



Diversity of order Phasmatodea: stick and leaf insects with plant associates in mountain ecosystems of Mindanao, Philippines

Jillian G. Ebeo*¹, Aimee C. Abdul¹, Alma B. Mohagan²

¹Natural Sciences and Mathematics Department, College of Arts and Sciences, Notre Dame of Marbel University, Koronadal City, South Cotabato 9506 Philippines

²Department of Biology, College of Arts and Sciences, Central Mindanao University, Musuan, Maramag, Bukidnon 8710 Philippines

*Email: ebeojillian@gmail.com

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Abstract

There was a limited study on the stick and leaf insects in the Philippines. The Order Phasmatodea is an underclass Insecta in which these species are phantoms or specters because the majority of them can camouflage themselves to the environment as sticks and leaves. Their characteristics to mimic the color, size, shape, and variation of leaves and sticks make them invulnerable to be seen by their predators. The study determined species abundance and richness of stick insects and leaf insects and their plant associates from the three selected mountain ecosystems of Mindanao, Philippines. The data gathered from the study provided information on the status and conservation of stick insects and leaf insects. Repeated transected walk, opportunistic method, and hand-picking were the techniques and methods used during the three-day collection in May and August 2022. 35 individuals under four subfamilies and five species were determined, and seven plant associates were identified. The *Euobrimus sp.* was the most abundant species among the Order Phasmatodea. Mt. Balatukan and Mt. Sumagaya had a higher number of species richness. For the diversity index, all three sites showed a low diversity, having a result lower than 0.5 index, which meant that these species were thriving but were disturbed by manmade activities. Regarding their conservation status, the species fall under the criteria of Not Evaluated, which means further study still needs to be conducted. Longer duration and a larger area should be considered in future studies.

Keywords: Balatukan, Conservation, Not evaluated, Melibengoy, Sumagaya

Introduction

In recent years, numerous research on highly resolved phylogenies for several insect lineages have been published and have led to many workable classifications for major groups related to the insect orders (Simon et al., 2019). Some of these are the stick insects and leaf insects of the order Phasmatodea that stand as one of the remaining insect lineages that are traditionally referred to as order for the robust higher-level phylogenetic hypothesis that is still lacking in which are highlighted in numerous textbooks (Simon, 2019). In the Philippines, there is a limited study on the stick and leaf insects. New genus and species of stick insects were found in the island of Mindoro (Vallotto et al., 2016). Mindanao has high terrestrial biodiversity in which there is a large range of species in the archipelago.

This study focused on the determination of species abundance, richness, diversity, and conservation status of Order Phasmatodea particularly the stick insects and leaf insects in the three selected mountain ecosystems of Mindanao, namely Mt. Melibengoy, Mt. Balatukan, and Mt. Sumagaya. Studying the diversity of insects such as the order Phasmatodea enables the formation of wildlife, including plants, mammals, and reptiles, to survive. The conservation and abundance of stick insects and leaf insects keep plant growth in check since they are known to be phyllophagous organisms that lower the development of early succession in plants by consuming their leaves, creating a balance in the cycle of the ecosystem.

Materials and methods

Sampling sites

The study was conducted in three (3) selected mountain ecosystems of Mindanao Philippines: Mt. Melibengoy, Mt. Balatukan, and Mt. Sumagaya (Fig. 1). The sampling sites where the study was conducted were in the agroforest ecosystem and montane forest ecosystem. The area in Mt. Melibengoy consisted of terrestrial trees, plants, and shrubs. The areas in Mt. Balatukan and Mt. Sumagaya were the same as Mt. Melibengoy, but the sampling sites of Mt. Balatukan and Mt. Sumagaya were more likely disturbed due to human activities conducted in the area. During the fieldwork, the weather condition was rainfall season and the temperature casually changed. During the night collection, the temperature lowered as the wind from the upper elevation moved downwards to the lower elevation of the mountains. In the establishment of the sampling sites, the method used was a repeated transect walk with the use of a Global Positioning System (GPS) tracker in the collection of specimens. Another method used was the opportunistic method in which the species found outside the sampling site were collected. For a great difference, three voucher

specimens or more were collected per species and are being sealed in a Ziplock bag with its associated plant. Meticulous searching was used for the collection method of species under the order Phasmatodea through the handpicking method during the day and night collection. A wildlife gratuitous permit RXII-2022 no. 11 and R10 2022-34 was requested from the Department of Environmental and Natural Resources for the conduct of the study. For the specimens collected from Misamis Oriental, a transport permit was requested from the City Environment & Natural Resources Office (CENRO) Gingoog City of Misamis Oriental.



Figure 1. Map of the Philippines and the three selected mountain ecosystems of Mindanao

Identification

For identification, photographs were taken upon the rearing of the specimens that were collected during the fieldwork. For specimens collected by Mt. Melibengoy, the photographs of the specimens were sent to the Central Mindanao University Center of Biodiversity Research and Extension in Mindanao (CEBREM). For the specimens that were collected at Mt. Balatukan and Mt. Sumagaya, Royce Cumming, an entomologist from the City University of New York (CUNY) Graduate Center was the one who identified the species in which it was sent via email. Most of the individuals collected were identified by family and genus levels. Articles, journals, books, and online sources such as phasmida.speciesfile.org and phasmid study group that have documentation and photographs of previously identified species were used.

For the plant associates, the plants collected were reared and pressed using Guevarra's (2017) herbarium method. The plant associates were sent to the Central Mindanao University Museum for identification and verification by Dr. Fulgent P. Coritico, a plant taxonomist at the University Museum.

Diversity assessment

The diversity assessment of order Phasmatodea, the species abundance, species richness, and Shannon-Wiener diversity order Phasmatodea, the species abundance, species richness, and Shannon-Wiener diversity index were determined using the BioDiversity Pro software version 2.0. The software has all the indices needed for the evaluation of collected data.

Results

Table 1. Species abundance and richness of Order Phasmatodea: Stick insects and Leaf insects in selected mountain ecosystems of Mindanao, Philippines

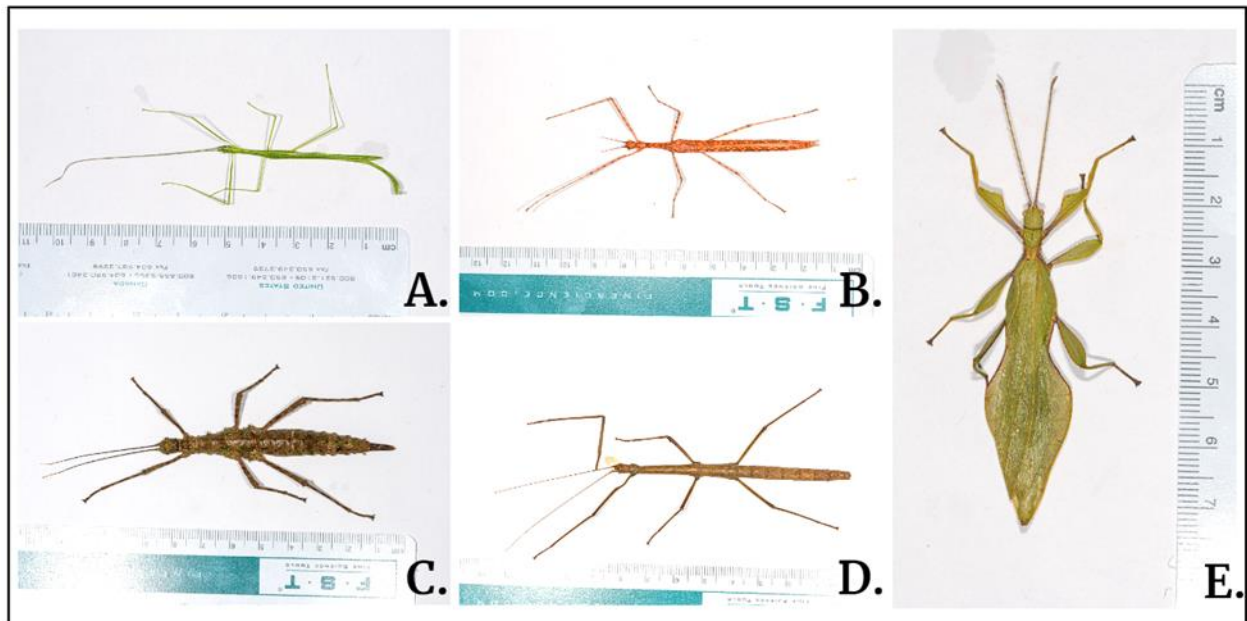
No.	Species	Mt. Melibengoy	Mt. Balatukan	Mt. Sumagaya
1	<i>Euobrimus</i> sp.	10	1	7
2	<i>Necrosia</i> sp. 1		3	
3	<i>Matutumetes</i> n.sp.			12
4	<i>Necrosia</i> sp. 2			1
5	<i>Phyllium</i> sp.		1	

Table 2. Diversity indices of Order Phasmatodea: Stick insects and Leaf insects in selected mountain ecosystems of Mindanao, Philippines

Species	Mt. Melibengoy	Mt. Balatukan	Mt. Sumagaya
Species abundance	10	5	20
Species richness	1	3	3
Number of endemic species	1	3	3
Shannon-Weiner diversity index	0.13	0.41	0.36

Table 3. Plant associates of Order Phasmatodea in the three selected mountain ecosystems of Mindanao

Subfamily	Species	No. of individuals	Associated plants
Obriminae	<i>Euobrimus</i> sp.	7	<i>Impatiens platypetala</i>
		3	(L.) C. Presl
		8	<i>Nephrolepis falcata</i> (Cav.) C. Chr. <i>Tibouchina heteromalla</i>
Necrosiinae	<i>Necrosia</i> sp. 1	3	<i>Melastoma malabathricum</i> L.
	<i>Necrosia</i> sp. 2	1	<i>Nephrolepis cordifolia</i>
Lonchodinae	<i>Matutumetes</i> n.sp.	10	<i>Shorea</i> sp.
		2	<i>Wendlandia</i> sp.
Phylliinae	<i>Phyllium</i> sp.	1	Undetermined

**Figure 2.** Photographs of stick insects and leaf specimens: A. *Necrosia* sp. 1, B. *Necrosia* sp. 2, C. *Euobrimus* sp., D. *Matutumetes* n.sp., and D. *Phyllium* sp. Photographs by Sam Youngdale

Discussion

Species abundance and richness

A total of 35 individuals under four (4) subfamilies and five (5) species were collected and identified from the three selected mountain ecosystems in Mindanao, Philippines. The species of stick insects identified were: subfamily Necrosciinae with two species, one genus was *Necroschia*; subfamily Obriminae, one species of genus *Euobrimus*; and subfamily Lonchodinae, genus *Matutumetes*. The leaf insect is a subfamily Phylliinae with the genus *Phyllium*. For the species abundance of Order Phasmatodea, the mountain ecosystem that had the highest number of individuals was Mt. Sumagaya, with 20 individuals collected, followed by Mt. Melibengoy, with ten (10) individuals, and lastly, Mt. Balatukan, with five (5) individuals. The genus *Euobrimus* sp. was the most abundant species, having 18 individuals. Regarding species richness, the mountain ecosystems of Mt. Balatukan and Mt. Sumagaya both had three species per site. According to Pielech (2021), the estimated total number of species showed a similar pattern; however, the highest number was estimated for riverine forests along 3rd order streams and, therefore, suggested an unimodal pattern of gamma diversity along a longitudinal (upstream-downstream) gradient. The topographic location, date, and season affected the total number of species. The Shannon-Weiner diversity index results showed that the study's three selected mountain ecosystem sites had low diversity results. The low species diversity was observed in Mt. Balatukan with $H'0.413$, followed by Mt. Sumagaya with $H'0.358$, and the lowest was Mt. Melibengoy with $H'0.132$. The low diversity results of stick insects and leaf insects of the three selected mountain ecosystems might be due to sampling frequencies or due to anthropogenic disturbance in the area. According to Heaney et al. (1989), the variability in patterns of species diversity, endemism, and distribution are influenced by two major factors: temporal (date and time) and spatial (country, region, faunal region, ecosystem, habitat, and microhabitat). The rapid increase in the human population has adversely affected diversity around the globe. The negative effects of this increase include pollution, climate change, deforestation, habitat loss, and invasion of exotic species (MG, S. et al., 2022).

Plant associates

A total of seven (7) plant species were identified to be associated with stick insects that were collected from the three selected mountain ecosystems of Mindanao identified as the following: *Impatiens platypetala* (L.) C. Presl, *Nephrolepis falcata* (Cav.) C. Chr., *Tibouchina heteromalla*, *Melastoma malabathricum* L., *Nephrolepis cordifolia*, *Shorea* sp., *Wendlandia* sp. The *Euobrimus*

sp. was identified and observed to have three plant associates out of the five species under the order Phasmatodea. The individuals on site were observed to be on the abaxial and adaxial surfaces of the leaves. For the species of *Matutumetes n.sp.*, all of the individuals collected on site were on the same plant and area in which the plant associate could be its food plant or the plant for its breeding. For the *phyllium sp.*, no plant associate was observed during collection since the individual was found in the cabana tent in which an opportunistic method was conducted to collect the specimen.

Status assessment

For the status assessment of the three selected mountain ecosystems of Mindanano, Mt. Sumagaya had three status assessments of Very rare endemic (*Necroscia sp. 1*), rare endemic (*Euobrimus sp.*), and common endemic (*Matutumetes n.sp.*); followed by Mt. Balatukan with three species under very rare (*Necroscia sp. 2*, *Euobrimus sp.* and *Phyllium sp.*); and Mt. Melibengoy with the status result of species being rare endemic (*Euobrimus sp.*). The results suggested that the endemism of order Phasmatodea in different locations can be due to the climate, plant species composition, elevation, and unique habitat that influence the existence of flora and fauna.

In the IUCN Red List 2022, the species collected were under the category Not evaluated (NE), which means that the species were not yet assessed by the International Union for Conservation of Nature. Based on its database, some species of stick insects and leaf insects are already listed, but they fall under the categories of least concerned and Data deficient.

Conclusion

In terms of the species diversity of Order Phasmatodea in the three selected mountain ecosystems, all the sites have a low diversity of 0.5, and the closer to the result is from Mt. Balatukan. It was also found that the most abundant species out of the five identified was *Euobrimus sp.*, and the species was present in the three selected mountain ecosystems of Mindanao making the species endemic to Mindanao. The plant associates were also identified, which would help in identifying these plants as food sources. For their status based on the IUCN Red List 2022, the species collected fall under the category of Not evaluated.

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