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Dung Beetles (Coleoptera: Scarabaedae) Composition to Three Different Ecosystem Functions: A Study Case in Malaysia

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Highlights

- Dung beetles from three ecosystems has been collected, which are from secondary forest, recreational forest, and wetland forest.
- Secondary forest (Sungkai) contains highest individuals and species collection throughout the study with 1,486 individuals and 25 species.
- Sungkai also holds the highest Shannon-Wiener (H') diversity index with 2.52, shared with BRF with 2.17.

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Dung Beetles (Coleoptera: Scarabaeidae) Composition to Three Different Ecosystem Functions: A Study Case in Malaysia

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Abstrak: Kumbang najis (Coleoptera: Scarabeidae) sensitif terhadap komposisi, perubahan dan kehilangan habitat. Kajian ini dijalankan bagi mengkaji kepelbagaian kumbang najis di tiga ekosistem hutan yang berbeza. Enam lokasi persampelan mewakili hutan sekunder (Hutan Simpan Bangi [BRF] dan Hutan Simpan Sungkai, Sungkai), hutan rekreasi (Pulau Langkawi, Langkawi dan Bukit Fraser [FH]) dan hutan tanah bencah (Tasik Bera [BL] dan Tasik Chini [CL]) telah dipilih. Sejumlah 15 perangkap lubang yang disusun di dalam tiga transek dengan menggunakan ikan busuk sebagai umpan telah dipasang. Sampel kumbang najis diambil dalam setiap 24, 48 dan 72 jam. Sejumlah 3,920 individu dengan 40 spesies telah berjaya dikumpulkan dengan Sungkai merekodkan jumlah tertinggi dan diikuti oleh CL, BRF, FH dan Langkawi. Berdasarkan dendrogram, kedua-dua kawasan tanah bencah dikumpulkan di dalam klad yang sama disebabkan kesamaan yang tinggi dalam komposisi spesies. BRF dan Langkawi juga berada dalam kumpulan yang sama yang mungkin disebabkan berlakunya "kesan pulau" terhadap BRF. Bagi komposisi spesies pula, Klad 1 dan 2 merupakan spesies yang umum yang kurang spesifik terhadap kebanyakkan ekosistem, manakala Klad 3 dan 4 lebih spesifik terhadap ekosistem tertentu. Kesimpulannya, selain kumbang najis digunakan bagi menentukan tahap kesihatan ekosistem, ia juga boleh menjadi spesifik kepada jenis ekosistem.

Kata kunci: Kumbang Najis, Kepelbagaian, Indikasi, Jenis Hutan

Abstract.: Dung beetles (Coleoptera: Scarabaeidae) are sensitive towards habitat composition, change, and loss. This study was carried out to investigate the diversity of dung beetles in three forest ecosystems and the habitat association. Six sampling sites represented secondary forest (Bangi Reserve Forest [BRF] and Sungkai Reserve Forest, Sungkai), recreational forest (Langkawi Island, Langkawi and Fraser's Hill [FH]) and wetland forest (Bera Lake [BL] and Chini Lake [CL]) have been chosen. A total of 15 pitfall traps were set up in three line transects rotten fish as bait. The dung beetles were collected in 24 h, 48 and 72 h. A total of 3,920 individuals with 40 species were successfully collected in which

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Sungkai has the highest collection followed by CL, BRF, FH, and Langkawi respectively. Based on the dendrogram, both wetlands site clustered together due to high similarity of species composition. BRF and Langkawi are also clustered together which may due to "island effect" occurred to BRF. In term of species composition and distribution, species from Clade 1 and 2 considered as less specific towards environment due to its presence in most ecosystems, while Clade 3 and 4 are more specific to certain ecosystem. In conclusion, besides dung beetles are used to measure ecosystem healthiness, it also can be specific to certain ecosystem types.

Keywords: Dung Beetle, Diversity, Indicator, Forest Type

INTRODUCTION

Logging, urbanisation, and deforestation were the common problems that forests facing all around the world (Gardner *et al.* 2009). Unfortunately, there are no efforts that come close to overcome the challenge as human needs were always come first before nature (Rands *et al.* 2010). Even though there were lots of researches has been done on the loss of diversity due to forest disturbance (Ostfeld & LoGiudice 2003; Barragan *et al.* 2011), yet the flora and faunal diversity are kept shrinking each year.

The species diversity has been vastly studied by many researchers, regardless of any species of plants or animals. It is important to know how diverse actually do the environment provide and what has been lost or extinct. Even though we have reached a consensus that ecological studies are the fundamental knowledge for conservation efforts, but it has been a debate on this issue (Ricotta 2007; Moreno & Rodrıguez 2011; Tuomisto 2011). Even so, it is still back to basic which the diversity data of certain area must be known before any further action to be taken.

The results of the forest disturbances and disruptions are that the forest becomes small, patch, and more open. These situations, however, are not necessarily become negatively affecting the flora and faunal diversity (Barlow *et al.* 2007). For some of the insect's diversity such as several species of Braconidae wasps is more populated in open forest area. This occurrence is known as hyperdynamism where a particular species increase the population in the more disturbed area (Yaakop & Aman 2013). However, for most organisms, forest disturbances will negatively be affecting the diversity and population (Barlow *et al*. 2007).

To measure the healthiness of ecosystems, dung beetles (Coleoptera: Scarabaeidae) can be considered as a consistent and precise indicator to be used (Davis 2000; Davis *et al.* 2001). Because of dung beetles has a close relationship with mammals, the absence of the mammals can be reflected through the dung beetle's diversity, distribution, and population (Harvey *et al.* 2006; Yamada *et al.* 2014). Mammals are the main food contributor for the dung beetles besides carrion, fungi, and other decaying materials (Marsh *et al.* 2013). Dung beetles also functioned as secondary seed dispersal and improve soil quality and aeration as well (Nichols *et al.* 2008).

Habitat fragmentation pushes dung beetles to either adapt, move to other locations, or will vanish from the forest (Shahabuddin 2010). This is due to lacking food supplies as mammals also diminishing from the forest as well. A small patch of forest is tending to hold smaller body-sized dung beetles besides in a smaller population compared to undisturbed forest (Muhaimin *et al.* 2015). So in this article, the objectives were to determine the diversity of dung beetles in several types of selected forest namely; secondary forests, recreational forests, and wetland forests. Secondary forest are expected to have the most diversity and composition compared to recreational and wetland forests. Besides that, we also would like to study the specificity of dung beetles' species towards the habitat type.

MATERIALS AND METHODS

Study Site

Secondary forest

Two localities of secondary forest were selected for this study, which are Bangi Reserve Forest (BRF) and Sungkai Reserve Forest (Sungkai). BRF (02º 54.836' N; 101º 47.216' E) is a forest patch owned by Universiti Kebangsaan Malaysia (National University of Malaysia, UKM) in the state of Selangor, while Sungkai (03º 01.571' N; 102º 22.110' E) is located in the state of Perak. Both of these forests had experience series of logging activities or for the surrounding developments. Shahabuddin *et al.* (2005) classified secondary forests as it has the highest trees are not more than 15 m, shrubs with 2 m height, and the age is around 10 years. Both of the selected forests are applicable with the characteristics listed. BRF faced the logging period on 1941–1968 as for UKM's development during that time (Noraini 1990; Mat Salleh 1999), but still underwent the disruption but in slower and smaller pace. While for Sungkai, it is the land under the supervision of The Department of the Wildlife and Natural Parks (PERHILITAN), it covers an area of 2468 ha. This forest act as rehab forest for several protected species such as the Malayan Gaur (*Bos gaurus hubbacki*). The last recorded forest changed in this area is on 1957 (PERHILITAN 2015).

Recreational forest

Langkawi Island (Langkawi) and Fraser's Hill (FH) has been selected as representative to recreational forest study sites. Langkawi located in the Northern part of Peninsular Malaysia in the state of Kedah and the exact sampling location is in the foothills of Gunung Raya (06º 23.162' N; 099º 47.827' E). While for FH (03º 42.036' N; 101º 22.110' E) is located in the middle part of Peninsular Malaysia in the state of Pahang. As its status as recreational forest, it is important for the management to provide a convenient surrounding for the tourists (Irland *et al.* 2001). Due to that, the forests area can be expected to be frequently disturbed and altered to provide the facilities. The rate can be significant increases if the area becomes more populated with visitors (Malmivaara *et al.* 2002). Plus, large animals also can be expected to be moved to another forest as the safety into concern.

Wetlands

Two study sites for wetland forest ecosystem are Bera Lake (BL) (03º 58.120' N; 102º 30.120' E) and Chini Lake (CL) (03º 01.571' N; 102º 22.110' E) which both in the state of Pahang. Wetlands have its own water bodies which make up the surrounding ecosystem and add up the complexes of niches and habitat. BL has an area of 38446 ha, while CL has 5026 ha respectively.

Sample Collection

A sampling of dung beetles was performed from November 2013 until October 2014 by using 15 rotten fish-baited pitfall traps that aligned into three transects. The fish were left in the open area for two days before it used as bait to ensure it rots and smells strong. For each trap, approximately 10–20 g of rotten fish were used and placed into plastic cups. Small pails (20 cm diameter, 17 cm deep) were buried into the ground, and the bait was placed into the pail before a mixture of soap water poured into the pail (see Shahabuddin *et al.* 2010; Muhaimin *et al.* 2015). Each transect consists of five pitfall traps which aligned in a straight line or any possible line based on the surrounding condition. The distance between the traps were about 4–5 m from each other, and the distance between transects was 8–10 m apart. The traps were then left for 24 h before collecting the samples, and the collection repeated three times. Samples were kept in 70% alcohol for preservation and further identification processes in the laboratory. The dung beetles were identified by using pictorial guidance (Ek-Amnuay 2008), keys (Ochi & Kon 1996; Ochi *et al.* 1996; Kon *et al.* 2000), and collections from the Centre for Insects Systematics, UKM.

Data Analysis

It is fundamental to observe the diversity of species in every study site. Indexes such as Shannon-Weiner Diversity Index (H'), evenness (E), and richness (R') (Magurran 1988) compute with PAST software. Higher evenness will increase Shannon-Wiener index because of more stable of abundance from species collection during sampling. Higher occurrence of singleton and doubleton species will make the Shannon-Wiener index to decrease. The indexes were computed for each replication during the sampling period to test the consistency and comparing with other localities by one-way analysis of variance (ANOVA) at $p = 0.05$. Post-hoc Tukey test also was done to determine in which the difference was occurs, and presented as box-plot analysis by using Minitab var 17. To observe the distribution of the dung beetles species according to forest types, two-way cluster analysis or dendrogram were constructed by using PC-Ord version 5 software. While to analyse the connection towards the localities and species, Principal Component Analysis (PCA) was done by using Log_{10} approach to minimise the range of difference.

RESULTS

Dung Beetle Diversity

This study manages to gather a total of 3,920 individuals with 40 species from all sampling localities. The highest abundance is from Sungkai with 1,486 individuals and 25 species, followed by BL (952 individuals, 18 species), CL (587, 11), BRF (575, 10), FH (192, 13) and the site with least collection are Langkawi with 128 individuals and 11 species (Tables 1 and 2). Note that the most abundant species in this study are a small species of roller dung beetle, *Sisyphus thoracicus* (1,251 individuals) that can be found in all sites except in FH. *S. thoracicus*, *Onthophagus rudis*, *O. babirussoides* and *O. semifex* are the four most abundant species that contribute more than 50% of total sample collection. While there are also four least species which are a singleton (*O. aphodiodes*) and doubleton (*Caccobius unicornis*, *Ochicanthon peninsularis* and *O. javanicus*) that provide 0.18% of a total population sample.

Table 1: Checklist of the dung beetle species collected from all sampling localities.

Species	Secondary forest		Recreational forest		Wetland forest	
	BRF	Sungkai	Langkawi	FH	CL	BL
Caccobius unicornis	0	1	0	0	0	1
Catharsius molossus	46	133	1	0	0	3
Catharsius sp. *1*	34	0	0	0	0	0
Copris doriae	0	9	0	0	0	1
Copris ramosiceps	0	3	0	0	0	0
Microcopris hidakai	46	0	0	0	0	0
Ochicanthon peninsularis	0	1	0	1	0	0
Ochicanthon sp.	0	0	0	3	0	0
Onthophagus "obscurior group"	96	0	0	0	0	0

(*continued on next page*)

Table 1: (continued)

Species	Secondary forest		Recreational forest		Wetland forest	
	BRF	Sungkai	Langkawi	FH	CL	BL
Onthophagus avocetta	0	0	10	0	0	0
Onthophagus babirussoides	0	225	1	0	16	2
Onthophagus crassicollis	137	0	0	0	0	45
Onthophagus deflexicollis	0	0	0	63	0	0
Onthophagus aphodiodes	0	0	0	0	0	1
Onthophagus egregious	0	5	0	0	0	0
Onthophagus fujiii	0	1	0	0	0	10
Onthophagus javanensis	0	0	0	2	0	0
Onthophagus leusermontis	0	21	0	0	0	0
Onthophagus orientalis	0	11	10	1	2	0
Onthophagus pacificus	0	54	2	7	7	1
Onthophagus pedator	0	26	0	5	7	0
Onthophagus peninsularis	0	4	0	0	0	2
Onthophagus peninsulotagal	0	1	0	12	0	0
Onthophagus rorarius	0	0	10	0	0	0
Onthophagus recticornutus	25	0	0	0	0	0
Onthophagus rudis	0	138	56	7	21	154
Onthophagus rutilans	52	0	14	1	21	0
Onthophagus semifex	0	127	0	1	93	23
Onthophagus trituber	52	0	0	0	0	0
Onthophagus viridicervicapra	0	33	0	0	0	8
Onthophagus vulpes	0	77	0	0	37	10
Onthophagus waterstradti	0	0	0	82	71	7
Paragymnopleurus maurus	47	150	21	0	0	3
Paragymnopleurus striatus	0	22	1	0	25	0
Phaeochroops freenae	0	0	0	0	0	4
Phaeochroops peninsularis	0	2	0	0	0	4
Phaeochroops rattus	0	124	0	0	0	0
Sisyphus thoracicus	40	249	2	0	287	673
Synapsis sp.	0	66	0	7	0	0
Yvescambefortins sarawacus	0	3	0	0	0	0

Table 2: Total dung beetles that collected throughout the study according to localities, Shannon-Wiener (H'), Evenness (E) and Richness (R').

Overall	BRF	Sungkai	Langkawi	FH	CL	BL
Species richness	10	25	11	13	11	18
Abundance	575	1486	128	192	587	952
Shannon (H')	2.17a,b	2.52a	1.74c	1.58b,c	1.67c	1.08d
Evenness (E)	0.88	0.50	0.52	0.37	0.48	0.16
Richness (R')	1.42	3.29	2.06	2.82	1.57	2.48

ANOVA test showing it significantly differences between of H' from the sampling localities ($F_{5,12} = 22.06$, $p < 0.05$), and post-hoc test indicates that Sungkai has the highest diversity of dung beetles compared to other sites except to another secondary forest site, BRF. In the same time, BRF diversity also overlapped with a recreational forest of FH. BL has the lowest dung beetle diversity compared to other localities.

Habitat Classification

Dendrogram based on the dung beetle's composition, both wetland sites have the most closely related site with close to 100% similarity and also grouped together with a secondary forest, Sungkai (Fig. 1). Even though the recreational forest, FH, and Langkawi in the same clade, but Langkawi has higher similarity with BRF than FH. While for species clade, it forms four groups based on 75% similarity, labeled as group 1 to 4 accordingly. Group 1 have nine species from *Caccobius unicornis* until *Onthophagus rorarius*. There are 18 species in Group 2, seven species in Group 3 and six species in Group 4 respectively.

Meanwhile, the PCA analysis indicates that some species show high interest in a particular locality. For example, dung beetle *O. crassicollis* are highly preferred BRF, even though also can be found in the wetland of BL. As for *S. thoracicus*, because of the species can be found in all localities except for FH, this species share common distribution to all study sites. Based on the length of the locality line, BRF and Sungkai are more likely has more specific species to be found compared to others. Langkawi and FH on the other hand, showing the least specific species to find in the area.

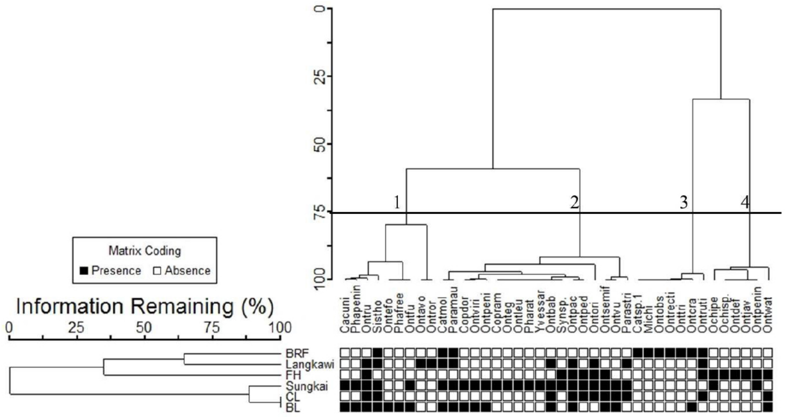

Figure 1: Two-way cluster analysis (dendrogram) showing the groups created based on the species present/absent in each sampling localities.

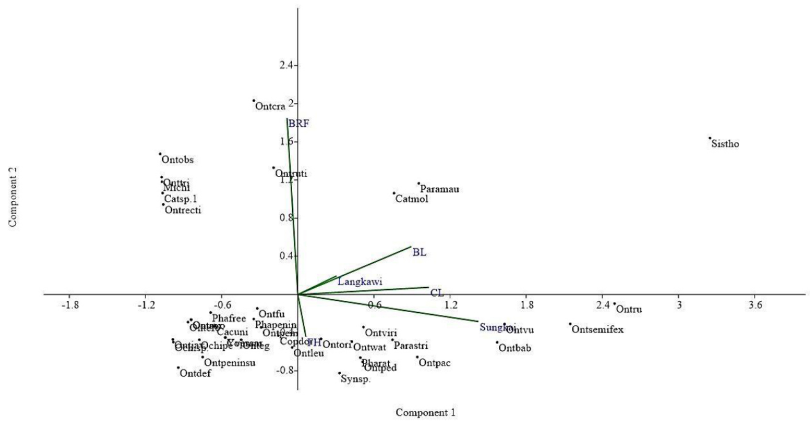

Figure 2: PCA scatter diagram showing the projection of sampling localities towards the dung beetles distribution. Longer projection indicates stronger connection of the species to the locality.

DISCUSSION

Dung Beetle Diversity

This study signifies that secondary forests hold the most diverse dung beetle species compared to recreational forests and wetlands. This finding is consensus on the claim that dung beetle prefers more stable forest area rather than disturbed forest environments (Aguilar-Amuchastegui & Henebry 2007; Andresen 2008). Wetlands for this study (CL and BL) are considered semi-disturbed due to residential areas and medium scale palm oil plantation. Thus, it gives another support that dung beetle is an excellent indicator for forest evaluation.

The first concern regarding the bait selection was to standardised along all the sampling sites, especially to the area that protected by The Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN). Sungkai and BL is the forest area that monitored by PERHILITAN and they are strict about the bait. Usually we chose cow dung as the bait, but it is prohibited by PERHILITAN, but allow to use rotten fish as also be used in dung beetle research (Korasaki *et al.* 2013).

Secondary forest may have more diverse fauna that contributes the main food source for the dung beetles (Harvey *et al.* 2006; Yamada *et al.* 2014). Sungkai has been the protected forest area for conservation of the Malayan Gaur and few other mammal species for over 50 years (PERHILITAN 2015). As the result, Sungkai can provide a convenient surrounding for dung beetles as there are plenty of food and other physical condition such as dense forest floor and shade which preferred by the beetles (Doube 1983; Andresen 2005). Even though BRF is a small patch of forest and surrounded by developed areas, but BRF still manage to maintain a high diversity of dung beetles. This is due to the species that found in BRF are already adapted to the ever going disturbance and can survive in the harsh environment, which called hyperdynamism (Yaakop & Aman 2013). In contrast from Sungkai, which have high diversity due to the high actual number of species and individuals, BRF gets its high diversity through high evenness between the species existed there.

While for recreational forest Langkawi and FH, both sites are famous for tourist activities and open for people to access the forest. The improvement of facilities for the convenience of visitors in both these places resulted in a negative impact on the environment (Malmivaara *et al.* 2002). The situation worsened in the event the visitors increased and the management had to provide more capacity to meet the visitors. Indirectly, the forest area will decrease in size and also fragmented. The mammal populations decline due to shrinking habitat and thus will be a negative impact on the diversity of the dung beetle (Nichols *et al.* 2009).

Both wetlands sites in this study are surrounded by oil palm plantation, and this may result that both of these sites have the lowest dung beetle diversity (Shahabuddin *et al.* 2010). Even though in Shahabuddin *et al*. (2010) does not cover oil palm plantation areas, but it also can represents the cocoa and maize plantations as land-use ecosystem. Furthermore, although the two wetlands are located in rural areas, the residential areas around the area make the environment fairly disturbed. Mammals population in the area also keeps declining due to the safety reason for the local people, and there is no presence of large mammals other than domestic mammals such as cows. This situation of human settlements, oil palm plantation, and low diversity of mammals will directly be affecting the dung beetle's population (Barragan *et al.* 2011).

The presence of high abundant species *S. thoracicus* found in all locations except for FH indicating that the study sites can be considered either happens in forest edge or at a disturbed forest because there is where this species can be found the most (Edwards *et al*. 2014; Hosaka *et al*. 2014). For Sungkai, the presence of this species is due to the sampling is done just in the inner part of the edge, not in the middle of the forest. But for the other localities, the disturbance is the main reason species *S. thoracicus* found in high abundance. Nevertheless, other than species *C. molossus*, all other species are small-bodied dung beetles, which also can reflect the constantly disturbed forest (Muhaimin *et al.* 2015).

Habitat Classification

Based on the dendrogram, a secondary forest, Sungkai had been placed together with wetlands BL and CL. This point out that all these three locations shared the high species similarities in term of its ecology and dung beetle distribution. Even though both wetlands have significantly lower dung beetle diversity compared to Sungkai, but the species composition is more likely similar. Banerjee (2014) also stated that wetlands may contain a diversity that similar to forest ecosystem due to high humidity content from its water bodies, which forest also has high humidity through the dense vegetation. CL and BL also supplied with continuous food, but not varied, from the domestic animals found there, which also somehow can sustain the dung beetle population (Horgan 2005).

Interestingly, BRF were grouped with the recreational forest of Langkawi, which both of it are different ecosystem functions. However, there is an existing similarity between the two locations. While Langkawi is an island which separated from the mainland, BRF also created the "island effect" by the patch forest surrounded by developments and settlements (Noraini 1990; Mat Salleh 1999). Island effect can be occurred not only in the actual island but also to the mainland where the environment being separated into totally different surrounding (Qie *et al*. 2011). The island effect will make the diversity rather static, but the population can be increased because of the species are already adapted to the ecosystem, but there is very slight possibility for the species to increase. The species that can survive in this isolated environment also can be classified as general in food choices because the food source itself is already limited and hard to find (Muhaimin *et al.* 2015).

As for species clustering, Clade 1 and 2 can be classified as species that commonly can be found in any kind of forest, whether less disturbed forests such as the secondary forests or the more disturbed for example recreational forests. Thus, these dung beetle species have general interest towards the environment that they live in. Species such as *S. thoracicus* that can be found in high abundance in all forest types (except FH) can be used as an indicator to the disturbed forest environments (Davis *et al.* 2001; Edwards *et al.* 2014; Yamada *et al.* 2014). Clade 2 however, showing a list of species from *Copris doriae* to *Yvescambefortius sarawacus* that are specific only to Sungkai. These species might possess the specific need to the forest that is more stable, dense vegetation and more variance food source, and also can be used as representative for this kind of forests.

While for Clade 3 and 4, the species are accumulating only to BRF and FH even though also some species can be found in other localities. Both of the locations are a secondary and recreational forest that experience frequent disturbance and alteration. Species in this clade are exposed to the disturbance, yet these species can survive there and showing their persistency characteristic (Yaakop & Aman 2013). All species in these clad are small bodied and reflects that they require a small portion of food (Muhaimin *et al.* 2015), which a disturbed forest can provide as there is no or a low number of large mammals.

CONCLUSION

In term of diversity, it is clear that more stable forest such as secondary forest can hold much higher diversity compared to other localities. But other types of forest also may contain similar diversity if the location can provide enough food, vegetation, and shade which vital for the dung beetle to survive. This situation reflects that the dung beetle is a precise indicator to evaluating a particular forest type. Besides, there are species that can represent or indicator a disturbed forest habitat such as *S. thoracicus* which found at the most abundance at the forest edge. More sensitive species only can be found in the less disturbed forest, for example, Sungkai for this study. Small bodied species also another factor to indicates for the disturbed forest which small bodied dung beetle are amassed.

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