the environmental carrying capacity in Sesaot and Suranadi Nature Tourism

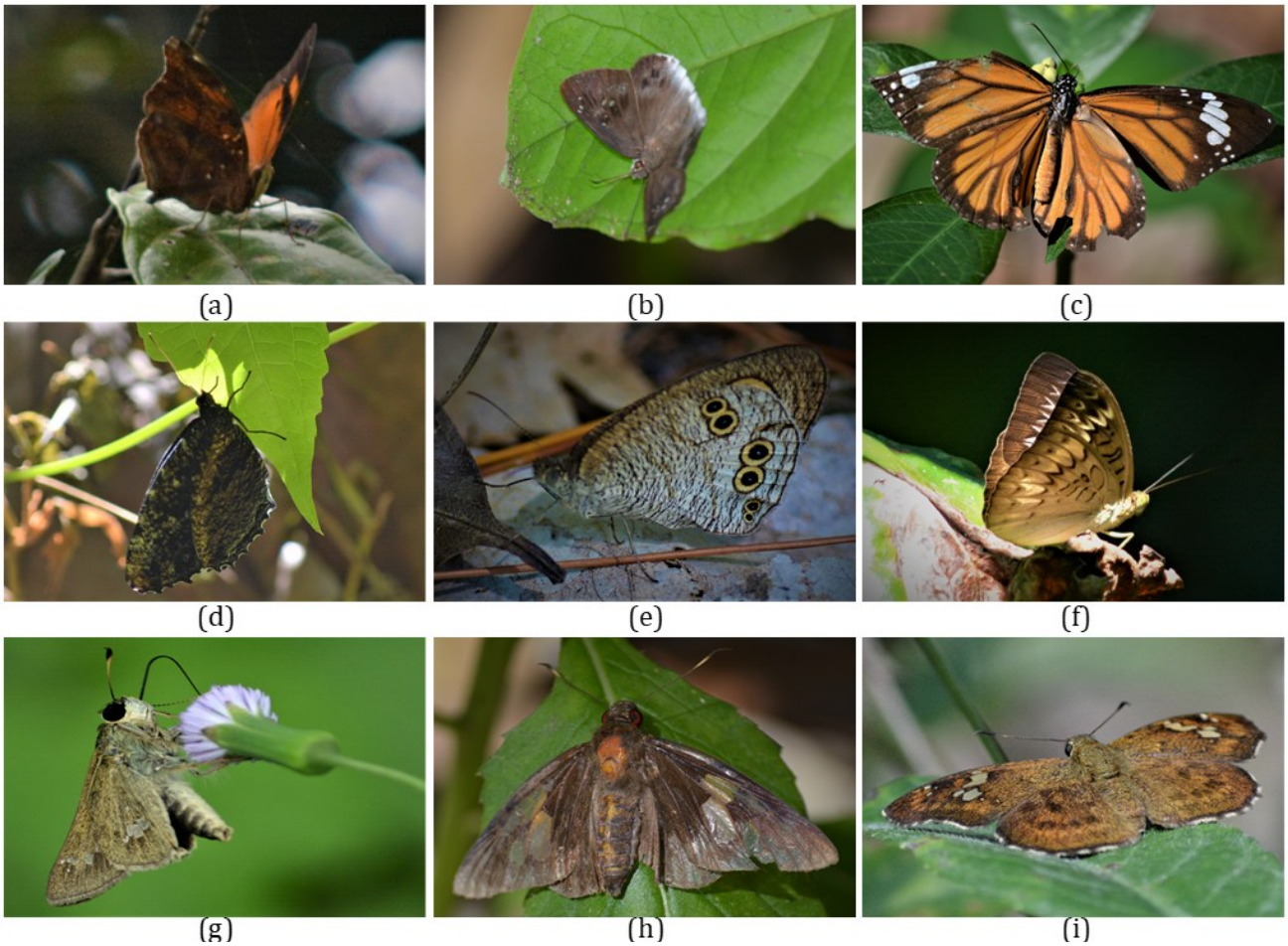

Figure 3. Some of the butterfly species documented in Segenter Waterfall Eco-Tourism Area: (a) *Junonia hedonia*, (b) *Tagiades gana*, (c) *Danaus chrysippus*, (d) *Elymnias casiphone*, (e) *Ypthima baldus*, (f) *Lebadea martha*, (g) *Parnara ganga*, (h) *Erionota torus* and (i) *Pseudocoladenia dan.*

Park. Environmental carrying capacity includes physical, chemical and biological habitat conditions. Physical and chemical conditions can be limiting factors. Several physical and chemical factors that can have an impact on butterflies include humidity, canopy, air temperature, wind speed and altitude (Koneri et al. 2020; Koneri & Nangoy 2019; Koneri et al. 2019). The biological factors include host plants, predators and parasitic organisms (Gordon & Kerr 2022; Mecenero et al. 2015). These biological factors can act as a dependent density factor. Greater availability of host plants allows for higher butterfly diversity, while the number of predators and parasitic organisms allows for the opposite.

Species diversity

The difference in species composition in SWF, when compared to several other areas on the island of Lombok and outside the island of Lombok, impacts differences in species diversity. Ecological characteristics at SWF show that the air temperature ranges between 26-27 °C, air humidity 79-89 %, canopy 65-95 % and wind speed 3-4 m s^{-1}. This condition is a good condition for the life of butterflies because it is within the tolerance range (Braby 2004). Air temperature was positively correlated with abundance and a significant predictor of species richness (Mahata et al. 2023). Warmer conditions favour butterfly populations (Gagnarli et al. 2023). Humidity had a positive impact on butterfly richness, where wetter conditions were favourable for butterfly diversity (Mahata et al. 2023). Canopy was a strong vegetative predictor of butterfly richness, with more open canopies supporting higher diversity (Bhardwaj et al. 2012). Wind speed generally has a smaller effect on butterfly communities than other factors. a study conducted in the Czech Republic showed that wind had only a small impact on butterfly abundance and species richness (Horák et al. 2021). However, in mountainous areas, wind speed can influence the distribution of butterflies by affecting their flight ability and dispersal, although these effects are often secondary to temperature and vegetation factors (Pires et al. 2020). The results of the analysis showed that the diversity index, evenness index, and dominance index of butterfly species in SWF were 3.115, 0.980, and 0.047, respectively. Based on Magurran (2021), this value is interpreted as (1) a high diversity of butterfly species and (2) no dominant species. Compared to that found in the Kembang Kuning Protected Forest Area, the diversity index in SWF was higher (3.115 > 3.08). Despite having a lower species richness (24 < 43), the SWF community has a higher similarity index while the dominance index is lower (Sumiati et al. 2018). In Suranadi Nature Park, Ilhamdi et al. (2018) found lower diversity in waterway habitat types (H' = 2.65). This is because the species richness is lower, which is only 18 species. Butterfly diversity in SWF is also higher than that reported in the Aik Bukak and Sesaot ecotourism areas (Ashari et al. 2022; Hapsari et al. 2022).

The higher diversity of butterflies compared to some other areas on Lombok Island shows that the sustainability/naturalness of the environmental conditions in SWF tourist spots (Putri et al. 2020; Rahayu & Hidayah 2018) provides benefits to ecological processes, especially to support life. various species of butterflies. The condition of this environmental carrying capacity needs to be maintained. Some things that need to be considered in the development of SWF ecotourism objects include: (1) physical development for tourist facilities should not significantly change the ecological processes of the area and (2) controlling tourist behaviour that has the potential to change the functions of the biotic and abiotic components of the ecosystem. which is still awake. It is intended that the use of SWF economically, in education and research by the community and local government can be optimized and sustainable.

CONCLUSIONS

The butterflies found at Segenter Waterfall consist of 24 species 5 families, namely Lycanidae, Nymphalidae, Papilionidae, Pieridae and Hesperidae. Analysis using the Shannon-Wiener index, Eveness index and Simpson index shows that the diversity of butterflies at Segenter Waterfall is high. This needs to be maintained through conservation efforts as a real action. Habitat restoration conservation efforts, establishment of special protection zones, and visitor education through community-based ecotourism and local training programs. In addition, organizing tourism activities, monitoring biodiversity, and conducting digital campaigns are also important to preserve butterfly diversity and support sustainable ecotourism.

AUTHOR CONTRIBUTION

M. L. I collected, designed the research, and supervised data analysis and manuscript writing, analysed data, wrote manuscript. A.A.I directed the flow of research, validated the data. A.H supervised manuscript. L.Z. supervised manuscript and directed data analysis. D.S directed the flow of research. G.H supervised the manuscript and data validators. M.S collected data and as field supervisor. G.C.W collected speciment and photography. J.R and A.S as director of manuscript writing.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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