



## RESEARCH ARTICLE

### HAWKMOTHS (HETEROCERA: SPHINGIDAE) DIVERSITY AND STATUS ON SELECTED VEGETATION TYPES OF A PROTECTED NATURAL FOREST (MT. HAMIGUITAN WILDLIFE SANCTUARY, SAN ISIDRO, DAVAO ORIENTAL) AND ECOTOURIST AREA (BUSAY GARDEN MARILOG DISTRICT, DAVAO CITY) PHILIPPINES.

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#### ABSTRACT

Recent ecological studies give so much attention to biodiversity and conservation. As some initiative on conserving biodiversity, naturalistic landscape designs are incorporated to various holiday destinations offering extreme sport adventures, promoting tourism as source of income while preserving natural habitat. However, it is not impossible that an alteration will be made from the original habitat or even frequent exposure to various anthropogenic activities that causes disturbances may seriously affect sensitive species. This study measured diversity of hawkmoths in two selected sites with different vegetation types: 1) the Mt. Hamiguitan ranges (Natural and protected forest) Ecopark (site 1), Camp 3 (Site 2), Black Mountain (site 3) and study area 2: Busay Garden and Spring Resort. The sampling was carried out using 500w bulb light trapping method powered by a portable generator. A total of 305 individuals representing 22 species of hawkmoth from both sites were recorded. Shannon-Weiner indicates that Hawkmoths were more diverse in Busay Garden and Mt. Hamiguitan site 1 where diversity index were the same with  $H' = 1.258$ . They have the same diversity indexes, but they differ on species richness ( $H_{max} = 1.301$  for site 1,  $H_{max} = 1.342$  for site 4) and evenness with  $J = 0.9672$  for site 1 (Ecopark) and  $J = 0.937$  for site 4 (Busay Garden). Diversity of hawkmoths increases as elevation increases except for site 3 ( $H' = 1.161$ ) where the elevation was higher than site 2 ( $H' = 1.06$ ). Bray-Curtis Similarity Index of hawkmoth in Busay Garden and the Eco-park of Mt. Hamiguitan have shown high (73%) species similarity. The diversity of hawkmoths was high at lower elevations and the results suggests that developing gardens into having more diverse host plants may promote higher species diversity. Further study on its implications with wider coverage and longer sampling duration is recommended.

**Key words:** Diversity, Sphingidae, Hummingbird moth, Hawkmoths, Mt. Hamiguitan Ecopark (site 1), Camp 3 (site 2), Black Mountain (site 3), and Busay Garden (site 4).

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#### INTRODUCTION

Hawkmoths, sphinx moth or hummingbird moth are members of family Sphingidae (Order lepidoptera: heterocera), a mega-diverse plant eating order of insects (Menken et al, 2010) which are medium to large size fast flying moth and are known for their ecological services (Scoble, 1995).

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They are important nocturnal pollinators of flowering plants and they are well represented in the tropics (Akite et al, 2015; Amorim et al, 2009). Moth exhibits different levels of fidelity to habitat and they respond to environmental changes; the presence and abundance of their species indicates the quality of their habitat and vegetation types (Braga and Diniz, 2015). Recent Ecological studies has been giving attention to active assessment of biodiversity (Chao et al, 2014) as biodiversity has been affected with the climate change as its major threat. As an initiative of some concern citizens, gardens are being

developed to promote diversity while generating income through tourism. Some gardens try to conserve original canopy vegetation but they also make alteration to understory habitat that may affect sensitive species (Braga and Diniz, 2015). Reports on population trends of Moths in European countries showed significant decline (Macgregor et al, 2015). In Philippines, population trend on this insect family even at any local level is not well explored. Hawkmoths from Mt. Hamiguitan range and Busay Spring Resort garden has not received attention yet. Mt. Hamiguitan Range is the only mountain that is a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage site in the Philippines. Its total area is more than 16, 000 hectares of which 6,834 was declared as a Protected Area in 2004 under Philippine Republic Act No. 9303 (DENR, 2014). This mountain is a home of a critically endangered endemic species *Pithecopha jefferyi* commonly known as Philippine eagle and the century old pygmy trees or bonsai forest where butterflies like *Delias magsadana* can be found in this habitat only and nowhere else in the world (Mohagan and Treadaway, 2010) with other Philippine and Mindanao endemic species of flora and fauna (DENR, 2014). On the other hand, Busay Spring resort was nestled near Mt. Malambo. The garden and spring resort has been developed for tourism and utilized as very affordable venue for relaxation, family picnics, religious events and other various activities. This study aimed to measure and compare diversity of hawkmoth in a minimal duration in the different vegetation types of protected forest (Mt. Hamiguitan Wildlife Sanctuary, Davao Oriental) and Ecotourist Area (Busay Garden Spring Resort at Marilog District, Davao City) Philippines. The study assumed that hawkmoths diversity and species richness is high in natural forest compared to a garden spring resort prone to anthropogenic disturbances.

## MATERIALS AND METHODS

**Entry protocol and Establishments of the sampling sites:** A permit to conduct the study and collect samples was acquired from the authorities of the selected study sites. The study was carried out in the three vegetation types of Mt. Hamiguitan Range Wildlife Sanctuary located at 124° 14' N, 5°21'E and Busay Garden and Spring Resort near Mt. Malambo (7° 38' 27" N 125° 18' 11" E) Southern Mindanao, Philippines (Fig.1). Light traps were established in different vegetation types of Mt. Hamiguitan and Busay Garden and Spring Resort (Fig. 2a): Ecopark (site 1, fig. 2b) 390-440masl, geographically located at N6°44'07.44 "E126°08'30.14"; Camp 3 (Site 2 Fig.2c) 1130-1160masl, at N6°43'40.10 "E126°11'05.10"; Black Mountain (site 3, fig. 2d) 1,225masl, N6°43'45.90 "E126°10'52.10", and Busay Garden Spring Resort on the month of February 2017. *Ecopark* (site1) habitat is composed of Dipterocarpus trees, a research site and developed for tourism with some amenities for extreme sports like zipline and sky-bicycle. This site offers a little experience from the peak of the mountain range where tourist can find plant species that can be found from the other vegetation types and higher elevation areas at the Natural Science Museum. There's a bridge that crosses the big stream between the road from the Museum and to the Science Research Center. Understory vegetation were dominated by different kinds of ferns, tree seedlings, sedges and grasses. *Camp 3* (site 2) light trap where it was established was surrounded by various tall trees with slight cover of moss and loaded with epiphytic plants, forking ferns; its understory has a little thin cover of leaf litters with

various tall grasses and sedges. Beyond the tall trees around the campsite is a sanctuary of flowering and fruiting pygmy trees. The *Black Mountain* is still part of the Mt. Hamiguitan range, adjacent to the camp 3, 30-minute hike away; habitat is composed of shrubs, and a mixture of bonsai and tall trees. Moth predators such as birds, lizards, frogs and spiders were observed in all sampling sites. *Site 4* Busay spring Resort was originally a primary forest with two caves, one was inaccessible where some species of bats shelters and one open small cave where insect feeder birds stays and in it are waters going down to the pool established and developed by the owner. Water on pipes were potable and local's source of water. This small cave gives way to a small forest patch inhabited by some tree ferns, *Pandanus* sp., ginger plants (*Etilingera* sp.), trees were loaded with epiphytic plants such as orchids and slightly covered with mosses and lichens. Understory vegetation were mostly herbaceous, magnoliophytes, grasses and sedges. A portion going to the entrance of the resort is an agroecosystem mostly covered with grasses *Agrostis*, *Cyperus* species of sedges and surrounded by some original dipterocarpus trees, pinophytes, various fruit trees like *Mangifera indica* (Mango tree), palms and other introduced species of ornamental potted plants.

**Collection, preservation and Data analysis:** Specimens were sampled in 2 (two) entire nights at each site where light traps were set. Hawkmoths attracted to a 500w bulb light hanged in a tripod in front of the white sheet in vertical position powered by portable generator that was established at different vegetation types were manually collected and killed with an injection of 95% EtOH (Ethanol) in the thorax (Lara-Pérez et al., 2017). One (1) representative of each specimen were mounted for University museum collection exhibit. It was partly sunny during the day, and light rain at around 7:00pm to 9:00pm during the sampling. All specimens collected were identified up to species level using illustrations from field guides and published articles of Order Lepidoptera family sphingidae. Identification were also confirmed by experts. BIO diversity Pro software was used to estimate diversity of hawkmoth sampled using Shannon-Weiner index; PAST 3.0 Rarefaction analysis was used to estimate and compare species richness among communities and evaluate effectiveness of the sampling; Bray-Curtis cluster analysis was used to estimate species similarities among the study sites (Gotelli and Colwell, 2001; Magurran and McGill, 2011)

## RESULTS AND DISCUSSION

Combined datasets of the selected sampling sites consists of 22 species and 305 individuals of Sphingidae. A portion of 149 individuals across the vegetation types of Mt. Hamiguitan and 156 individuals from Busay Garden spring resort. A total of 16 species were represented in both Mt. Hamiguitan and Busay Garden spring resort sampling sites, Species *Ambulyx staudingeri* (Distributed Philippines (Hogenes and Treadaway, 1998)) was found common in all sites and composed the most of the total population, 5 species were found unique to Mt. Hamiguitan ecopark (*Agrius convuolvuli*, *Ambolyx uchancoi*, *Clanis surigaensis*, *Daphnis h. hypothous*, & *Marumba amboinicus luzoni*), and Only 1 Species *Hippotion boershavior* was found unique in Busay Garden spring resort (A list of hawkmoths collected were presented in Table 1). The total number of species and number of its individuals varied at each site with a striking assemblage pattern. Diversity index of hawkmoths estimated using Shannon-Weiner index presented in Fig. 3 shows that diversity of hawkmoths is high at lower

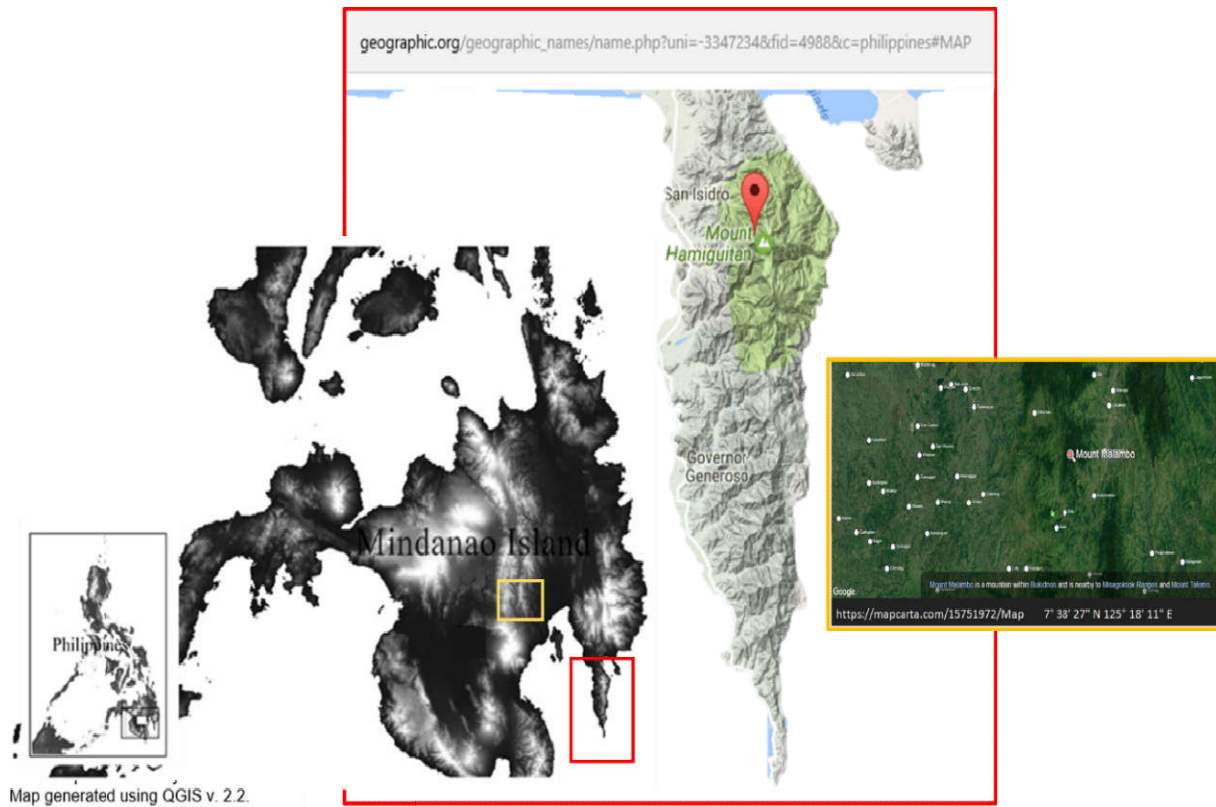


Figure 1. Geographical location of the study sites: Map of the Philippines, Mindanao Island, Mt. Hamiguitan (in red outlined box) and Busay Garden located near Mt. Malambo (yellow box)



Figure 2. Light trap setups: Panoramic view from the light trap setup of Site 4: Busay garden (A) and different Vegetation types of Mt. Hamiguitan: Site 1: Eco-park (B), Site2: Camp 3(C) and Site 3: Black Mountain (D)



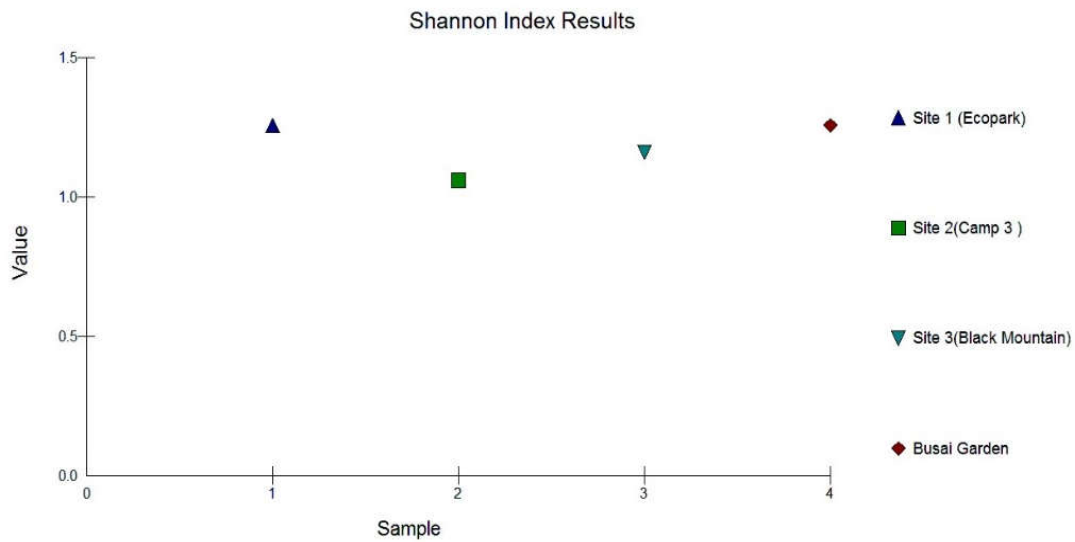


Figure 3. Shannon Weiner Diversity Index of Sphingidae of Two Selected study sites

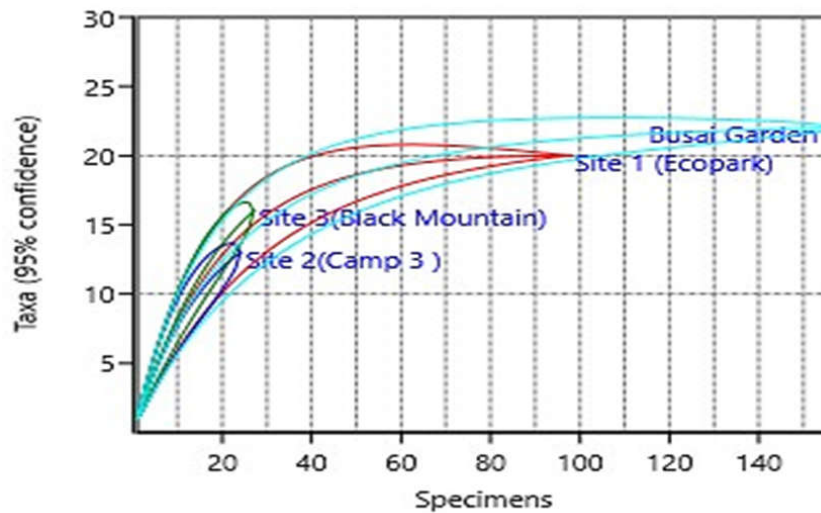


Figure 4. Rarefaction Curve (using PAST3) software of Sphingidae in Mt. Hamiguitan & Busay Garden Spring Resort

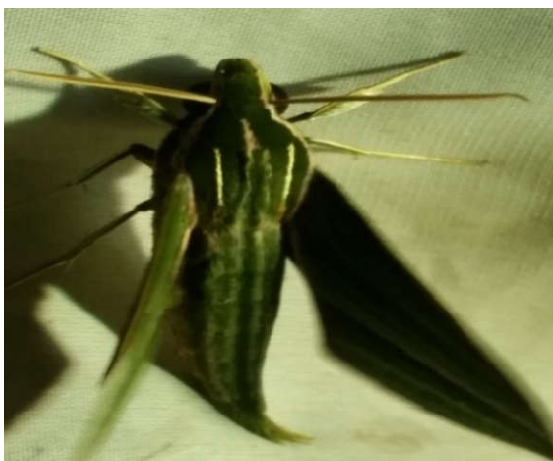


Figure 5. *Theretra manilae*

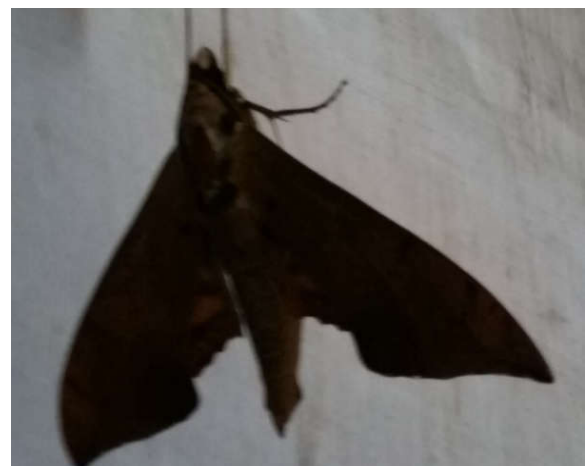


Figure 6. *Ambulyx staudengeri* -endemic

elevation areas and decreases as elevation increases with an exception for Black mountain site 3 where Shannon-Weiner diversity index is higher than Camp 3 Site 2. The results suggest that diversity of hawkmoth at the Mt. Hamiguitan Ecopark Site 1 and Busay Garden Site 4 were high ( $H' = 1.258$ ) and most

diverse compared to the other selected study sites of the Natural Protected Forest of Mt. Hamiguitan, Davao Oriental with  $H' = 1.06$  for site 2 (Camp 3) and  $H' = 1.161$  for site 3 (Black mountain). Figure 4 generated by Past software rarefaction plot comparing species richness among study sites

**Table 1. Local Status and Species composition of hawkmoth in Mt. Hamiguitan and Busay Garden**

Species	Site 1 (Ecopark)	Site 2 (Camp 3)	Site 3 (Black Mountain)	Site 4 (Busay Garden)
<i>Agrius convolvuli</i> Linnaeus 1858	/			//
<i>Acosmeryx anceus subdentata</i> Rothschild & Jordan 1903	//	/	/	//
<i>Acosmeryx socrates</i> Boisduval, 1875	//	/	/	//
<i>Acherontia lachesis</i> Fabricius 1958	/	/	/	//
<i>Amplexeris panopus panopus</i> Cracner, 1979	/	/	/	//
<i>Ambulyx bakeri</i> Clark 1929	//	/	/	//
<i>Ambulyx staudingeri</i> Rothschild 1894	//	/	/	//
<i>Ambulyx uchancoi</i> Clark 1938	/			//
<i>Ambulyx wilemani</i> Rothschild & Jordan 1916	//		/	//
<i>Cechenna helops helops</i> Walker 1856	/		/	//
<i>Clanis surigaoensis</i> Clark 1928	/			//
<i>Daphnis hypothous hypothous</i> Cracner 1780	/			//
<i>Eupanacra busiris busiris</i> Walker 1856		/	/	//
<i>Hippotion brunneum</i> Semper 1896	/	/	/	//
<i>Hippotion boershaviai</i> Fabricius 1775				/
<i>Hippotion rosetta</i> Swinhoe 1892	/		/	//
<i>Marumba amboinicus luzoni</i> Clark 1935	//			//
<i>Meganoton rufescens philippinensis</i> Clark 1938	/	/	/	//
<i>Theretra insularis insularis</i> Swinhoe 1892	//	/	/	//
<i>Theretra clotho clotho</i> Drury 1773	/	/	/	//
<i>Theretra manilae</i> Clark 1922	/	/	/	//
<i>Theretra nessus</i> Drury, 1773	/	/	/	//
Total No. of Species:	22	20	13	16
Total No. of Individuals:	305	98	24	27
				22
				154

Status Legends (based on arbitrary counting during sampling): // common / rare

**Figure 7. *Ambulyx* sp.****Figure 8. *Amplexeris panopus mindanensis***

showed high at site 4 (Busay garden) followed by site 1 (Mt. Hamiguitan Ecopark), site 3 (black mountain) and low at site 2 (camp 3). Species abundance was highest at lower elevations specially at the Busay Garden ( $H_{max}=1.342$ ) where there were  $S=22$  species of hawkmoth recorded with  $n=156$  individuals (51% of total species individual) followed by Site 1 (Ecopark) with  $H_{max}=1.301$  where  $n=98$  (32%) species individuals belonging to  $S=20$  species (90% of the total no. of species recorded) of hawkmoth; then site 3 (Black mountain) ( $H_{max}=1.204$ ) where there were  $S=16$  (72%) species with  $n=27$  (8.8%) individuals; and lowest at site 2 (Camp 3) with  $H_{max}=1.114$  where there were  $S=13$  (59%) species and  $n=24$  (7.9%) individuals.

Visual assessment of Rarefaction accumulation curves (fig. 4) shows that species richness is high at Site 4 (Busay Garden) it also shows that the curves didn't reached asymptote for each site, especially at sites 1, 2 and 3 which suggests that sampling effort for these sites was not enough and there could be more species to be found if we combined techniques for sampling and or continue to sample (Magurran and McGill, 2011; Tobergte *et al.*, 2014).

But according to Landau *et al* (1999), intensive sampling yielded 76% overlap in species recorded between long-term and short-term sampling effort comparison, moreover, Summerville and Crist (2005) also reported that the increased sampling effort only reduced the proportion of singletons and unique species and this peaked after 10 trap nights. Therefore, the observed changes in species richness and abundance of sphingidae across our sampling sites are real, that the recorded species are the species that can be found at the sites of that month at the most minimum intensive sampling time. Species Evenness pattern inconsistent decline as the sampling sites elevation inclines. Species evenness in Mt. Hamiguitan site 1 (Ecopark) suggests that the number of species found from this site were more evenly represented with  $J=0.967$  followed by site 3 (Black Mountain) where  $J=0.964$ , site 2 (Camp 3) with  $J=0.952$  and  $J=0.937$  in site 4 (Busay Garden) where diversity index was high and the same with site 1 (Ecopark) with higher species abundance ( $H_{max}=1.342$ ) among the sites. Although we don't have striking good estimates of the total sphingidae moth richness, the result suggests that the two (2) study areas still provide a good environment for the species recorded and probably for their hostplants as well especially at the Busay

garden which provides diversity of food plants for hawkmoth and the lower elevation level of Mt. Hamiguitan protected forest. Most of the species recorded does not require a very good quality of forest or habitat to survive, most of them are even distributed widely in Southeast Asian Countries. The Sphingidae in general are commonly feed on younger leaves; variability of our data could be due to the individual response to the state of the local environment through their guild membership (Holloway and Herbert 1979); vegetation types they are in and what food is available for the species recorded, regarding to the species uniqueness to Mt. Hamiguitan ecopark where there were 5 species found only in the ecopark, those species were probably the forest specialist moth that are monophagous and they only feed on woody plants, trees and vines; the species found favoring the disturbed sites like Busay Garden spring resort as it is promoting tourism, are moths which are polyphagous feeding on herbaceous and weedy food plants (Usher and Keller, 1998; Kitching et al, 2000). According to Chan et al (2016), Seasonal and daily climate variation have opposite effects on species elevational range size, furthermore, he also reported that tropical montane species are thermal specialist which makes them vulnerable to climate changes and this might be the reason why species richness and abundance is low in montane forest (Site 2- Camp 3) of Mt. Hamiguitan, compared to its site 3 (Black Mountain) where the elevation is higher than the montane forest and where diversity, species richness and abundance are expected to be lower than site 2 (Camp 3) as an usually observed pattern in general.

### Conclusion

The study provided baseline information on sphingidae of the selected sites. The result revealed that diversity of hawkmoths (sphingidae) are higher at lower elevations of Mt. Hamiguitan and in Busay gardens spring resort. Obviously, the study has important implications for research, developing garden with more diverse plants as food host for hawkmoth may promote their diversity, species richness and individuals where host plants are abundant and are also diverse. Actions that may cause decline or total removal of this species affects ecological services given by hawkmoths and which only they can provide, the absences of their guilds affects the functions of other guilds and species dependent to them as source of food, it affects biodiversity in a way that it may lead to its serious decline and altering ecological integrity of their usual habitat and the habitats that are linked to their habitat.

### Recommendation

Hawkmoths are sphingophalous plant consumers, the study suggests repeatedly monitoring for seasonal diversity, correlate diversity of sphingophalous plants to diversity of hawkmoth, extend sampling effort or compare short-term long-term sampling at the area, types of habitat, its vertical stratification to cover full forest diversity and duration at both study site, edges of sampling sites and between vegetation types, protected or non-protected forest or wider coverage for further information on Philippine Hawkmoth.

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