Pertanika J. Trop. Agric. Sci. 38 (4): 519 - 532 (2015)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Colonisation of Dung Beetles (Coleoptera: Scarabaeidae) of Smaller Body Size in the Bangi Forest Reserve, Selangor, Malaysia: A Model Sampling Site for a Secondary Forest Area

Muhaimin, A. M. D., Hazmi, I. R. and Yaakop, S.*

Centre for Insect Systematics, School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, 43600 Bangi, Selangor, Malaysia

ABSTRACT

The diversity of dung beetles (Coleoptera: Scarabaeidae) was measured at the Bangi Forest Reserve in Selangor, Malaysia (Hutan Simpan Bangi, HSB), as a model sampling site for the secondary forest ecosystem. The diversity analysis gave a value of 2.17 for the Shannon diversity index (H'), 1.42 for the richness index (R') and 0.87 for the evenness index (E). A total of 575 individuals belonging to 10 species of dung beetles were collected. They comprised of *Catharsius renaudpauliani*, *Catharsius* sp. 1, *Microcopris* aff. *hidakai*, *Onthophagus* "*obscurior* group", *Onthophagus crassicollis*, *O. recticornutus, O. rutilans*, *O. trituber, Paragymnopleurus maurus* and *Sisyphus thoracicus.* The small dung beetle *Onthophagus crassicollis* had the highest number of individuals (137/575, 23.83%) with a body size range of 4.5 ± 2.5 mm in length. A total of 9/10 species collected in HSB were classified as small-bodied species (8% large body, 92% small body) and the statistical analysis showed a significant body size difference compared with the large-bodied species, *C. renaudpauliani*. *O. crassicollis* showed the highest abundance in the secondary forest, a model site for studying forest disturbance. The abundance of dung beetles could potentially be used as a good bioindicator of habitat disruption in the tropical forest ecosystem. Our study also highlighted that the abundance of species based on body size was affected by the availability of the food sources also from different sizes of mammal dung.

Keywords: Scarab beetles, biodiversity, bioindicator, Shannon diversity index

ARTICLE INFO

Article history:
Received: 4 February 2015
Accepted: 16 July 2015

E-mail addresses:
abdullahmuhaimin1990@gmail.com (Muhaimin, A. M. D.),
izfariza.hazmi@gmail.com (Hazmi, I. R.),
salmah78@ukm.edu.my (Yaakop, S.)
* Corresponding author

ISSN: 1511-3701

INTRODUCTION

Dung beetles (Coleoptera: Scarabaeidae) belong to one of the insect groups that are well-studied because they play multiple roles in the ecosystem (Gardener *et al.,* 2008; Nichols *et al.,* 2008). For example, they are involved in nutrient recycling (Yokoyama & Kai, 1993; Vitousek *et al.,* 1997; Bang *et al.,* 2005), secondary dispersal of seeds (Andresen & Feer 2005; D'hondt *et al.,* 2008), biological control of pest fly species (Ridsdill-Smith & Hayles, 1990; Byford *et al.,* 1992; Bishop *et al.,* 2005) and indirectly helping plant growth by providing soil nutrients (Behling *et al.,* 2000; Bang *et al.,* 2005). One of iconic behaviours of dung beetles is food relocating behaviour that belongs to the roller group that makes a ball-shaped sphere from its food and rolls it to other places (others are tunnellers and dwellers) of dung beetles.

Dung beetles are diverse, abundant and widely distributed in the natural ecosystems of tropical rainforests (Hanski & Camberfort, 1991). Several studies have been conducted to measure the species' composition, population structure, as well as dynamics of dung beetles in the humid tropical rainforests (Hanski & Camberfort, 1991; Andresen, 2002; 2003; 2008; Shahabuddin *et al.,* 2005; 2010; Shahabuddin, 2013). In tropical and temperate forests, a 1.5 kg dung pat can attract up to 16,000 dung beetles (Hanski & Camberfort, 1991), which take only about two hours to finish consuming all the dung (Anderson & Coe, 1974). However, tropical rainforest dung beetles are very sensitive to forest changes that could significantly alter the habitat such as vegetation structure, microclimate, soil and food sources (Shahabuddin *et al.,* 2005; Spector, 2006). Furthermore, the abundance of dung beetles could also be influenced by other factors such as temperature, solar radiation and rainfall (Fincher *et al*., 1970). Gardner *et al*. (2008) classified dung beetles as cost-effective to be used in measuring forest condition, which meet both efficiency and low cost sampling consumption. Therefore, dung beetles are well-known as good bioindicators for measuring forest disturbance (Gardner *et al.,* 2008).

Forest disturbance and landscape modification generally reduce the diversity and abundance of most insect taxa (Lawton *et al.,* 1998), except for several species such as solitary bees and wasps, which are able to react and adapt to the extreme conditions or disturbance of an area (Klein *et al.,* 2002). According to Camberfort (1991), a reduction in the number of large mammals occurred parallel to a reduction of dung beetles, influenced by the food source for these scarab species.

A study by Lee *et al*. (2009) indicated that environmental factors influence the abundance, diversity and body mass of the dung beetle, whereas more disturbed area would give less in every aspect. A high number of dung beetles successfully collected from a forest area, however, would not necessarily indicate that it had a greater abundance and diversity compared to other ecosystems; rather, this might be due to and depend generally on food availability. A study conducted by Shahabuddin *et al.* (2005) in Sulawesi confirmed that the abundance and diversity of dung beetles were affected by human-induced activities. Results of their study also showed that the dung beetle populations in the study forest were significantly different from those in areas that lacked forest mammals. Dung beetles have been the subjects of much study due to their important functions and roles in the ecosystem as great manure decomposers, deterring nitrogen release into the atmosphere (Yokoyama *et al.,* 1991; Yokoyama & Kai, 1993). The presence of scarabs ensures the recycling of carbon and minerals back into the soil to generate humus for plant growth.

Other than measuring the diversity of the dung beetles to evaluate forest disturbance, body size also reflects the same role as diversity. More disturbed forest seems to have smaller sized dung beetles due to less dung amounts produced from the mammals to sustain larger dung beetles (Halffter & Arellano, 2002). Meanwhile, competition among dung beetles also can be one of the factors contributing to small dung beetles because of the competition to get the limited sources. Thus, a disturbed forest may show high diversity but give smaller body size (Filgueiras *et al*., 2011). The main objectives of our study were to measure the diversity and body size of dung beetles in the Bangi Forest Reserve in Selangor, Malaysia, and generate fundamental specific data focusing on the dung beetle as a bioindicator in measuring ecosystem disturbance in the humid tropics by taking into account the body size of dung beetles species.

MATERIALS AND METHODS

Sampling Sites

The study area was Hutan Simpan Bangi (HSB) that is located within the main campus of Universiti Kebangsaan Malaysia (UKM) in Bangi, Selangor, covering an area of approximately 100 ha, with a highest peak at 105 m above sea level (UKM, 2011). The historical significance of this reserved forest is that it is the site of the official launching of the UKM permanent campus developed in the early 1970s. HSB experienced a series of deforestations from 1945 to 1968 (Noraini *et al*., 1990; Mat Salleh, 1999) due to further expansion of the UKM campus, as well as rapid development of the adjacent land mainly for settlement and industrial and urban centres. Thus, the original Bangi Forest Reserves became fragmented into two small forest patches, namely the Hutan Penyelidikan Alam (HPA) and the Bukit Rupa (UKM 2011), which are the two sites selected for this study. Their coordinates are 101° 47.216” E;02° 54.836” N for HPA and 101° 45.969” E; 02° 55.016” N for Bukit Rupa. Although this forest is just reaching its maturity after 30 years since the last major forest clearings, the HSB is still continuously being disturbed either for small-scale development or for research purposes. As a result, there are very few large emergent trees left standing in this forest, which affect forest litter and the associated forest floor and soil fauna composition.

Collection of Dung Beetles

Dung beetles were sampled four times in October and November 2013 by means of six baited pitfall traps. A small plastic pail (20 cm diameter, 17 cm deep) was used as the pitfall trap, buried into the ground up to its upper rim. About 10–15 g of fresh cow dung (less than 6-hrs old) was put into a plastic cup, which was then placed into the pail. A mixture of water and detergent (1000:1 ml) was then poured into the pail to drown any beetles that fell into the trap. All traps were arranged at 4.0 –5.0m intervals in a straight line transect, and they were left for 24 hr before the beetles were collected. The beetles were preserved in 70% alcohol and taken to the laboratory for sorting and taxonomic identification.

Species Identification and Body Size

The beetles were identified to the subfamily level in the laboratory based on morphological characteristics using available keys (Triplehorn & Johnson, 2005; Ek-Amnuay, 2008). They were then further identified into the species (Ochi *et al.,* 1996) and morphospecies levels for diversity analysis. For each species, the length (from tip of clypeus to apex of elytra) of 10 individuals was measured with a pair of Vernier calipers (accuracy 0.05 mm) for body size analysis. Photographic records of each species were taken with a Canon EOS 6D camera mounted on a stereo microscope (model Zeiss Stemi SV11).

Data Analysis

In order to evaluate the sampling efforts for each sampling activity, sample-based rarefaction curves were constructed by using the EcoSim version 7.0 computer software. The Shannon diversity index (H’) and the evenness index (E) were determined for the dung beetle community (Hanski, 1983; Klein, 1989) in this study area. The richness index (R’) was also calculated to determine the expected number of species that could be found if the sampling efforts were to be increased. However, it is also related to the sample-based rarefaction curve analysis. All of the indices (H’, R’, and E) were calculated by using the PAST software (Hammer *et al.,* 2001).

RESULTS

Species Composition, Diversity and Body Size

Of the total 575 beetles collected at Hutan SimpanBangi (HSB), they were classified into ten species in five genera, and comprised of *Catharsius renaudpauliani*, *Catharsius* sp. 1, *Microcopris* aff. *hidakai*, *Onthophagus* “*obscurior* group”, *Onthophagus crassicollis*, *O. recticornutus, O. ru*tilans, *O. trituber*, *Paragymnopleurus maurus* and *Sisyphus thoracicus*. The genus *Onthophagus* was the most abundant at 63% (362 individuals), followed by *O. crassicollis* about 24% (137 individuals) (Fig.2 – Fig.11). The least frequently collected species was *O. recticornutus*, comprising only 25 individuals (4.3%)

(Table 1). The diversity analyses showed that the Shannon diversity (H'), evenness (E), and richness (R') indices were 2.17, 0.87 and 1.42, respectively (Table 1). The rarefaction curve (sampling effort) showed that the number of individuals from each collection was sufficient to conduct the analysis for diversity estimation of dung beetles in the HSB.

TABLE 1
List of species and number of individuals collected from Bangi Forest Reserve (HSB)

Species	HSB
Catharsius renaudpauliani	46
Catharsius sp. 1	34
Microcopris aff. *hidakai*	46
Onthophagus "*obscurior* group"	96
Onthophagus crassicollis	137
Onthophagus recticornutus	25
Onthophagus rutilans	52
Onthophagus trituber	52
Paragymnopleurus maurus	47
Sisyphus thoracicus	40
Total	575
($t = 5.535$, $df = 122.58$, $p=1.7798$, $P > 0.05$)	
Shannon (H')	2.17
Richness (R')	1.42
Evenness (E)	0.87

The richness (R') and evenness (E) indices calculated for HSB were 1.42 and 0.87, respectively (Table 1). The size of the dung beetles that were sampled in the HSB was classified into large-sized and small-sized (Fig.1). Out of the 10 species collected from HSB, only *C. renaudpauliani* is considered a large-sized with an average body length of 27.5 mm (Table 2). *Catharsius* sp., *M.* aff. *hidakai* and *P. maurus*, with an average length of 10.5 mm (i.e., almost half the size of *C. renaudpauliani*) is considered as a group that is close to *C. renaudpauliani* in term of their body-size. The smallest dung beetle from HSB was *O. crassicollis* (average size of 5.5 mm). The average body length of *C. renaudpauliani* does not overlap with other species found in HSB, showing obvious differences between the large and small groups of dung beetles in HSB (Fig.1). With a total of 46 individuals, *C. renaudpauliani* represented 8% of the dung beetles collected in HSB.

TABLE 2
Body size range of each species collected from the Bangi Reserve Forest (HSB)

HSB	Size (mm)
Catharsius renaudpauliani	27.5 ± 6.0
Catharsius sp. 1	10.5 ± 4.0
Microcopris aff. *hidakai*	5.5 ± 2.0
Onthophagus "*obscurior* group"	7.5 ± 3.5
Onthophagus crassicollis	4.5 ± 2.5
Onthophagus recticornutus	5.5 ± 2.0
Onthophagus rutilans	9.0 ± 3.0
Onthophagus trituber	6.0 ± 2.5
Paragymnopleurus maurus	10.5 ± 3.5
Sisyphus thoracicus	6.5 ± 3.0

DISCUSSION

Scheffler (2005) and Gardner *et al*. (2008) reported that the dried body mass and length of dung beetles increase or decrease gradually and are consistent. In this regards, the body length of dung beetles collected in HSB was measured to investigate and classify the body size. The body size of dung beetles species inhabiting the two different ecosystems has shown significant difference, i.e., logged [body length (mm) 6.9 ± 2.4] and unlogged forests [body length (mm) 8.5 ± 3.5] with p-value = 0.001, < 0.05, whilst the richness and abundance of species at the two ecosystems showed no difference at all (Nichols *et al*., 2008; Hosaka *et al*., 2014). Our result from HSB supported that the high number of the small-sized dung beetle inhabiting a forest area of the secondary forest ecosystem. The body size in dung beetles also showed positive correlation and was sensitive to the effect of forest modification (Gardner *et al*., 2008) and fragmentation. Besides measuring the forest disturbance of forest, body size (large or small) is one of the key factors affecting the magnitude of dung burial and seed dispersal (Slade *et al*., 2011; Nichols *et al*., 2013).

In our study, only one species, that is *C. renaudpauliani*, is considered as a large-sized dung beetle collected in HSB. This might be due to the limitation of the large-sized species to find sufficient food sources to accommodate their needs (Bartholomew & Heinrich, 1978). A similar situation was also reported in Singapore, where a large-sized roller dung beetle species, *P. maurus*, which was sampled at the small area of Lower Pierce. The same finding was also obtained from the small island of Tasik Kenyir, Terengganu, which can be classified as a secondary forest (Lee *et al*., 2009). The presence of a small number large dung beetle species directly reflects on the prevailing status of the disturbed forests, whereby the degraded habitat would not be able to support a high population density of large-sized dung beetles. This is partly because forest disruption dispels the larger animals to other areas, or many would perish because they were unable to adapt and survive in the disturbed area (Horgan, 2005; 2008).

According to Nichols *et al*. (2009), dung beetles species have shown indirect effects with the mammalian faecal resources or for the dung beetles' food sources. Due to that reason, lack of animal wastes would

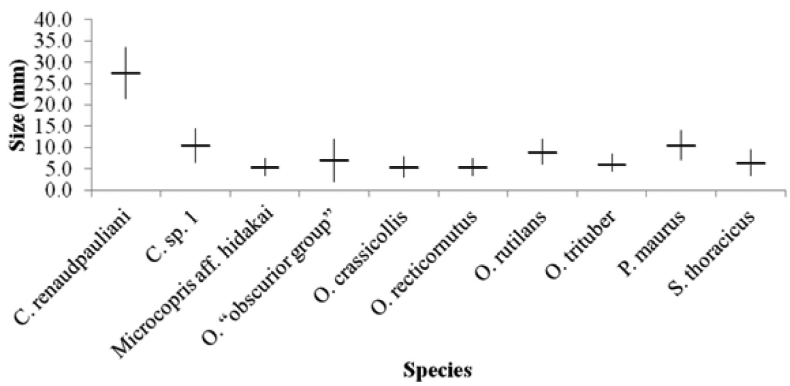

Fig.1: Significant sizes of dung beetles species collected from Bangi Reserve Forest

in turn affect the diversity and population abundance of the dung beetles that depend on them as a food source. Apart from species diversity and population abundance, the body sizes of dung beetles are also useful indicators in evaluating the status of a forest area (Hosaka *et al*., 2014) because these data are indicative of the population structure and diversity of the mammals in the study area (Camberfort, 1991). Unlike

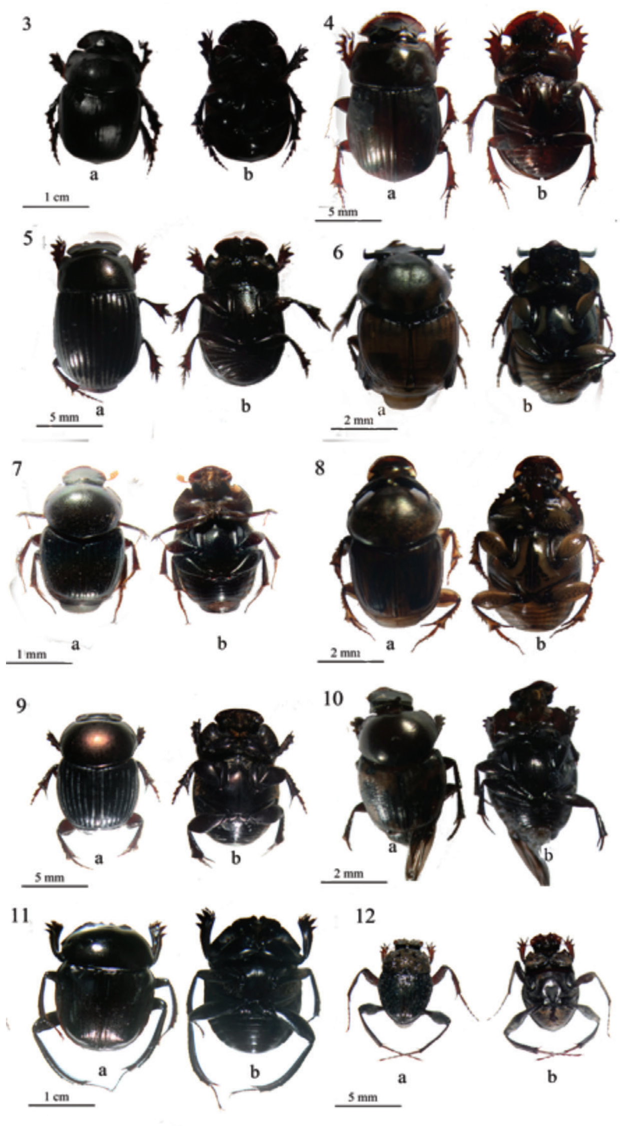

Fig.2 - Fig.11: 2: *Catharsius renaudpauliani*, 3: *Catharsius* sp. 1, 4: *Microcopris* aff. *hidakai*, 5: *Onthophagus* "*obscurior* group", 6: *Onthophagus crassicollis*, 7: *Onthophagus recticornutus*, 8: *Onthophagus rutilans*, 9: *Onthophagus trituber*, 10: *Paragymnopleurus maurus*, 11: *Sisyphus thoracicus*

the natural forest ecosystems, secondary forests have less capacity to support larger mammals and wildlife species, as reflected by the population profile of the dung beetle species. As in Bangi Reserve Forest (HSB), no large mammal has been reported, where it is believed to accommodate only small mammals in the area. Habitat disturbance is one of the factors that reduces the abundance of mid-large-sized mammals (Laidlaw, 2000) that provide food sources for the beetle species (Estrada *et al*., 1993) and it has shown decrement with increasing fragmentation and disturbance of forests such as in the Neartic regions.

A strong relationship can be observed between food source and body mass of beetles because a high demand for food supply is required to maintain the large-sized dung beetles in substantial numbers (Nichols *et al.,* 2007). In Malaysia, it is recorded that the largest dung beetle species is *Heliocopris* sp.; in HSB, however, only *C. renaudpauliani* of the average body length (27.5 mm) was collected. Ong *et al.* (2013) carried out a survey in Singapore and observed the presence of *Catharsius molossus*. This species is of a similar size with *C. renaudpauliani*, and is ecologically preferred herbivorous dung as its food source. Therefore, it was assumed that *C. renaudpauliani* also has similar food preference from larger mammals, although large mammals viz. elephants, Samba deers and rhinos have never been reported in the HSB. A study by Md. Zain *et al.* (2010) noted that omnivorous species such as primate, *Macaca fascicularis* and wild boars are abundant in HSB, as well as Malayan Colugo or flying lemurs and Banded Leaf monkeys (*Galeopterus variegates*) (Yaakop & Aman, 2013). Therefore, it is presumed that somehow, these large-sized beetles could still survive by consuming the excrement of other types of animals, which are usually from the small mammals such as rodents and primates. This is an interesting prospect that merits further investigation. Besides that, Nichols *et al*. (2013) also cited that large tunnellers like *Catharsisus* could persist or continue to exist in the forested agriculture lands, but not in more disturbed areas (non-forested agriculture lands).

Another reason for the obvious lack of large-sized dung beetles may be that these insects are more vulnerable to forest fragmentation (Klein, 1989; Ong *et al.,* 2013). Referring to Ong *et al*. (2013), the largest species (>10mm), *C. molussus* (*Catharsius molussus*) collected from Singapore, is commonly found in old-growth continuous forest or undisturbed forest with elephants, rhinoceros and clouded leopards inhabit the type of forest (Marsh & Greer, 1992). Again, there could be a strong correlation with the abundance of animals that provide dung as a food source. Larger mammals tend to avoid forest fragments because of insufficient food, home range and cover. On the other hand, small-sized dung beetles can survive better in forest fragments because smaller vertebrates can still furnish them with sufficient food supply. In our study area, the small-sized dung beetles of *O. crassicollis* were the most abundant of all species, confirming other reports by

Andresen (2003) and Horgan (2005) and indicating that forest reduction has adverse impacts on the population abundance, species diversity, and distribution of dung beetles.

The results of our study on the diversity of dung beetles are congruent with the findings of other studies, in that dung beetles could serve as useful and representative bioindicator organisms of forest disruption (Andresen, 2002, 2003; Davis *et al.,* 2001; Horgan, 2001, 2005, 2008). Several studies (Klein *et al.,* 2002; Davis & Philips, 2005; Kanda *et al.,* 2005; Shahabuddin, 2013) have concluded that disturbed forests have low to moderate diversity indices (H' $\leq$ 2.3) for dung beetles, which are very sensitive to the open forest and forest disturbance, while for more disturbed areas (e.g., plantation and crop areas), the diversity of dung beetles is expected to be even lower when compared to the primary or deep forests. As our study forest had experienced long-term disturbance, it was not expected that there would be a high diversity of species, as reflected by the Shannon diversity index.

On the other hand, continuous and high-intensity forest disturbance could also produce high diversity because many microsites or microclimatic conditions could be created, providing diverse niches for the scarab beetles to exploit, depending on the species (Enari *et al.,* 2011). However, the diversity of dung beetles is also highly related to the population of vertebrates due to their dependency on animal wastes as their primary food source. Among the genera of dung beetles collected in our study area, *Onthophagus* was the most successful genus in terms of survival in a disturbed area, and this genus is also reported to be prevalent in many other types of disturbed habitats (Davis *et al.,* 2001; Prize, 2004; Davis & Philips, 2005; Shahabuddin *et al.,* 2005, 2010; Agoglitta *et al.,* 2012).

CONCLUSION

This study gives an overview of the diversity of the dung beetles of secondary forests. Moderate diversity indexes indicate the environmental conditions of Bangi Forest Reserve (HSB). Apart from that, body size is another factor that serves as the key indicator of forest disturbance. Small-bodied dung beetles survive more successfully in secondary forests compared to larger dung beetles. Small dung beetles are more likely to survive in the forest because the dung of small animals is sufficient for their survival and existence.

ACKNOWLEDGEMENTS

The authors would like to express their special gratitude to Dr. Darren Mann for species identification, Prof. Dr. Maimon Abdullah for her critical comments and editing of the manuscript, Associate Prof. Dr. Wan Juliana Wan Ahmad, the Coordinator for the Bangi Forest Reserve (HSB), Selangor, for permission to conduct the research, and Mr. Mohamad Ruzi Abd. Rahman for the technical assistance rendered during field sampling. This project was fully supported by Grant GUP-2014-029 and FRGS/12014/SG03/UKM/02/1.

REFERENCES

Agoglitta, R., Moreno, C. E., Zunino, M., Bonsignori, G., & Dellacasa, M. (2012). Cumulative annual dung beetle diversity in Mediterranean seasonal environments. *Ecological Research, 27*, 387-395.

Anderson, J. M., & Coe, M. J. (1974). Decomposition of elephant dung in an arid, tropical environment. *Oecologia*, *14*, 111-125.

Andresen, E. (2002). Dung beetles in a Central Amazonian rainforest & their ecological role as secondary seed dispersals. *Ecological Entomology, 27*, 257-270.

Andresen, E. (2003). Effect of forest fragmentation on dung beetle communities and functional consequences for plant regeneration. *Ecography*, *26*, 87-97.

Andresen, E., & Feer, F. (2005). The role of dung beetles as secondary seed dispersers and their effect on plant regeneration in tropical rainforest. In P. M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall, *Seed Fate: Predation, Dispersal and Seedling Establishment* (pp. 331-349). UK: CABI International.

Andresen, E. (2008). Dung beetle assemblages in primary forest and disturbed habitats in a tropical dry forest landscape in western Mexico. *Journal of Insect Conservation, 12*, 639-650.

Bang, H. S., Lee, J. H., Kwon, O. S., Na, Y. E., Jang, Y. S., & Kim, W. H. (2005). Effects of paracoprid dung beetles (Coleoptera: Scarabaeidae) on the growth of pasture herbage and on the underlying soil. *Applied Soil Ecology*, *29*, 165-171.

Bartholomew, G. A. & Heinrich, B. (1978). Endothermy in African dung beetles during flight, ball making, and ball rolling. *Journal of Experimental Biology*, *73*, 65-83.

Behling, M. C. H., Santos, J. C., & Bianchin, I. (2000). The role of *Digionthophagus gazella* on pasture cleaning and production as a result of burial of cattle dung. *Pasturas Tropicales*, *22*, 14-18.

Bishop, A. L., McKenzie, H. J., Spohr, L. J., & Barchia, I. M. (2005). Interactions between dung beetles (Coleoptera: Scarabaeidae) and the arbovirus vector *Culicoides brevitarsis* Kieffer (Diptera: Ceratopogonidae). *Australian Journal of Entomology*, *44*, 89-95.

Byford, R. L., Craig, M. E., & Crosby, B.L. (1992). A review of ectoparasites and their effect on cattle production*. Journal of Animal Science*, *70*, 597-602.

Camberfort, Y. (1991). Dung beetles in tropical savannas In I. Hanski & Y. Cambefort (Eds.), *Dung beetle ecology* (pp. 156-178). Princeton, NJ: Princeton University Press.

Davis, A. J., Hooloway, J. D., Huijbregts, H., Krikken, J., Kirk-Springgs, A. H., & Sutton, S. F. (2001). Dung beetle as indicators of change in forest of northern Borneo. *Journal of Applied Ecology, 38*, 593-616.

Davis, A. L., & Philips, T.K. (2005). Effect of deforestation on a southwest Ghana dung beetle assemblage (Coleoptera: Scarabaeidae) at the periphery of Ankasa Conservation Area. *Environmental Entomology*, *34*, 1081-1088.

D'hondt, B., Bossuyt, B., Hoffmann, M., & Bonte, D. (2008). Dung beetle as secondary seed dispersers in a temperate grassland. *Basic and Applied Ecology*, *9*, 542-549.

Ek-Amnuay, P. (2008). *Beetles of Thailand*. Bangkok, Thailand: Amarin Printing and Publishing.

Enari, H., Koike, S., & Sakamaki, H. (2011). Assessing the diversity of dung beetle assemblages utilizing Japanese monkey feces in cool-temperate forests. *Journal of Forest Research, 16*, 456-464.

Estrada, A., Halffter, G., Coates-Estrada, R., & Meritt Jr., D. A. (1993). Dung beetles attracted to mammalian herbivore (*Alouatta palliate*) and omnivor (*Nasua narica*) dung in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical Ecology*, *9*, 45-54.

Filgueiras, B. K. C., Iannuzzi, L., & Leal, I.R. (2011). Habitat fragmentation alters the structure of dung beetle communities in the Atlantic Forest. *Biological Conservation*, *144*, 362-369.

Fincher, G. T., Stewart, T.B., & Davis, R. (1970). Attraction of coprophagus beetles to feces of various animals. *Journal of Parasitology*, *56*, 378-383.

Halffter, G., & Arellano, L. (2002). Response of dung beetle diversity to human-induced changes in tropical landscape.*Biotropica*, *34*, 144-154.

Gardner, T. A., Barlow, J., Araujo, I.S., Avila-Pires, T.C., Bonaldo, A.B., Costa, J.E., Esposito, M.C., Ferreira, L.V., Hawes, J., Hernandez, M. I. M., Hoogmoed, M. S., Leite, R. N., Lo-Man-Hung, N. F., Malcolm, J. R., Martins, M. B., Mestre, L. A. M., Miranda-Santos, R., Overal, W.L., Parry, L., Peters, S.L., Ribeiro-Junior, M.A., da Silva, M. N. F. C.. da Silva Motta, C., & Peres, C.A. (2008). The cost-effectiveness of biodiversity surveys in tropical forest. *Ecology Letters*, *11*, 139–150.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). Past: Paleontological Statistics Software Package for Education andData Analysis. *Palaeontologia Electronica*, *4*, 9.

Hanski, I. (1983). Distributional ecology and abundance of dung and carrion-feeding beetles (Scarabaeidae) in tropical rain forests in Sarawak, Borneo. *Acta Zoologica Fennica*, *167*, 1-45.

Hanski, I., & Camberfort, Y. (1991). Dung Beetle Ecology. , Princeton, NJ: Princeton University Press.

Horgan, F. G. (2001). Burial of bovine dung by coprophagus beetles (Coleoptera: Scarabaeidae) from horse and cow grazing sites in El Salvador. *European Journal of Soil Biology, 37*, 103-111.

Horgan, F. G. (2005). Effects of deforestation on diversity, biomass and function of dung beetle on eastern slopes of the Peruvian Andes. *Forest Ecology and Management*, *216*, 117-133.

Horgan, F. G. (2008). Dung beetle assemblages in forest and pastures of El Salvador: a functional comparison. *Biodiversity Conservation, 17*, 2961-2978.

Hosaka, T., Niino, M. Kon, M., Ochi, T. Yamada, T., Fletcher, C., & Okuda, T. (2014). Effects of logging road networks on the ecological functions of dung beetles in Peninsular Malaysia. *Forest Ecology and Management*, *326*, 18-24.

Kanda, N., Yokota, T., Shibata, E., & Sato, H. (2005). Diversity of dung-beetle community in declining Japanese subalpine forest caused by increasing sika deer population. *Ecological Research*, *20*, 135-141.

Klein, A. M., Steffan-Dewenter, I., Buchori, D., & Tscharntke, T. (2002). Effects of land-use intensity in tropical agroforestry systems on coffee flower-visiting and trap-nesting bees and wasps. *Conservation Biology*, *16*, 1003-1014.

Klein, B. (1989). Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. *Ecology*, *70*, 1715-1725.

Laidlaw, R. K. (2000). Effects of habitat disturbance and protected areas on mammals of Peninsular Malaysia. *Conservation Biology, 14*, 1639–1648.

Lawton, J. H., Bignell, D. E., Bolton, B. Bloemers, G. F., Eggleton, P., & Hammond, P. M. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical rain forest. *Nature, 391*, 72-76.

Lee, J. S. H., Lee, I. Q. W., Lim, S. L. H., Huijbregts, J., & Sodhi, N.S. (2009). Changes in dung beetle communities along a gradient of tropical forest disturbance in South-East Asia.*Journal of Tropical Ecology, 25*, 677–680.

Marsh, C. W. & Greer, A.G. (1992). *Forest land-use in Sabah, Malaysia: an introduction to Danum Valley.* Philosophical Transactions of the Royal Society of London B *335*, 331–339.

Mat Salleh, K. (1999). The role and function of Universiti Kebangsaan Malaysia permanent forest reserve in research and education. *Pertanika Journal of Tropical Agricultural Science*, *22*, 185-198.

Md. Zain, B. M., Sha'ari, N. A., Mohd-Zaki, M., Ruslin, F., Idris, N.I., Kadderi, M. D. & Idris, W.M.R. (2010). A Comprehensive Population Survey and Daily Activity Budget on Long-tailed Macaques of Universiti Kebangsaan Malaysia. *Journal of Biological Science, 10*(7), 608-615.

Nichols, E., Larsen, T., Spector, S., Davis, A.L., Escobar, F., Favila, M., & Vulinec, K. (2007). Global dung beetle response to tropical forest modification and fragmentation: A quantitative literature review and meta-analysis. *Biological Conservation, 137*, 1-19.

Nichols, E., Spector, S., Louzada, J., Larsen, T., Amezquita, S., Favila, M.E., & Vulinec, K. (2008). Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. *Biological Conservation, 141*, 1461–1474.

Nichols, E., Uriarte, M., Bunker, D.E., Favila, M., Slade, E.M., Vulinec, K., Larsen, T., Vaz-de Mello, F.Z., Louzada, J. Naeem, S., & Spector, S.H. (2013). Trait dependent response of dung beetle populations to tropical forest conversion at local to global scales. *Ecology, 94*, 180–189.

Noraini, M. (1990). Profil Hutan Bangi [pp. 125-138]. In A. Latif (Ed.), *Ekologi dan Biologi Hutan Simpan Bangi, Universiti Kebangsaan Malaysia*. UKM, Bangi, Malaysia.

Ochi, T., Kon, M., & Kikuta, T. (1996). Studies on the family Scarabaeidae (Coleoptera) from Borneo. I. Identification keys to subfamilies, tribes and genera. *Giornale Italia Entomologia*, *8*, 37-54.

Ong, X. R., Chua, S.C., & Potts, M.D. (2013). Recent records of the dung beetle *Catharsius renaudpauliani* (Coleoptera: Scarabaeidae) in Singapore. *Nature in Singapore*, *6*, 1-6.

Prize, D. L. (2004). Species diversity and seasonal abundance of scarabaeoid dung beetles (Coleoptera: Scarabaeidae, Geotrupidae and Trogidae) attracted to cow dung in central New Jersey. *Journal of the New York Entomological Society*, *12*, 334-347.

Ridsdill-Smith, T. J., & Hayles, L. (1990). Stages of bush fly, *Musca vetustissima* (Diptera: Muscidae), killed by scarabaeine dung beetles (Coleoptera: Scarabaeidae) in unfavourable cattle dung. *Bulletin of Entomological Research*, *80*, 473-478.

Scheffler, P. Y. (2005). Dung beetle (Coleoptera: Scarabaeidae) diversity and community structure across three disturbance regimes in eastern Amazonia. *Journal of Tropical Ecology*, *21*, 9-19.

Shahabuddin. (2013). Contribution of alpha and beta diversity across land-use type to the regional diversity of dung beetles in Central Sulawesi. *HAYATI Journal of Biosciences, 20*, 72-79.

Shahabuddin, P., Hidayat, S., Manuwoto, W., Noerdjito, T., Tscharntke, T., & C. Schulze. (2010). Diversity and body size of dung beetles attracted to different dung types along a tropical land-use gradient in Sulawesi, Indonesia. *Journal of Tropical Ecology, 26*, 53-65.

Shahabuddin, C. Schulze, H., & Tscharntke, T. (2005). Changes of dung beetle communities from rainforests towards agroforestry systems and annual cultures in Sulawesi (Indonesia). *Biodiversity and Conservation*, *14*, 863-877.

Slade, E. M., Mann, D. J., & Lewis, O. T. (2011). Biodiversity and ecosystem function of tropical forest dung beetles under contrasting logging regimes. *Biological Conservation*, *144*, 166–174.

Spector, S. (2006). Scarabaeine dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae): an invertebrate focal taxon for biodiversity research and conservation. *Coleopterists Bulletin, 5*, 71-83.

Triplehorn, C. A., & Johnson, N. F. (2005). *Borror and DeLong's Introduction to the Study of Insects*. UK: Thomson Learning, Inc..

UKM. (2011). Hutan Simpan Kekal. Retrieved 16 January 2014 from www.ukm.my/hutan/index.php

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science, 277*, 494-499.

Yaakop, S., & Aman, A. Z. (2013). Does the fragmented and logged-over forest show a real hyperdymanism on braconids Species? *Malaysian Applied Biology, 42*(2), 1-5.

Yokoyama, K., & Kai, H. (1993). Distribution and flow of nitrogen in cow dung-soil system colonized by paracoprid dung beetles. *Edaphologia*, *50*, 1-10.

Yokoyama, K., Kai, H., Koga, T., & Aibe, T. (1991). Nitrogen mineralization and microbial populations in cow dung, dung balls and underlying soil affected by paracoprid dung beetles. *Soil Biology and Biochemistry, 23*, 649-653.