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Community Structure and Diversity of Carabid Beetles in Eastern Visayas, Philippines

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ABSTRACT

A pioneer study has been carried out to provide data about community structure and diversity of carabid beetles in six forests of Eastern Visayas namely: Lake Danao, Mt. Nacolod, Kuapnit Balinsasayao, Asug Forest, City Forest, and Closed Canopy on January to June of 2019. Collected carabid beetles was comprised of 7844 individuals belonging to 41 species under 25 genera, 13 tribes, and two (2) subfamilies. Twenty-six species were recorded from Lake Danao, 32 species in Mt. Nacolod, 20 species in Kuapnit Balinsasayao Forest, 11 species in Asug Forest, 19 species in City Forest, and 26 species in Closed Canopy Forest. A total of 19 endemic species were recorded of which 12 are Philippine endemic, 6 are endemic to Leyte, and 1 is endemic to Samar. The survey found new species and new records of carabid beetles in the region. Carabid beetles were collected using pitfall traps and handpicking (ground searching). Carabid species diversity, as estimated by diversity indices, was significantly different among the six forests. Of the six forests, Mt. Nacolod had comparatively high diversity (4.00). equitability (0.78), dominance (2.709), and species richness (32); Lake Danao and Closed Canopy forests had almost the same values in high diversity (3.37), equitability (0.86), dominance (2.798), and species richness (26). Indices for Kuapnit and City forests did not differ significantly, both have low diversity (2.787 and 2.464), high equitability (0.85 and 0.89), dominance (2.53 and 2.58), and species richness (20 and 19), but were relatively lower than Mount Nacolod. Asug forest got the lowest indices value for both dominance, diversity and species richness. In terms of habitat types, there were 41 species belonging to 25 genera identified among 3,771 carabids collected from natural forests of Eastern Visayas. In agricultural habitat type, 28 species were identified from 4, 073 carabid beetles. Natural forest had comparatively high diversity (5.95), high equitability (0.80), dominance (3.1), and species richness (41) over agricultural land.

KEYWORDS: *Carabid beetles, community structure, species richness, species diversity, natural forest, agricultural land.*

I. INTRODUCTION

Habitat alteration by humans has taken place for over thousand years in different parts ofthe world, but more drastically so during the past 300–400 years (Esseen et al. 1997). As a result, the terrestrial landscape is a mosaic of different-aged forests, mires, meadows, human settlement areas and farmlands, and human impact is visible almost everywhere (Hansson 1992). Habitat patchiness affects the spatial distribution of invertebrates at several spatial scales (Niemela¨ et al. 1992; Niemela¨ 1996, 1993). Understanding the variation in abundance of species within and between habitat patches is obviously crucial from the points of view of biogeography and conservation. Increased patchiness of habitat 'islands' – habitat 'islands' being isolated and often small in size – increases the amount of habitat edges (ecotones) where different types of habitat meet (Murcia 1995) affect microclimate (Matlack 1993; Chen et al. 1995), which can modulate the species composition of two adjacent environments.

The distribution of carabids and environmental structure is used to cover the structural elements of the soil and vegetation in the immediate surroundings of the carabids, as factors which could exert an influence on their distribution (Theil, 1977).

Carabids satisfy different environmental roles within biological systems, aside from giving economic

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advantage in agricultural systems (Wilson 1987; Isaacs et al. 2009). Arthropods like carabids work as prey sources for some groups, as critical predators, and as pollinators and seed dispersers (Bond and Slingsby 1984; Wilson 1987; Isaacs et al. 2009). Likewise, arthropods are vital for the decomposition process and nutrient cycling, making supplement rich soils for plants (Seastedt and Crossley 1984). Changes in plant composition and soil qualities as a result of plant invasions might have negative effects for arthropods because of their restricted dispersal mobility on the ground and numerous species require particular host plants for their food and reproduction (Wilson 1987; Kremen et al. 1993; Niemela and Mattson 1996; Tallamy 2004; Burghardt et al. 2008). Soil parameters like moisture, ambient temperature, light intensity, and pH are also factors for the distribution, abundance and reproductive success of other carabid taxa, and these basic changes in terms of community structure because of invasive plants may change environment quantity and quality (Niemela and Mattson 1996, Antvogel and Bonn 2001; de Souza and de Souza Modena 2004; Lassau et al. 2005).

Changes across the edge gradient have been reported for carabid beetles (Coleoptera: Carabidae) across forest-grassland edges (Kotze and Samways 1999; Magura et al. 2001) and forest clear-cut edges (Helio¨la¨ et al. 2001). The ecotone between agricultural land and forest may potentially represent a stricter barrier for carabid beetles than the clear-cut-forest boundary. Carabids associated with closed-canopy habitats can be almost equally abundant in the clear-cuts and in the adjacent mature forests, whereas open-habitat species are restricted to the clear-cuts (Helio¨la¨ et al. 2001). Carabid beetles live in nearly every available habitat, although some species are associated with particular ecosystems, like meadows, woodlands, or crop fields. Due to the habitat specificity of some species, these beetles can be used as biological indicators to assess land use changes among different ecosystems. This paper will look into the distribution of carabid beetles at the open forest and agricultural habitat types and take note of its vegetation and physico-chemical parameters.

Tropical forests as the most varied and the most biologically complex ecosystem provide apparently over 33% all species considered (Raven 1980; Wilson 1992) and assume an excessively vast part in worldwide carbon and other nutrient cycles (Detwiler and Hall 1988). In view of its high heterogeneity, more prominent assortment of microhabitats, a wider scope of microclimates and expanded resource range could happen. It can likewise offer a rich diversity of invertebrates and vertebrates (Huston 1993; Townsend et al. 2008).

The implication of the loss of natural vegetation is the decrease of forest covers due to unlawful logging activities and slash-and-burn farming. Information on deforestation in the tropics of South-East Asia showed as the most fast-paced (Laurance 1999), achieving 1.6% between the range of 1982 and 1990 and in contrast to 0.9% with the rest of the tropics (Groombridge 1992). The notable cost of the decrease of natural habitat is the decline of fauna and flora's diversity and subsequently resulting to the decrease of ecosystem services, organisms' interactions, destabilization, and degradation.

Up to this point, limited studies embark around the biodiversity of cleared and fragmented land in the tropics, as compared to temperate areas where there are numerous studies alluding to the diversity, functions and interactions in the agricultural systems. Carabids are cosmopolitan, with species richness highest in the tropical regions (Erwin 1982). However, our knowledge stems from research conducted in temperate regions of the northern hemisphere, resulting in inevitable bias. Despite their significant role in the ecosystem, ecological studies of ground-

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dwelling beetles are rather scarce in the northeastern hemisphere, particularly in Asia (Magagula 2003, Padayachi et al. 2014). The majority of studies focus on beetles in northern hemisphere, where the taxonomy and ecology of this group of beetles are well-known (Thiele 1977, Atlegrim et al. 1997, Fahy and Gormally 1998, Jukes et al. 2001, Woodcock et al. 2003). Although sporadic studies of ground-dwelling beetles have been conducted in the Philippines, these have focused primarily on the tiger beetles and cannot be used to account for the total number and diversity of carabids in the country. The Philippines is characterized by considerable insect diversity, thus, the study of insect diversity is of great value. Baltazar (2001) reported that Coleoptera in the Philippines included 87 families, 1567 genera, and 7375 species with 5840 being endemic. However, very little attention has been given to the beetle communities, their conservation status, and the likely influence of habitat fragmentation and anthropogenic activities on these communities in the Philippines. This, being a pioneer study aims to identify the occurrence and habitat preferences of carabid beetles and analyze species richness, diversity and distribution of carabid beetles in different forests and habitat types in Lake Danao, Mount Ncolod, Kuapnit Balinsasayao, Asug Forest, City Forest, and Closed Canopy Forest in Eastern Visayas to provide baseline data for the conservation of carabid beetles.

II. METHODS

Site selection. The study was conducted in selected forests of Eastern Visayas: (1) Lake Danao National Park of Ormoc City, Leyte; (2) Kuapnit Balinsasayao National Forest of Abuyog and Baybay City, Leyte; (3) City Forest and Marble Park in Calbayog City, Samar; (4) Asug Forest Reserve, Biliran; (5) Mount Nacolod Forest in Silago, Southern Leyte; and (6) Borongan-Llorente Closed Canopy Forest in Borongan, Eastern Samar (Fig. 1). These forests were chosen based on (1) slope position (incline extending from ≥8-18% can be utilized for regular and lasting yield generation), (2) cultivated area is located near the forest, (3) portions of the forest have been formed by slash-and-burn practices, and (4) contains areas under current cultivation. These forests are either declared as protected areas or proposed protected areas by the Department of Environment and Natural Resource (DENR) of Eastern Visayas.

Survey methods. Carabid beetles were collected using pitfall trapping and manual collection and/or searching the ground. The pitfall traps were 500-ml plastic containers (11.4 cm long x 11.4 cm wide x 8 cm high) which were half-filled with bait substance and were buried in the ground so that the top of the trap was at the soil surface. One hundred traps were placed in every habitat type at each forest with a total of 200 pitfalls traps placed in every study site. The traps were arranged in square grids with 20 m between adjacent traps to avoid trap interactions (e.g., the "digging in" effect [Hoekman et al. 2017]).

After a 2-wk comparison of baits, we decided to use vinegar, vinegar with catsup, fermented fish with vinegar, and ground meat as attractants in the traps. Pitfall traps captured carabid beetles using these bait materials, while previously used baits did not effectively capture any carabid beetles. A 13 x 13 cm piece of metal was secured over each trap as a shield from rain, litter, and disturbance by animals. Traps were emptied and refilled twice weekly at which time carabids were collected and returned to the laboratory for sorting and identification.

Meanwhile, hand picking/searching on the ground (GS) was conducted by actively searching for the beetles on the ground, in leaf litter, under logs and other substrates, under tree bark, and in rotting deadwood. Sixty man-hours were spent in active searching for each visit at each site, occurring primarily between 2000 and 2300 h, as most carabid beetles are nocturnal. Collections were made 4 times a month over 6 months (i.e., January-June 2019) for each site.A 0.5-cm mesh screen was used to sift dry leaf litter for carabid beetles. Moist leaf litter was scooped onto white clothes and a pair of forceps was used to collect beetles. Likewise, resting and running beetles were sampled by manual searching under logs, stones and tree bark. Collecting took place both during the day and at night. All specimens were transferred into a killing agent preservative (9.0:0.5:0.5 parts of 70% ethyl alcohol, table vinegar, ethyl acetate (3:1) as per Hoekman et al. (2017).

Identification. Carabids were identified to the species level when possible using the works of Thiele (1977), Lindroth (1949), Scholtz (2005), Luff (1987), Kirschenhofer (2008), and Trautner et al. (1987). All identifications were confirmed by Dr. Bernard Lassalle (French Entomological Society, France) and Dr. Rainer Schnell (University of Duisburg Essen, Germany). Representative specimens are stored in the Biology Laboratory, Leyte Normal University, Philippines.

Vegetation survey. In each study site, 40 x 5 m (200 m^2) (Gillison, 1981, 1988, 2000, 2001a, b) quadrats were established. To estimate plant richness in the open forest, all individuals of trees and shrubs were counted and identified observing the Braun-Blanquet Method. This method is based on 100% identification and listing of all species in the plots. At each plot, data collection was undertaken separately for each of the 3 canopy layers or vegetative stratifications. The vegetative strata used were: 1) ground layer, for plants of up to 2-m high; 2) understory, for plants whose leaf canopy reaches 2-m to 7-m high; and 3) the tree layer, for all plants over 7-m in height. At each layer data collection started with identification of all species present.

For the agricultural land or cultivated area, the plot size of each crop grown as well as single plants (e.g. pineapples, fruit trees, cassava), planted in between the crop patches was considered. The agricultural flora within the field was examined from January to June 2019. Depending on the homogeneity of the fields, a larger or smaller number of quadrates was placed in order to collect data which are representative of the whole area sampled.

Data Analysis. Besides Pielou's evenness index, Simpson's dominance index, and Shannon index of diversity, other measurments of diversity of carabid beetles for each forest were also consulted, namely: Simpson's diversity, Menhinick index and Margalef's index (Simpson 1949), and Sorensen's index of similarity (Sorensen 1948). And before the data were statistically analyzed, the data were first checked for normality, i.e. to guide on the appropriate tests to be employed. Since data obtained is not normally distributed, i.e. data on richness by method per habitat type, thus nonparametric Mann-Whitney U test which is equivalent to the independent two-sample t-test was used. This is an appropriate analysis to compare

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differences that come from same population when the dependent variable is ordinal (Leech, Barrett & Morgan, 2005). Furthermore, Kruskal-Wallis test was used to determine if there are statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable. PAST (Version 3.10) RStudio and softwares were used for calculation and plotting (Hammer et al. 2001).

III. RESULTS

In total, 7,844 carabid beetle individuals were collected, belonging to 25 genera and 41 species in the six selected forests of Leyte and Samar. There were 26 species recorded from the forest of Lake Danao, 32 species in Mt. Nacolod, 20 species in Kaupnit Balnsasayao Forest, 11 species in Asug Forest, 19 species in City Forest and 26 species found in Closed Canopy Forest. Mt. Nacolod garnered the most number of individual with 2315 which accounts for 31% of the total carabid beetles collected, followed by Lake Danao and Closed Canopy with 1647 and 1198 individuals acoounting for 22% and 16% respectively.

Out of 7844 individuals, 1251 were *Pheropsophus hassenteufeli*, 1149 were *Tricondyla aptera punctipennis*, 719 were *Tricondyla conicicollis*, 651 were *Tricondyla ovicollis*, 625 were *Pheropsophus azouleyi*, and 496 were *Pheropsophus lumawigi*, respectively, accounting for 19.54, 14. 64, 9.2, 8.30, 7.97, and 6.32 % of the total number of carabid beetles collected. These were the top most species with the highest number of individuals all throughout the forests and were considered dominant species. All the remaining species comprising less than 5% were considered common and rare species.

Of the six forest, Mt. Nacolod had comparatively high diversity (4.00). equitability (0.78), dominance (2.709), and species richness (32); Lake Danao and Closed Canopy forests had almost the same values in high diversity (3.37), equitability (0.86), dominance (2.798), and species richness (26). Indices for Kuapnit and City forests did not differ significantly, both have low diversity (2.787 and 2.464), high equitability (0.85 and 0.89), dominance (2.53 and 2.58), and species richness (20 and 19), but were relatively lower than Mount Nacolod. Asug forest got the lowest indices value for both dominance, diversity and species richness

A total of 41 species belonging to 25 genera in two subfamilies were identified among 3,771 carabids collected from an open forest of six selected forests of Leyte and Samar. In agricultural habitat type, 28 species were identified from 4, 073 carabid beetles. Species like *Trigonotoma goeltenbothi*, *Prothyma heteromallicollis, Pheropsophus sp., Pheropsophus nigerrimus, Orthogonius luzonicus, Haplochlaenius femoratus philippinus*, *Oodes sp.*, *Trichotichnis sp.*, *Lebia Poecilothais sp.*, *Catascopus aequatus, Pentagonica sp., Dicranoncus philippinensis, Dolichoctis gilvipes, Tachys sp.,* and *Cicindela sp.* were exclusively found in an open forest. The rest of the species were both found in open forest and agricultural land

Both the open forest and agricultural sites were dominated by *Pheropsophus hassenteufeli* and *Tricondyla aptera punctipennis* (20% and 16.51%, respectively). Twelve species accounted for less than 5% of the caught (less than approximately 50 individuals) (Table 3.4). In agricultural lands, *Pheropsophus*

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hassenteufeli, *Pheropsophus azouleyi*, *Tricondyla aptera punctipennis*, *Tricondyla conicicollis*, and *Pheropsophus lumawigi* were relatively abundant species than in open forests.

Natural forest had comparatively high diversity (5.95), high equitability (0.80), dominance (3.1), and species richness (41) over agricultural land. The use of Mann-Whitney U test between richness of forest and agricultural land showed significant, i.e. p-value = 0.01722, indicating that the mean abundance of forest richness is significantly different from the mean abundance of agricultural richness. Along with other factors, these habitat parameters are influenced by the nature of the vegetation. In this study, no correlation was shown between the number of species and different physico-chemical parameters. The result of the correlation test indicates that the number of carabid species is not due to any of the physico-chemical parameters, such as pH, % OM. Total N, available P, and exchange K.

Different forest eosystems as study sites in this study showed different values in soil physico-chemical paramters. In terms of pH, Kuapnit forest garnered the highest value, around 7.1, followed by Lake Danao with 5.6. Closed Canopy and Mt. Nacolod almost have the same pH with 5. City forest has a pH of 4.8 and Asug forest has the lowest pH recorded at 4.5. For the result of organic matter (%OM), both Lake Danao and Mt. Nacolod have 5.0, showing a higher percentage over the other forests. Available phosphorus in soil showed that Kaupnit forest has the highest at 139.507 mg/kg, followed by City forest, Closed Canopy, Asug forest, and Mt. Naccolod respectively. For the total N, Lake Danao garnered the highest value of 0.449 %, followed by Kaupnit forest with 0,424 %, Closed canopy with 0.128%, Asug forest with 0.122; lagging behind are Mt. Nacolod and City forest with 0.116 % and 0.105%, respectively. For the parameter of exchange K, it showed that Kaupnit forest has the highest value with 411.350mg/kg, Lake Danao with 373.580 mg/kg, followed by Asug forest, City forest, Closed Canopy, and Mt. Nacolod with 147.795, 135.050, 121.973, and 70.911 mg/kg, respectively.

Communities can differ in a number of ways. Considering both flora and fauna components of a system, two communities can differ in species composition (taxonomy), total number of species (richness), and the relative abundance of species (evenness). Species diversity refers to a community level concept that combines both richness and evenness. In terms of species assemblage, Lake Danao and Mt. Nacolod are more similar with computed Sorensen's index of similarity of 0.66 . The two forests shared 19 common species. On the other hand, City Forest and Closed Canopy Forest are also more similar with a Sorensen's index of similarity of 0.67, sharing 13 similar species.

IV. DISCUSSION

Different habitat types are one of the important factors affecting species diversity in an area. This study presented the differences in species composition and diversity of carabid beetles in different habitat types among the selected forests of Leyte and Samar. Open forest had higher ground beetle species diversity than agricultural field. This result is in consistent with the findings by Abayon, (2020); where open forest yielded high number of carabid beetle species than agricultural field, and was consistent in the

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six open forest ecosystems studied; Yu et al. (2009) and Warren-Thomas et al. (2014), where open oak forest showed higher diversity than cultivated farmlands in northern China, North America, and Europe (Fahy and Gormally 1998, Magura et al. 2003, Finch 2005). Farmland represented an agricultural habitat type, and its community structure was dissimilar from that of forest habitats in terms of its vegetation, unique microenvironmental conditions due to interference of agricultural activities, such as plowing and sowing (Rusch et al. 2013), impacts of different crops (Liu et al. 2010), and application of fertilizers (Schröter and Irmler 2013).

In this study, agricultural habitat type showed a higher abundance but lower diversity with relatively high uniformity and dominance indices. Garnering a total of 28 species from a total of 4,073 individuals is much lower than an open forest with 41 identified species from 3,771 individual carabids. This can be attributed to several species occurring in greater numbers causing decreased equitability and dominance. For example, *Pheropsophus hassenteufeli* and *Tricondyla aptera punctipennis* accounted for 38 % of the total agricultural carabids, which demonstrates the sensitivity of the diversity index to changes in species abundance, and also shows that abundance directly affects community structure and biodiversity. Species composition and the number of ground beetles in different habitat types differ and depend on edaphic factors (Bukejs and Balalaikins, 2008). Carabid beetle species contribute significantly to the insect diversity in farmland because many species are adapted to agriculture and generally occur at high densities (Booij, 1994). According to Thiele (1977) and Kromp (1999) cultivated land is comprised of widely distributed, eurytopic ground beetle species, many of which have high tolerance to disturbances.

In the present study, the main reason for the low species diversity towards agricultural field was assumed to be the loss of micro habitats towards the agricultural land. In the forest the vegetation is composed of trees, bushes, ferns, epiphytes and undergrowth vegetation which in total provides a manifold structure of plant organs from the bottom up to the canopy, thus a high number of micro habitats. In the agricultural land, a smaller number of habitats is composed by similar crop plants and weeds. Similarly, but only regarding Lepidoptera, Schulze et al. (2004) reported a decrease in diversity from the forest towards the agricultural field, when sampling the abundance of Lepidoptera species richness from an open forest towards maize fields on Sulawesi. With regards to carabid beetles, Baranová et al. (2013) found a significant lower diversity of species in cultivated land, compared to primary forest. They also related the loss of carabid species in the modified habitats of the agricultural land to a loss of microhabitats. Furthermore, decrease of carabid richness in the agricultural lands in the current study is likely to be associated with changes in ecosystem properties triggered by agricultural practices. This decrease of species richness from an open forest to cultivated areas is consistent with several published studies (Bonham et al. 2002; Finch 2005; Vanbergen et al. 2005; Packeman & Stokan 2014).

In addition, carabid beetle richness and composition are also affected by microclimatic factors, such as soil water content and ground surface temperature (G.Lövei and K. D. Sunderland, 1996). Because of their close associations with vegetation structure undergoing natural and anthropogenic changes and the microclimatic variations associated with such changes (Niemelä et al. 2002), carabid beetles have been suggested to serve as useful bioindicators of environmental change. Although, in the present study, the result showed no correlation between the number of species and soil parameters but species composition of carabid beetles has been shown to change across habitats characterized by different vegetation structures, such as the presence of a tree canopy or forest type which is the same to the result of the study of Isaia, M. et al. (2015). The richer vegetation found in natural forest compared to limited number of crops in the agricultural land could be the factor resulting to a higher species diversity in the forests than in agricultural land. Habitat type is in that case more influential.

Differences in ground beetle assemblages between forest types or management regimes have been widely examined but only rarely at national, regional, or larger spatial scales (Kotze and O'Hara 2003). This study involving forests of Leyte and Samar, to the best of my knowledge, represents the first study of carabid beetle communities in Region 8. The recorded 41 species with 9 species still to be identified, under 25 genera will be used as a substantial baseline information about carabid beetle's diversity and community structure.

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