DIVERSITY AND ABUNDANCE OF CANOPY BEETLES IN A FOREST RESTORATION SITE IN LUASONG, TAWAU, SABAH, MALAYSIA

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ABSTRACT

A study on the canopy beetle's diversity was conducted at Species Demo Plot in Luasong, Tawau, Sabah, Malaysia. This is a part of a forest restoration project under the Innoprise-IKEA (INIKEA) Forest Rehabilitation Program managed by Yayasan Sabah. This study focused on the beetle diversity on the canopy of 11-year-old trees. The objectives of this study were to compare the diversity of canopy beetles between the Dipterocarps and non-Dipterocarp trees and to compare the abundance of canopy beetles between the two group of trees. Fogging method using handheld pyrethrum insecticide was performed to sample the canopy arthropods. The trees that were sampled were *Dipterocarpus conformis*, *Dryobalanops lanceolata* and *Hopea ferruginea* from the Dipterocarp group, and *Diospyros* sp., *Pentace laxiflora* and *Mangifera odorata* from the non-Dipterocarp group. Results showed that the Shannon-Wiener Diversity Index, H' for the canopy beetles for Dipterocarp tree was 3.5827 while for non-Dipterocarp was 3.2986 which indicates a high diversity of canopy beetles of both tree groups. Study showed that there is no significant difference between the Shannon-Wiener Diversity Index between two groups (T-test, t=1.237, df=22, P>0.05). In addition, there is no significant difference in the abundance of beetles between the Dipterocarp and non-Dipterocarp group (T-test, t=0.958, df=18, P>0.05) and between the tree species (ANOVA, F=1.098, df=22, P>0.05). The outcome of this study can be used as appropriate guidelines to manage restoration projects, by using canopy beetle diversity and abundance on various tree species as indicator of biodiversity recovery. In the future, studies should be conducted by comparing the beetle composition across multiple stages of restoration projects which varies in forest condition and structures.

Keywords*:* Restoration, canopy beetles, diversity, Dipterocarp, non-dipterocarp

ABSTRAK

Kajian mengenai kepelbagaian kumbang kanopi telah dijalankan di kawasan Plot Demo Spesies yang terletak di Luasong, Tawau, Sabah, Malaysia. Ia merupakan sebahagian daripada kawasan restorasi di bawah projek Program Restorasi Innoprise-IKEA (INIKEA) yang diurus oleh Yayasan Sabah. Kajian memfokuskan kepada kepelbagaian kumbang kanopi pada pokok berusia 11 tahun. Objektif kajian ini adalah untuk membandingkan kepelbagaian kumbang kanopi di antara pokok Dipterokarpa dan bukan Dipterokarpa dan membandingkan jumlah individu kumbang di antara kedua-dua kumpulan pokok tersebut. Artropoda kanopi disampel dengan menyembur racun serangga pyrethrum melalui kaedah semburan kabut. Pokok yang disampel adalah *Dipterocarpus conformis, Dryobalanops lanceolata* dan *Hopea ferruginea* dari kumpulan Dipterokarpa serta *Diospyros* sp.*, Pentace laxiflora* dan *Mangifera odorata* dari kumpulan pokok bukan Dipterokarpa. Kajian menunjukkan bahawa Indeks Kepelbagaian Shannon-Wiener H' untuk kumbang kanopi pada kumpulan pokok Dipterokarpa adalah 3.5827 dan 3.2986 untuk kumpulan pokok bukan Dipterokarpa. Ini menunjukkan terdapat kepelbagaian kumbang kanopi yang tinggi bagi kedua-dua kumpulan. Tiada perbezaan yang signifikan diantara kepelbagaian kumbang untuk kedua-dua kumpulan pokok (T-test, t=1.237, df=22, P>0.05). Selain itu tiada perbezaan yang signifikan di antara jumlah individu kanopi kumbang untuk kedua-dua kumpulan pokok (T-test, t=0.958, df=18, P>0.05) dan di antara spesies pokok (ANOVA, F=1.098, df=22, P>0.05). Hasil kajian boleh digunakan sebagai panduan yang sesuai untuk menguruskan projek restorasi dengan menggunakan kepelbagaian dan kelimpahan kumbang kanopi pada pelbagai spesies pokok sebagai petunjuk pemulihan kepelbagaian biologi. Kajian pada masa akan datang boleh dilakukan dengan membandingkan komposisi kumbang bagi pokok yang ditanam di pelbagai projek restorasi yang berbeza dari segi keadaan dan struktur hutan.

Kata kunci: Restorasi, kumbang kanopi, kepelbagaian, Dipterokarpa, bukan Dipterokarpa

INTRODUCTION

Tropical rainforests are known to promote extremely rich species of arthropod assemblages in the world (Itioka et al. 2015). With nearly 400,000 described species, beetles from the order Coleoptera are among the most diverse and important groups of animals on Earth (Bouchard et al. 2014). In relation to the forest vegetation, juvenile and adult beetles are known as groups that feed on different parts of trees from the roots up to the youngest shoots. Besides, Coleopterans play important roles as scavengers, predators, pollinators and soil engineers in the forest ecosystem (Toivanen et al. 2009). Beetles that are classified as pests includes the herbivorous and wood feeding groups. The herbivorous group in particular, are beetles that are commonly found on the foliage of young seedlings as well as trees (Chung et al. 2001; Chung et al. 2013). Herbivorous beetles that live on the canopy of trees are usually associated with food preference that determines their host specificity. In the tropical forest ecosystem, the knowledge of beetles' host specificity is central for understanding food web dynamics and biodiversity patterns (Wardhaugh et al. 2014). This explains why beetle fauna is commonly studied (Grove & Stork 2000).

In restoration projects, planting selected tree species to improve the quality of the forests involves intensive planning which can influence the desired result of the management. The common consideration includes selecting various tree species with low mortality when introduced to the degraded area, high crown density, the food source for seed-dispersed animals and easy to be planted during the initial planting in the nursery (Meli et al. 2014). While various studies focused on the selection of dipterocarp trees, studies focused on the tree parameters such as survivability and tree growth such as tree height and diameter (Wasli et al. 2014; Widiyatno et al. 2020; Yeong et al. 2016). Similarly, study on non-Dipterocarp trees were also conducted focusing on the similar parameters (Safa 2004). However, there is a still lack of study in relation to the species selection of trees that can help to facilitate the recovery of insect community in a restoration forest, particularly canopy insects. Insect community is often incorporated later to the management mostly as indicator of biodiversity recovery (Halamova 2017; Mustafa 2016). This information is worth to be explored since different tree species found to support various community of organisms, particularly insects (Schulz & Wagner 2002; Wagner 2000).

This study intended to compare the diversity and abundance of canopy beetles between Dipterocarp and non-Dipterocarp trees. This information is beneficial for decision-making stage for various managements and stakeholders as a supplementary guideline in selecting the appropriate tree species that can help to rebuild the ecosystem in degraded ecosystems areas.

MATERIALS AND METHODS

This study was conducted at Species Demo Plot, located in Tawau, Sabah. The area was developed under the Innoprise-IKEA (INIKEA) Forest Rehabilitation Project located in Tawau, Sabah. Trees were planted in 2008 in a line planting method with a distance of two meters apart. This study focused on the beetle diversity on the canopies of Dipterocarp and non-Dipterocarp trees. A total of three Dipterocarp and three non-Dipterocarp tree species were chosen for this study. Each tree species is represented by four replicates. The mean height of trees is 5.66 (SE±0.51) meter while the mean diameter is 3.84 (SE±0.46) cm. A one-time sampling visit was conducted on each tree canopy in August 2017 for a period of one month. Sampling was conducted in the early morning between 7.00 am to 11.00 am. Sampling during strong wind and the raining day was avoided. Sampled trees were chosen based on the location, height, crown sizes and accessibility of tree canopy at the site.

Canopy beetles were chosen for the study due to its abundant communities on tree canopies (Stork & Grimbacher 2006) as well as known to be important groups on the canopy such as detritivores, herbivores, frugivorous and predators (Lassau et al. 2005). Canopy beetles were sampled using fogging method. Fogging method is a common method used to sample canopy arthropods (Chung et al. 2001; Dial 2006). With the modification of using handheld pyrethrum insecticides, fogging technique was applied to the chosen tree canopy. Prior to the fogging activity, a white canvas was laid out underneath the tree canopy. Fogging was then conducted for 30 seconds, followed by another 30 seconds to wait for the insecticide to take effect and knock down the insects. The trees were then shaken to allow the knocked-down insects to fall onto the white canvas. Insects collected from the canvas were kept inside the vials containing 70% alcohol solution for preservation. All insects were sorted according to insect orders. Mounted beetle specimens were brought to Sabah Forest Research Centre (FRC) for identification. Classification of beetle is based on Chung (2003). Analysis for this study was conducted using PAST Software version 3.20 and IBM SPSS Statistics version 21.0.

RESULTS AND DISCUSSIONS

This study recorded a total of 122 beetle individuals consisting of 68 species from 19 families, including five unidentified species (Table 1). Beetles from the family Chrysomelidae yielded the highest number of beetle species with a total of 21 species. Chrysomelid beetles are well known as leaf beetles and highly recorded due to their feeding range. The high occurrence of Chrysomelid beetles on the canopy is related to their natural feeding behaviour that mainly feeds on leaves (Chung et al. 2001). Besides feeding on leaves or subterranean parts of plants, some species are also leaf-miners or consumers of dead plant material (Riley et al. 2002). Based on the species accumulation curve that still increases progressively after the sampling has been completed (Figure 1), it is expected that more beetle species can be found on the tree canopies at the site.

Table 1. Total number of beetle species recorded on the tree canopy according to respective beetle families

Beetle Family	**No of Morph Species**
Chrysomelidae	21
Staphylinidae	7
Anthicidae	5
Coccinellidae	5
Unknown	5
Curculionidae	4
Eucnemidae	4
Anobiidae	2
Lagriidae	2
Lycidae	2
Scolytinae	2
Cerambycidae	1
Mordellidae	1
Scarabaeidae	1
Scaphidiidae	1
Erotylidae	1
Hybosoridae	1
Leoididae	1
Phalacridae	1
Tenebrionidae	1
Total	**68**

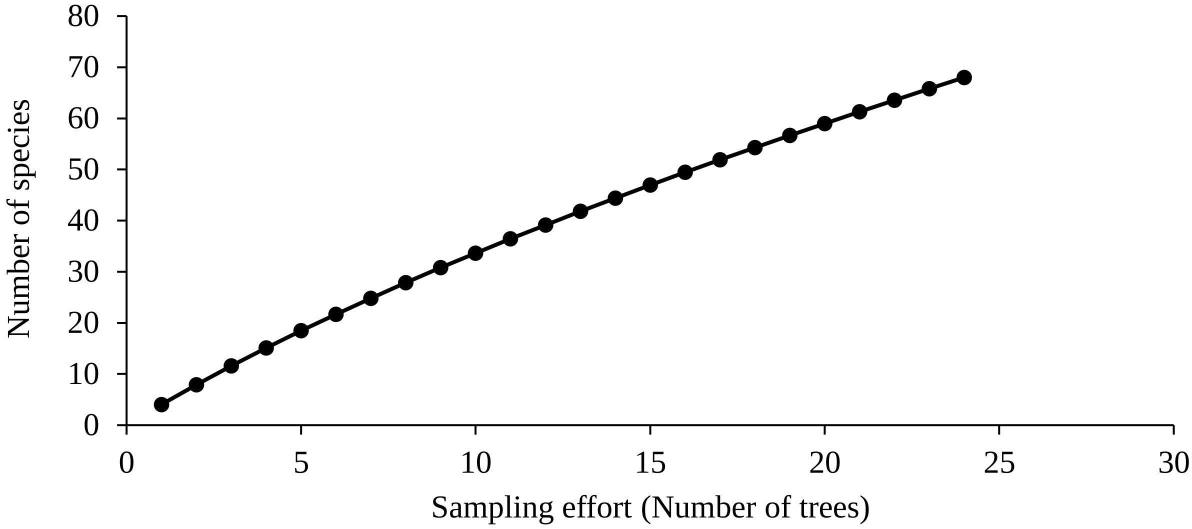

Figure 1. Species accumulation curve of beetles captured at Species Demo Plot

Table 2 shows a comparison of beetle species composition between the Dipterocarp and non-Dipterocarp trees. A total of 65 individuals from 44 species and four unknown species were recorded at Dipterocarp trees. Meanwhile a total of 57 individuals from 33 species and one unknown species were recorded at non-dipterocarp trees. Beetles were most abundant on the canopy of *Hopea ferruginea* followed by *Mangifera odorata* and *Diospyros* sp., as shown in Figure 2. The abundance of beetles recorded in the canopies of *Hopea ferruginea* may be related to the feeding preference of the herbivorous beetles towards the leaves of Dipterocarp family. Generally, Dipterocarp trees exhibit leaves characteristics related to the insect feeding preference, including phenolic content, laminar fracture toughness, laminar thickness, and nitrogen content (Eichhorn et al. 2007).

Table 2. Comparison of total beetle individuals pe family recorded between Dipterocarp and non-Dipterocarp trees

Beetle Family	**Dipterocar**	**Non-Dipterocarp**	**Total**
Chrysomelidae	21	21	42
Eucnemidae	4	9	13
Coccinellidae	8	4	12
Staphylinidae	8	2	10
Anthicidae	2	6	8
Anobiidae	6	1	7
Curculionidae	4	2	6
Unknown	4	1	5
Lycidae	1	2	3
Scolytinae	1	2	3
Lagriidae	2	0	2
Hybosoridae	0	2	2
Phalacridae	0	2	2
Cerambycidae	1	0	1
Mordellidae	1	0	1

Scarabaeidae	1	0	1
Scaphidiidae	1	0	1
Erotylidae	0	1	1
Leoididae	0	1	1
Tenebrionidae	0	1	1
Total	**65**	**57**	**122**

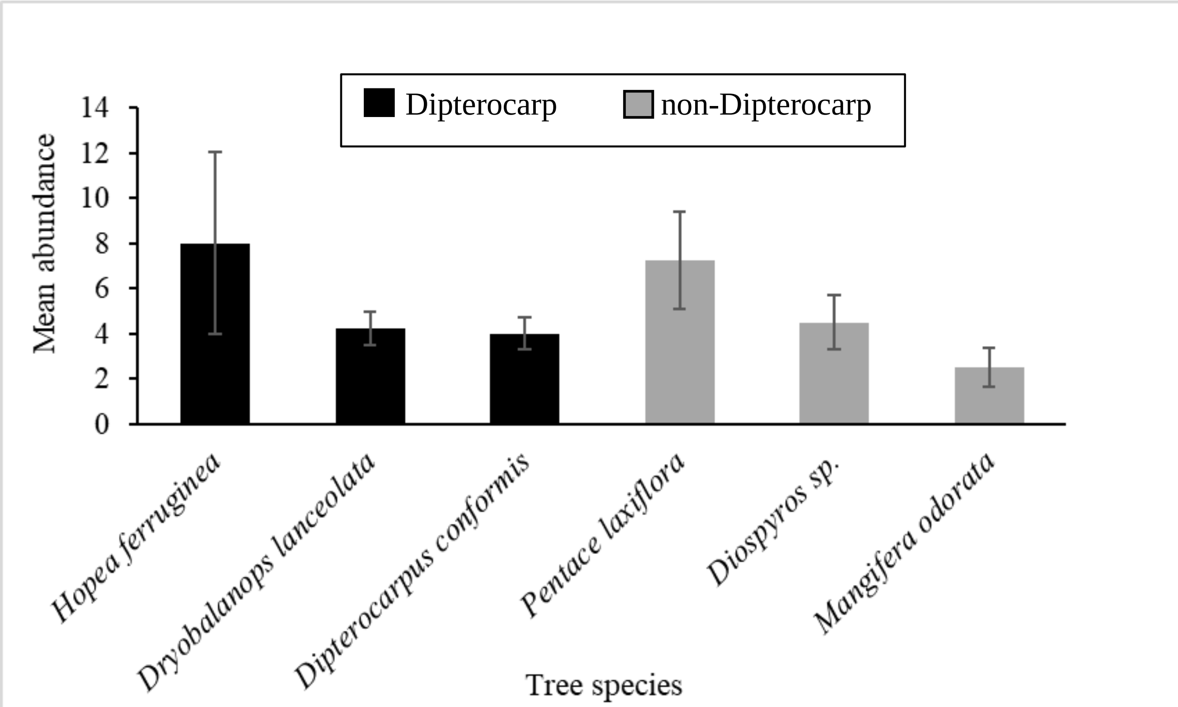

Figure 2. Mean (±SE) beetle abundance recorded on the canopy of Dipterocarp and non-Dipterocarp trees

The Shannon-Wiener Diversity Index value, H' of canopy beetles for both Dipterocarp and non-Dipterocarp trees were 3.5827 and 3.2986 respectively. The values exceed 3.00 indicate a high diversity of beetles (Magurran 2004). The high diversity and abundance of canopy beetles could be due to the various roles of beetle family in the forest ecosystem. In addition, the diversity is also related to the beetle's feeding behaviour. According to Odegaard (2000), beetles that feed on green parts or flowers petals and fruits consist of 1/3 of the herbivorous insect on earth. Therefore, the availability of food resources on the tree canopy of both Dipterocarp and non-Dipterocarp explains the high number of herbivorous beetles found in this study.

The comparison shows that there was no significant difference between the diversity of beetles, H' among Dipterocarp and non-Dipterocarp trees (T-test, t=1.237, df=22, P>0.05). Similarly, there is no significant difference of beetle abundance between the Dipterocarp and non-Dipterocarp trees (T-test, t=0.958, df=18, P>0.05) and between the tree species (ANOVA, F=1.098, df=22, P>0.05). The 11-year-old trees are relatively similar in height and diameter; and were planted with a distance of two meter. This may allow the beetles, particularly for abundant groups such as Chrysomelidae and Curculionidae to forage from one tree canopy to another. In a dense area with multiple tree species, the high availability of food sources may reduce the chance for specialist beetles to encounter its' specific hosts, thus resulting in a similar abundance and diversity of canopy beetles across the trees (Kambatch et al. 2016). Likewise, Wagner (2000) found that the canopy beetles' community are similar across tree species sampled within the same forest area, as compared to tree species that were planted in different forest types. Probably, undertaking measures such as comparing the beetles' diversity and abundance on tree species planted across the various stage of restoration area which possesses different forest conditions and structures could show another interesting result in the future.

CONCLUSION

In conclusion, results from this study showed a high diversity and abundance of beetle community on the canopy of Dipterocarps and non-Dipterocarp trees. Beetles of the Chrysomelidae family were the most abundant beetle family, with 21 morphospecies recorded across all the canopies of Dipterocarp non-Dipterocarp trees sampled in this study. In terms of abundance, the beetle community was highest on the canopy of *Hopea ferruginea* with a total of 32 individuals. There is no significant difference between the Shannon-Wiener Diversity Index, H' between the Dipterocarp and non-Dipterocarp trees (T-test, t=1.237, df=22, P>0.05). Comparison of canopy beetle abundance among the tree groups showed no significant difference (T-test, t=0.958, df=18, P>0.05). Similarly, there was no significant difference in canopy beetle abundance among the tree species (ANOVA, F=1.098, df=22, P>0.05). It is recommended that similar studies be conducted on trees planted in different stages and different sites of restoration forests.

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