http://dx.doi.org/10.22161/ijeab/4.1.30 ISSN: 2456-1878

Effects of Land use Change on Dung Beetle (Scarabaeinae) Community Structure in South Western Ghats

Thomas Latha[1,*], Thomas K. Sabu[2]

[1]Department of Science, Faculty of Science and Technology, University of Belize, Belize
[2]Post Graduate and Research Department of Zoology, St. Joseph's College, Devagiri, Kozhikode, Kerala, India
[*]Corresponding Author: lthomas@ub.edu.bz

***Abstract*—*Western Ghats in the Indian subcontinent is one of the world's eight 'hottest hotspots' of biological diversity along with Sri Lanka. Land use changes in the Western Ghats caused by agricultural expansion and other anthropogenic activities have resulted in loss of forests and is a major threat to Western Ghats biodiversity. In the present study, Scarabaeinae dung beetles were used as biological indicators to study the effects of land use change on biodiversity in the South Western Ghats. Community attributes such as abundance, species richness, species composition, functional guild composition, temporal guild composition and beetle sizes were compared between a forest and agriculture habitat in the South Western Ghats region. Cow dung baited pitfall traps were used to collect dung beetles in the presummer, summer and monsoon season during 2007-2008 study period. The study showed that dung beetle community attributes were affected due to land use changes. Of the 31 species collected between the two habitats, only 15 species were shared between forest and agriculture habitat accounting for 51.6% species turnover. Low abundance recorded in agriculture habitat resulted from low diversity and amount of dung types available to beetles when compared to forest habitat, while high species richness in agriculture habitat resulted from the presence of heliophiles and synanthropic species that has established in the region owing to decades of anthropogenic disturbance. Functional guild tunneler, dominated both the habitats because of their superior competitive nature. Temporal guild was dominated by nocturnal guild in the forest due to the availability of dung at night from wild animals, and diurnal guild in agriculture habitat owing to the availability of dung during the day as a consequence of agricultural practices. Small beetles dominated both the habitats as a result of decline in large dung pad producing mammals in the region as a consequence of anthropogenic disturbance. Further deterioration of forests in the region is important to conserve the remaining forest specialists.*

Keywords*— *Scarabaeinae, dung beetles, land use, community attributes, biological indicator, South Western Ghats.

I. INTRODUCTION

Population growth and rising consumption exerts continuous pressure on land for increased food production. Higher production is possible either by intensification on existing agricultural land or expansion into new areas (Tilman *et al*., 2011). Conversion of forests into agricultural land is the most widespread method of agricultural expansion and is considered as the leading cause of global forest loss (Kissinger *et al*., 2012). Such land use changes can have serious environmental consequence particularly on biodiversity (Alroy, 2017; Phalan and Balmford, 2014; Wright, 2010). Changes in biodiversity have a strong potential to alter ecosystem properties and the goods and services they provide to humanity (Hooper *et al*., 2005, Isbel *et al*., 2018).

The Western Ghats in the Indian Subcontinent is a 1,600 km long chain of mountains running parallel to India's western coast. Western Ghats with its exceptionally high level of biological diversity and endemism is recognized as one of the world's eight 'hottest hotspots' of biological diversity along with Sri Lanka. It has profound influence on the rainfall pattern of peninsular India and has high geological, aesthetic and cultural values. The existing forests of Western Ghats are highly fragmented and is facing the prospect of increasing degradation (Bawa *et al*., 2007). Land use changes in the Western Ghats over the last century caused by agricultural expansion, conversion to plantations, non-timber forest product harvest and infrastructural projects have resulted in loss of forests and is a major threat to Western Ghats biodiversity (Jha *et al*., 2000; Kumar, 1993; Menon and Bawa, 1997; Shahabuddin and Prasad, 2004).

Scarabaeinae dung beetles are ecologically important group of insects widely used to study the effects of habitat modifications on biodiversity. They are cost effective bioindicators as they can be easily sampled, are sensitive to ecosystem changes, are broadly distributed, and their taxonomy and ecology are relatively well known (Nichols *et al*., 2007). Adults and larvae from this subfamily are detritivores and use decaying organic material, such as mammal excrement, dead animal carcasses, rotting plant matter, and other resources, as food (Halffter and Mathews, 1966). Through their feeding habits, they perform important ecological services such as nutrient recycling, seed dispersal, forest regeneration, control populations of disease causing parasites, and reduce carbon emissions (Ardali *et al*., 2016, Forgie *et al*., 2018, Piccini *et al*., 2017; Slade *et al*., 2016).

Scarabaeinae beetles are categorized into three functional groups based on the way they use the resources for feeding and reproduction; they are telecoprids or rollers (food balls are rolled some distance before burial), paracoprids or tunnelers (tunnels are dug next to or below the food source), and endocoprids or dwellers (feed and reproduce inside the food resource) (Halffter and Mathews, 1966). Since dung is an ephemeral source, to avoid competition, dung beetles also exhibit different activity pattern during a day based on which they are divided into temporal guilds (Feer and Pincebourde, 2005). Diel periodicity studies commonly distinguishes two major groups of dung beetle species, nocturnal and diurnal (Krell *et al*. 2003; Krell-Westerwalbesloh *et al*. 2004).

In the present study effects of land use change on dung beetle community attributes in South Western Ghats was studied. Dung beetle community attributes such as abundance, species richness, species composition, functional guild composition, temporal guild composition and beetle sizes were compared between a forest and agriculture habitat in the region.

II. MATERIALS AND METHODS

2.1 Study site

The study region, Nelliampathi is situated in the South Western Ghats just south of the Palghat Gap. The Palghat Gap is a transverse valley about 32 km wide and is the only major break in the continuous mountain range. It sharply divides Wayanad and the Nilgiris in the north from Nelliampathi Hills of the Thrissur district, to the south (Ali, 1999). The study was carried out in Kaikatty in Nelliampathi, located at 10^0 31'N and 76^0 40'E, at an elevation of 960 msl (Fig. 1). It is an ecologically high sensitive area enclosing the Nelliampathi Reserve forest and is bordered by the Parambikulam tiger reserve towards the south and southeast (Nair, 1991; Joy, 1991). The land forms a corridor for the movement of long ranging species such as *Panthera tigris*Linnaeus, 1758 (tiger), *Panthera pardus* Linnaeus, 1758 (leopard), *Bos gaurus* Smith, 1827 (wild gaur), and is also a crucial migratory route for *Elephas maximus* Linnaeus, 1758 (elephant) (Sukumar and Easa, 2006).

The forest in the study site consisted of a 971 hectare reserve forest characterized by West Coast Semi-Evergreen trees (Champion and Seth, 1968). The agriculture habitat consisted of a 372 hectare banana and orange plantations (Fig. 1). The transition between the forest habitat and the agriculture field occurred over the space of five to eight metres.

2.2 Sampling

Dung beetles were collected in May (summer), September (monsoon) and December (presummer) of 2007-2008. Cow dung baited pitfall traps were used to collect dung beetles from the forest and agriculture habitat. Ten traps were placed 50m apart in each of the two habitats during each collection effort. The traps in forest and agriculture habitats were separated by a distance of 100m. The trap contents were collected at 12 h intervals (6:00-18:00h and 18:00-6:00h) to separate diurnal and nocturnal species. Collected beetles were preserved in 70% alcohol and later identified to species levels using taxonomic keys available in Arrow (1931) and Balthasar (1963a, b) and also by verifying with type specimens available in the Coleoptera collections of St. Joseph's College, Devagiri, Calicut.

Species were sorted into the three functional guilds, rollers (telecoprids), tunnelers (paracoprids) and dwellers (endocoprids) (Cambefort and Hanski, 1991). For categorizing temporal guilds, the beetles collected only during the diurnal collections were labelled as diurnal and only in nocturnal collections were labelled as nocturnal beetles. For those beetles collected in diurnal and nocturnal collections, their abundance were tested statistically to designate them as diurnal and nocturnal beetles; those showing no significant variation in abundance between the diurnal and nocturnal collections were labelled as generalist species. Singleton species were excluded from the temporal guild study. Length of the beetles were measured and beetles < 10 mm was designated as small beetles ≥10 mm was designated as large beetles (Barrágan *et al*., 2011).

2.3 Analysis

To show how common or rare a species is in relation to other species, a relative abundance graph was plotted for the two habitats. Since the data was not normally distributed, non-parametric test Kruskal-Wallis was performed to compare the functional guild and temporal guild abundance within the two habitats. Differences with a p-value <0.05 was compared using Wilcoxon-Mann/Whitney Test. Overall abundance between the two habitats was compared using Wilcoxon Signed Ranks Test and in beetle sizes within the habitats was

http://dx.doi.org/10.22161/ijeab/4.1.30 ISSN: 2456-1878

compared using Mann-Whitney U test. The tests were carried out using SPSS 21.

III. RESULTS

A total of 622 beetles belonging to 21 species and seven genera were collected from forest and 343 beetles belonging to 25 species and eight genera were collected from agriculture habitat (Table 1). The abundance of dung beetles between the two habitats did not vary significantly (p=0.54). Of the 31 species collected between the two habitats, only 15 species were shared by forest and agriculture habitat, resulting in 51.6% species turnover. *Onthophagus pacificus* (37.78%) and *Onthophagus furcillifer* (24.92%) were the dominant beetles in the forest assemblage and together constituted 62.70% of the total abundance. *Caccobius meridionalis* (25.66%) and *Onthophagus fasciatus* (21.57%) were the dominant beetles in the agriculture habitat assemblage and together constituted 46.23% of the total abundance. The Rank abundance plot for the two habitats showed a steep slope as a result of dominance of these two species and a long tail of several rare species (Fig.2).

Functional guild composition showed significant variation in abundance within forest and agriculture habitat (Table 2). Tunnelers dominated the forest (93.41% of total abundance, 18 species) and agriculture habitat (96.50% of total abundance, 22 species). Rollers were represented by two species, *Paragymnopleurus sinuatus* and *Sisyphus araneolus* in the forest habitat and was the second most abundant functional guild (6.43% of total abundance) but was absent in agriculture habitat. Dwellers represented by one species, *Tibiodrepanus setosus* (0.16% of the total abundance) was the least dominant guild in the forest assemblage but dwellers represented by three species *Liatongus indicus*, *Tibiodrepanus setosus* and *T. sinicus* (3.50% of total abundance) was the second dominant guild in agriculture habitat (Fig.3).

Temporal guilds showed significant variation in abundance within forest and agriculture habitat (Table 2). Nocturnal guild was the most abundant guild (60% of abundance) in the forest assemblage but diurnal guild dominated agriculture habitat (66% of total abundance). Generalist species were least abundant in both the habitats (Fig.4).

Small species dominated the assemblage in forest (85.70% of total abundance) and agriculture habitat (82.22% of total abundance). Large species accounted for 14.30% of abundance in forest and 17.78% of abundance in agriculture habitat (Fig.5). There was no significant variation in abundance between large and small beetles in agriculture (p=0.219) or forest habitat (p=0.142).

IV. DISCUSSION

In the present study dung beetle community attributes were affected by land use change in South Western Ghats. High abundance was recorded in forest habitat when compared to agriculture habitat. Similar observations were made in multiple studies done in modified habitats (Nichols *et al*., 2007). Cultivated land often lacks the microhabitat diversity of natural habitats and there are fewer dung types available due to the disappearance of large wild mammals (Nichols *et al*., 2007; Nielsen, 2007). Agriculture habitats in Nelliampathi are relatively small patches amidst vast stretches of plantations and forests and though incursions of wild animals into agriculture habitat has been observed, still the diversity and amount of dung types available is less compared to the forest habitat, which in turn affected the abundance of dung beetles in agriculture habitat.

Higher species richness in agriculture habitat can be attributed to the establishment of heliophiles and synanthropic species in the region as a result of decades of anthropogenic activities such as deforestation, habitat modification and fragmentation in the South Western Ghats region (Sukumar and Easa, 2006; Latha and Unnikrishnan, 2007; Prabhakaran, 2011). These are species capable of thriving in man-made habitats in the region (Vinod, 2009; Sabu *et al*., 2011; Sabu, 2011; Venugopal *et al*., 2012). *Caccobius meridionalis, C. gallinus, C. ultor* which were absent in forest and present in agriculture habitat with preference towards ruminant herbivore dung (Hanski and Cambefort, 1991) are considered as such synanthropic species (Sabu, 2011).Similar presence of synanthropic species were observed in Colombia in studies done in natural and anthropogenic habitats (Escobar, 2004), in guamil patches with secondary successions in Gautemala (Avendano-Mendoza *et al*., 2005) and in pastures of Central America (Horgan, 2007). Such increase in species richness in disturbed habitats associated with species that respond positively to disturbance is not considered a positive attribute, as original species composition is altered to favor disturbance adapted species (Davis *et al*., 2001). *Onthophagus furcillifer* and *Onthophagus pacificus* which were the dominant beetles in the forest habitat and were also well represented in the agriculture habitat are considered as heliophilic species, well adapted to survive in the degraded forests and agriculture habitat of the region.

Tunnelers represented the most speciose and abundant functional guild both in forest and agriculture habitat. Tunneler guild dominated the assemblage in other forests of Western Ghats also (Sabu *et al*., 2006, 2007; Vinod and Sabu 2007; Sabu *et al*. 2011). Aggressive and superior competitive nature of tunnelers in utilizing the dung resource

http://dx.doi.org/10.22161/ijeab/4.1.30 *ISSN: 2456-1878*

(Doube, 1991; Krell-Westerwalbesloh *et al*., 2004) contributed to their success and dominance in the habitats. Rollers though the second most dominant guild in Nelliampathi forest was absent from agriculture habitat. Rollers require firm (less liquid) dung than the tunnelers because of the need to make them into balls (Halffter and Mathews, 1966). The low forest floor temperature and high humidity in these moist forests, keeps the dung moist and in a semi fluid state for longer periods, which makes dung ball making and rolling an energetically costly behaviour (Sabu *et al*., 2007). Thick under storey vegetation in these moist forests also act as a hindrance to ball rolling activities (Vinod, 2009). Their absence in agriculture habitat can be related to their sensitivity to changes in vegetation, microclimate and land use (Nielsen, 2007). Dwellers are strongly associated with large herbivore dung pads and breeds successfully only in undisturbed dung pads with little competition from competitively superior tunnelers and rollers (Hanski and Cambefort 1991; Krell *et al*., 2003; Krell-Westerwalbesloh *et al*., 2004). Low abundance of megaherbivores and their dung pads, in these forests due to extensive human interference (Abraham *et al*., 2006; Joy, 1991; Mathew *et al*., 1998; Sukumar and Easa, 2006) and competition from the competitively superior tunnelers limits the availability of undisturbed dung pads for use by dwellers in both the habitats (Doube, 1991; Krell *et al*., 2003). Moreover, in the agriculture habitat, dung pads are removed by farmers during agricultural practices like tilling, ploughing, manuring, which disrupts feeding and breeding activities of dwellers (Sabu and Vinod, 2005).

Dawn and dusk are two periods when defecation of mammals peak and this corresponds to the increase in activity of dung beetles during these times (Gill, 1991). Dominance of nocturnal guild in the forests of Nelliampathi is probably related to the availability of food resource at night as many mammals void their dung at the end of a feeding day. But in agriculture habitat, the main source of dung is contributed by domestic herbivores which are active during the day and confined to sheds at night. This led to the dominance of diurnal species in agriculture habitat. Similar dominance of diurnal species were observed in pastures, croplands and areas used for raising cattle in Honduras (Halffter *et al*.,1992), Mexico (Horgan, 2002) and Colombia (Escobar, 2004). Diurnal beetles were smaller in size than nocturnal and generalist species (Cambefort, 1991) and this is partially related to thermoregulatory constraints (Bartholomew and Heinrich, 1978). Large beetles dissipate heat more slowly during the day compared to small beetles and may face the problem of overheating. Predation may also play some role in limiting the size of diurnal beetles (Cambefort and Walter, 1991) as small beetles will be less visible to the predator during the day than large beetles.

Studies have recorded local extinctions and abundance declines on large-bodied beetles with increase in anthropogenic disturbance (Feer, 2008; Gardner *et al*., 2008; Jankielsohn *et al*., 2001; Shahabuddin *et al*., 2005). Large beetles prefer large dung pads (Doube, 1990; Hanski and Cambefort, 1991) and also use disproportionately large share of resources, they are therefore negatively affected by reduction in resource availability as in disturbed habitats (Doube, 1990; Larsen *et al*., 2008). Anthropogenic disturbance in the South Western Ghats region (Abraham *et al*., 2006; Joy, 1991; Mathew *et al*., 1998; Sukumar and Easa, 2006) has led to the decline in large dung pad producing mammals like elephant, gaur and the abundance of small dung pad producing mammals in these forests. This has resulted in small sized beetles dominating the forest and agriculture habitats. In addition physiological intolerance to thermal stress in the degraded open forest and agriculture habitat also affects large beetles (Bartholomew and Heinrich, 1978; Chown, 2001). Such dominance of small beetles can negatively affect the ecosystem functions these beetles provide, such as dung removal in a habitat (Kenyon *et al*., 2016).

V. CONCLUSION

In the present study, land use change affected dung beetle community structure in a forest and agriculture habitat in South Western Ghats region. Natural habitat such as the forest supported higher abundance of dung beetles when compared to anthropogenic habitat like agriculture field due to the abundance and diversity of food resource available. But higher species richness in agriculture habitat due to the establishment of synanthropic and heliophilic species dominating the region is of concern. Further studies are recommended in the region to document the general trend in other forests and modified habitats and measures should be taken to protect the remaining forests to conserve the forest specialists.

ACKNOWLEDGEMENTS

We wish to thank the University Grants Commission, India for the financial assistance, St. Josephs College, Devagiri, for the laboratory facilities; Vinod, Shiju, Nithya for statistical and technical assistance.

REFERENCES

[1] Abraham S.K., Easa P.S., Sivaram M. (2006). Status and distribution of Nilgiri Tahr *Hemitragus hylocrius* in Kerala part of Western Ghats. *Zoo's print journal,* 21(9):2379-2385.

[2] Ali S. (1999). *Birds of Kerala,* 3rd edition. Kerala Forests and Wildlife Department.
[3] Alroy J. (2017). Effects of habitat disturbance on tropical forest biodiversity. *Proc. Natl. Acad. Sci. USA* 114:6056–6061.
[4] Ardali E. O., Tahmasebi P., Bonte D., Milotic T., Pordanjani I., Hoffmann M. (2016). Ecological Sustainability in Rangelands: The Contribution of Dung Beetles in Secondary Seed Dispersal (Case study: Chaharmahal and Bakhtiari province, Iran). *European Journal of Sustainable Development* 5 (3) 133- 139. 10.14207/ejsd.2016.v5n3p133.
[5] Arrow G.J. (1931). *The Fauna of British India including Ceylon and Burma, Coleoptera: Lamellicornia (Coprinae)*.Taylor and Francis. London. 3: pp. i-xii+428.
[6] Balthasar V. (1963a). *Monographic der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen Region (Coleoptera: Lamellicornia)*. Volume 1, Verlag der Tschechoslowakischen Akademie der Wissenschaften. Prag, 391 pp,PI. XXIV
[7] Balthasar V. (1963b). *Monographic der Scarabaeidae und Aphodiidae der Palaearktischen und Orientalischen Region (Coleoptera: Lamellicornia)*. Volume 2. Verlag der Tschechoslowakischen Akademie der Wissenschaften. Prag, 627 pp,PI. XVI.
[8] Barragán F., Moreno C.E., Escobar F., Halffter G., Navarrete D. (2011). Negative Impacts of Human Land Use on Dung Beetle Functional Diversity. *PLoS ONE*, 6(3): e17976.
[9] 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.
[10] Bawa K.S., Das A., Krishnaswamy J., Karanth K.U., Kumar N.S., Rao M. (2007). *Ecosystem profile, Western Ghats and Sri Lanka biodiversity hot spot, Western Ghats region*. Critical Ecosystem Partnership Fund, 95 pp.
[11] Cambefort Y., Walter P. (1991). Dung beetles in Tropical forests in Africa. In: Hanski I., Cambefort Y., editors. *Dung beetle ecology*, 198-210. Princeton University Press.
[12] Cambefort Y. (1991). Dung beetles in Tropical Savannas. In: Hanski I., Cambefort Y., editors. *Dung beetle ecology*, 156-178. Princeton University Press.
[13] Cambefort Y., Hanski I. (1991). Dung beetle population biology. In: Hanski I., Cambefort Y., editors. *Dung beetle ecology*, 36-50. Princeton University Press.
[14] Champion H.G., Seth S.K. (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications, 404 pp.
[15] Chown S.L. (2001). Physiological variation in insects: hierarchical levels and implications. *Journal of Insect Physiology*, 47: 649-660.
[16] Davis A.J., Holloway J.D., Huijbregts H., Kirk-Spriggs A.H., Sutton S.L. (2001). Dung beetles as indicators of change in the forests of northern Borneo. *Journal of Applied Ecology*, 38: 593-616.
[17] Doube B.M. (1991). Dung beetles of South Africa. In: Hanski I., Cambefort Y., editors. *Dung Beetle Ecology*, 133-155. Princeton University Press.
[18] Escobar F. (2004). Diversity and composition of dung beetle (Scarabaeinae) assemblages in a heterogeneous Andean landscape. *Tropical Zoology*, 17: 123-136.
[19] Feer F. 2008. Responses of dung beetle assemblages to characteristics of rain forest edges. *Ecotropica*, 14: 49-62.
[20] Feer F., Pincebourde S. (2005). Diel flight activity and ecological segregation with in an assemblage of tropical forest dung and carrion beetles. *Journal of Tropical Ecology*, 21: 21-30.
[21] Forgie S. A., Paynter Q., Zhao Z., Flowers C., Fowler S.V. (2018). Newly released non-native dung beetle species provide enhanced ecosystem services in New Zealand pastures. *Ecological Entomology*. doi:10.1111/een.12513
[22] Gardner T.A., Hernández M.I.M., Barlow J., Peres C.A. (2008). Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for neotropical dung beetles. *Journal of Applied Ecology*, 45: 883-893.
[23] Halffter G., Mathews E.G. (1966). The natural history of dung beetles of the sub family Scarabaeinae (Coleoptera, Scarabaeidae). *Folia Entomologica Mexicana*, 12-14: 1-132.
[24] Halffter G., Favila M.E., Halffter V. (1992). A comparative study of the structure of the scarab guild in Mexican tropical rain forest and derived ecosystems. *Folia Entomologica Mexicana*, 84: 131-156.
[25] Hanski I., Cambefort Y. (1991). Resource partitioning. In: Hanski I. and Cambefort Y., editors. *Dung Beetle Ecology*, 330-349. Princeton University Press.
[26] Hooper D. U., Chapin III F. S.,Ewel J. J, Hector A., Inchausti P., Lavorel S., Lawton J. H., Lodge D. M., Loreau M., Naeem S., Schmid B., Setälä H., Symstad A. J., Vandermeer J., Wardle D. A. (2005). Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. Ecological Monographs, 75 (1), 3-35.
[27] Horgan F.G. (2002). Shady field boundaries and the colonization of dung by coprophagous Beetles in Central

American pastures. *Agriculture, Ecosystems and Environment*, 92: 25-39.

[28] Isbell F.,Cowles J., Dee L. E., Loreau M., , Reich P. B., Gonzalez A., Hector A., Schmid B. (2018). Quantifying effects of biodiversity on ecosystem functioning across times and places. *Ecology Letters*, 21(6), 763-778. https://doi.org/10.1111/ele.12928

[29] Jankielsohn A., Scholtz C.H., Louw S.V. (2001). Effect of Habitat Transformation on Dung Beetle Assemblages: A Comparison between South African Nature Reserve and Neighboring Farms. *Environmental Entomology*, 30(3): 474-483.

[30] Jha, C. S., Dutt, C. B. S., Bawa, K. S. (2000). Deforestation and land use changes in the Western Ghats, India. *Current Science*.79 (2): 231-238.

[31] Joy M.S. (1991). *Keralathile Vanyajeevi sankethangal (Wild Life Reserves in Kerala)*. State Institute of Languages, Kerala.

[32] Tania M., Kenyon T.M., Mayfield M.M., Monteith G. B., Menéndez R. (2016). The effects of land use change on native dung beetle diversity and function in Australia's Wet Tropics. 41 (7): 797-808. https://doi.org/10.1111/aec.12366

[33] Kerala Forests and Wildlife Department, Government of Kerala. 2004. Accessed on March 30, 2009. http://www.keralaforest.gov.in/html/flora/index.htm.

[34] Kissinger G., Herold M., De Sy V., Angelsen A., Bietta F., Bodganski A., Boucher D., et al., (2012). Drivers of Deforestation and Forest Degradation: A Synthesis Report for REDD+ Policymakers, Vancouver, Canada.

[35] Krell F.T., Krell-Westerwalbesloh S., Weiß I., Eggleton P., Linsenmair K.E. (2003). Spatial separation of Afrotropical dung beetle guilds: a trade-off between competitive superiority and energetic constraints (Coleoptera: Scarabaeidae). *Ecography*, 26:210-222.

[36] Krell-Westerwalbesloh S., Krell F.T., Kelinsenmair E. (2004). Diel separation of Afrotropical dung beetle guilds-avoiding competition and neglecting resources (Coleoptera: Scarabaeoidea). *Journal of Natural History*, 38: 2225-2249.

[37] Kumar S. (1993). *Survey and mapping of shola forests and grasslands in the Upper Nilgiri Plateau and assessment of human utilization of the vegetation*. Report submitted to World Wild Fund for Nature– India.

[38] Latha A., Unnikrishnan S. (2007). *RBO driven campaign to preserve downstream ecological flows of a Western Ghats river*. Accessed on March 10, 2010. *www.riversymposium.com.*

[39] Larsen T.H., Lopera A., Forsyth A. (2008).Understand trait dependent community disassembly: dung beetles, density functions and forest fragmentation. *Conservation Biology*, 22: 1288-1298.

[40] Mathew G., Rugmini P., Sudheendra kumar V.V. (1998). *Insect Biodiversity in Disturbed and Undisturbed Forests in the Kerala Parts of Western Ghats*. Kerala Forest Research Institute research report No. 135, 113 pp.

[41] Menon S., Bawa K. S. (1997). Applications of Geographic Information Systems (GIS), remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats. *Current Science*.73: 134-145.

[42] Nair S.C. 1991. *The Southern Western Ghats- a biodiversity conservation plan*. Indian National Trust for Art and Cultural Heritage, New Delhi, 92 pp.

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

[44] Nielsen S.T. (2007). Deforestation and biodiversity: effects of bushland cultivation on dung beetles in semi-arid Tanzania. *Biodiversity and Conservation*, 16: 2753-2768.

[45] Phalan B., Green R., Balmford A. (2014). Closing yield gaps: perils and possibilities for biodiversity conservation. Phil. Trans. R. Soc. B. 369(1639): 20120285.

[46] Piccini I., Arnieri F., Caprio E., Nervo B., Pelissetti S., et al. (2017). Greenhouse gas emissions from dung pats vary with dung beetle species and with assemblage composition. PLOS ONE 12(7), e0178077. https://doi.org/10.1371/journal.pone.0178077

[47] Prabhakaran G. (2011). 27 Nelliampathi estates broke rules, says report. *The Hindu*, July 15.

[48] Sabu T.K., Vinod K.V. (2005). Comparative assessment of the guild structure and taxonomic diversity of two beetle (Coleoptera: Scarabaeinae) assemblages in the Wayanad region of Western Ghats. In: Mary R., editor. *Proceedings of the National Conference safe environment for the future generations*, 47-52.Dept. of Zoology, Auxilium College.

[49] Sabu T.K. (2011).*Guild structure, taxonomic diversity and biosystematics of dung beetles (Coleoptera: Scarabaeinae) in the agriculture and forest habitats of south Western Ghats*. Project report submitted to University Grant Commission, India.

[50] Sabu T.K., Vinod K.V., Latha M., Nithya S., Boby J. (2011). Cloud forest dung beetles (Coleoptera: Scarabaeinae) in the Western Ghats, a global biodiversity

hotspot in southwestern India. *Tropical Conservation Science*,4(1): 12-24.

[51] Sabu T.K., Vinod K.V., Vineesh P.J. (2006). Guild structure, diversity and succession of dung beetles associated with Indian elephant dung in South Western Ghats forests. *Journal of Insect Science*, 6: 17.

[52] Sabu T.K., Vinod K.V., Vineesh P.J. (2007). Succession of dung beetles (Scarabaeinae: Coleoptera) in the dung pats of gaur, *Bos gaurus* H. Smith (Artiodactyla: Bovidae), from the moist deciduous forests of southern Western Ghats. *Biosystematica*, 1(1): 59-69.

[53] Shahabuddin G., Prasad S. (2004). Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. *Conservation and Society*. 2, 235-250.

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

[55] Slade E.M., Riutta T., Roslin T., Tuomisto H.L. (2016). The role of dung beetles in reducing greenhouse gas emissions from cattle farming. *Scientific Reports* 6, 18140.

[56] Sukumar R., Easa P.S. (2006). Elephant conservation in south India: issues and recommendations. *Gajah*, 25: 71-86.

[57] Tilman D., Balzer C., Hill J., Befort B. L. (2011). *Global food demand and the sustainable intensification of agriculture*. Proceedings of National Academy of Sciences, USA108, 20260- 20264.

[58] Venugopal K.S., Thomas S.K., Flemming A.T. (2012). Diversity and community structure of dung Beetles (Coleoptera: Scarabaeinae) associated with semi-urban fragmented agricultural Landin the Malabar cast in southern India. Journal of Threatened Taxa 4(7): 2685-2692.

[59] Vinod K.V. (2009). *Studies on the Systematics and Distribution of Dung Beetles (Scarabaeinae: Coleoptera) in the Forests and Agricultural Fields of Wayanad*. Ph.D. Thesis, Forest Research Institute University.

[60] Vinod K.V., Sabu T.K. (2007). Species composition and community structure of dung beetles attracted to dung of gaur and elephant in the moist forests of South Western Ghats. *Journal of Insect Science*, 7: 1-56.

[61] Wright S. (2010).The future of tropical forest species. Annals of the New York Academy of Sciences 1195, 1-27.

Fig. 1: A. Map showing South Western Ghats; Habitats under study in Nelliampathi B. Semi-evergreen forest, C. Agriculture habitat.

http://dx.doi.org/10.22161/ijeab/4.1.30 ISSN: 2456-1878

*Table.1: Dung beetle species, abundance, temporal guild (Di= diurnal, N= nocturnal, G= generalist, *= guild not specified); functional guild (T= tunneler, R= roller, Dw= dweller) and beetle sizes (S= small, L= large) in a semi-evergreen forest (SEG) and agriculture habitat (AGR) of Nelliampathi during 2007-2008 study period.*

No.	Species	SEG	AGR	Temporal guild	Functional guild	Size
1	*Caccobius gallinus*	0	5	Di	T	S
2	*Caccobius meridionalis*	0	88	Di	T	S
3	*Caccobius ultor*	0	3	G	T	S
4	*Catharsius molossus*	1	12	N	T	L
5	*Copris repertus*	28	27	N	T	L
6	*Liatongus indicus*	0	1	*	Dw	S
7	*Onitis subopacus*	0	1	*	T	L
8	*Onthophagus amphicoma*	1	3	G	T	S
9	*Onthophagus andrewesi*	8	1	Di	T	S
10	*Onthophagus bronzeus*	29	2	G	T	S
11	*Onthophagus castetsi*	16	0	N	T	S
12	*Onthophagus cavia*	1	0	G	T	S
13	*Onthophagus centricornis*	1	0	*	T	S
14	*Onthophagus ensifer*	3	12	Di	T	S
15	*Onthophagus fasciatus*	0	74	Di	T	S
16	*Onthophagus favrei*	2	5	G	T	S
17	*Onthophagus furcillifer*	155	44	Di	T	S
18	*Onthophagus insignicollis*	1	2	G	T	S
19	*Onthophagus laevis*	18	4	G	T	S
20	*Onthophagus manipurensis*	19	8	G	T	L
21	*Onthophagus pacificus*	235	13	N	T	S
22	*Onthophagus porcus*	0	1	*	T	S
23	*Onthophagus rectecornutus*	0	1	*	T	S
24	*Onthophagus turbatus*	16	12	N	T	S
25	*Onthophagus vladimiri*	7	0	G	T	S
26	*Paracopris cribratus*	40	7	N	T	L
27	*Paracopris davisoni*	0	6	N	T	L
28	*Paragymnopleurus sinuatus*	1	0	*	R	L
29	*Sisyphus araneolus*	39	0	N	R	S
30	*Tibiodrepanus setosus*	1	10	G	Dw	S
31	*Tibiodrepanus sinicus*	0	1	*	Dw	S

Table.2: Statistical analysis of functional and temporal guild abundance of dung beetle species associated with a semi- evergreen forest and agriculture habitat of Nelliampathi during 2007-08 study period.

Parameters	Kruskal-Wallis H test			Wilcoxon-Mann/Whitney Test (*P* value)		
Functional guild	**H**	**DF**	***P***	**T-R**	**R-Dw**	**T-Dw**
Agriculture habitat	19.569	2	< .001	< .001	.042	.003
Forest habitat	21.629	2	< .001	.126	.005	.007
Temporal guild	**H**	**DF**	***P***	**Di-N**	**N-G**	**Di-G**
Agriculture habitat	65.842	2	< .001	< .001	.001	< .001
Forest habitat	49.891	2	< .001	< .001	<.001	.053

http://dx.doi.org/10.22161/ijeab/4.1.30 *ISSN: 2456-1878*

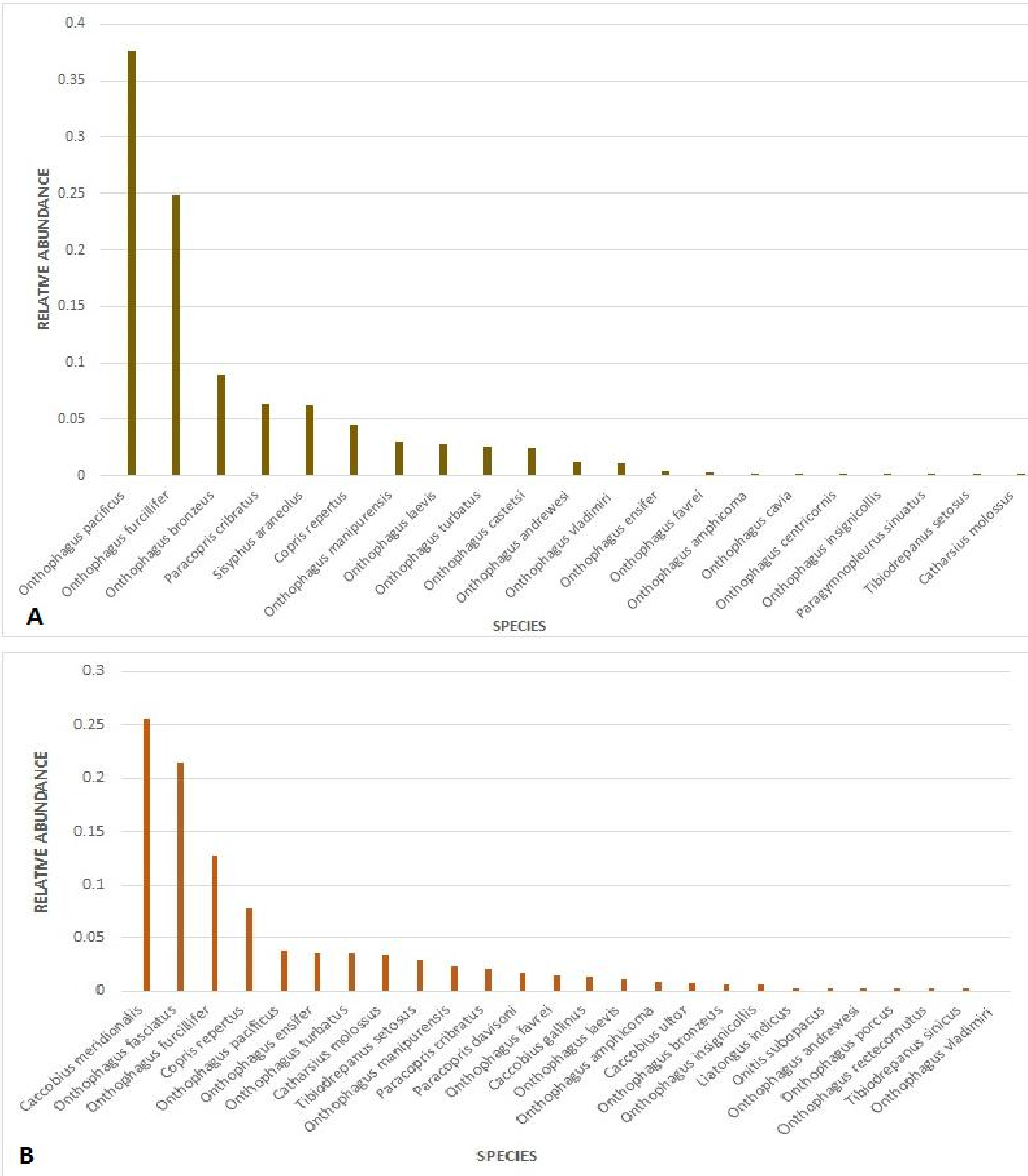

Fig.2: Relative abundance of dung beetle in a (A) Semi-evergreen forest and (B) Agriculture habitat of Nelliampathi during the 2007-2008 study period

http://dx.doi.org/10.22161/ijeab/4.1.30 ISSN: 2456-1878

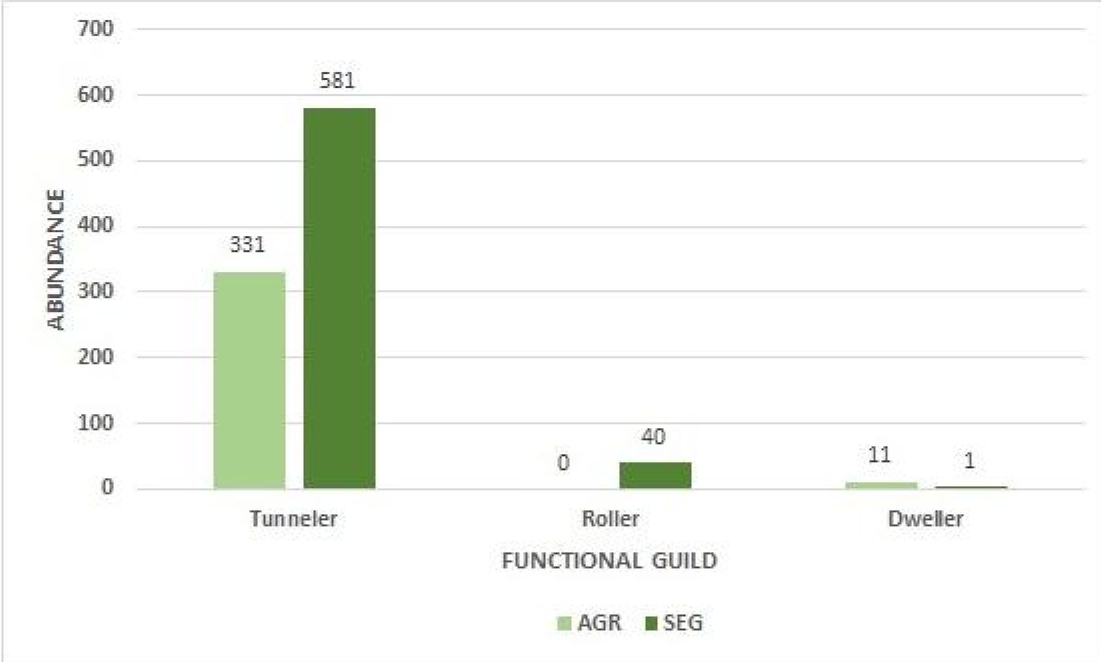

Fig.3: Functional guild composition and abundance of dung beetle species in a Semi-evergreen forest and Agriculture habitat of Nelliampathi during the 2007-2008 study period

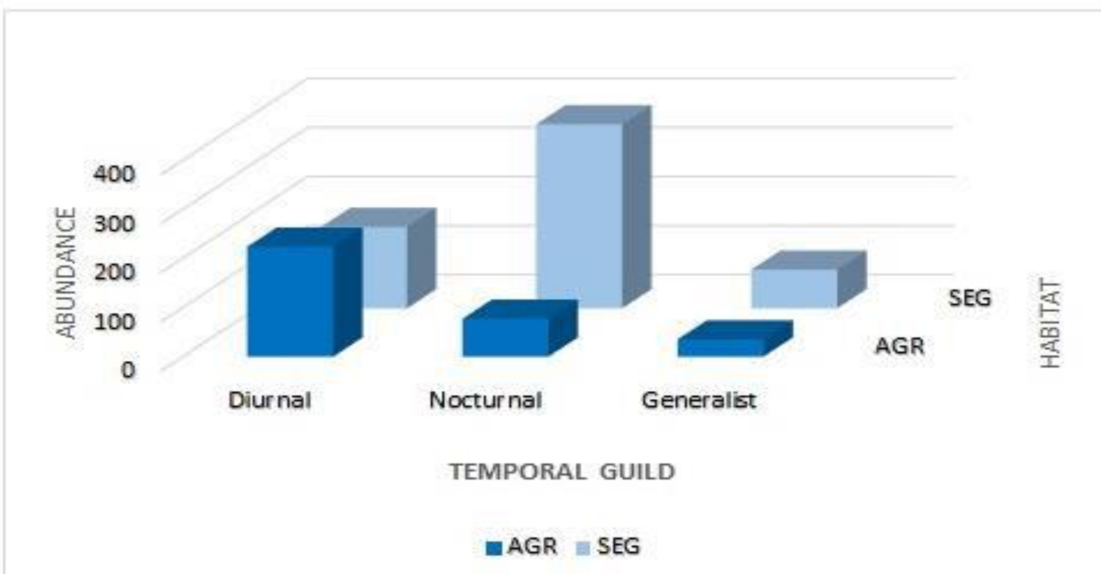

Fig.4: Temporal guild composition and abundance of dung beetle species in a Semi-evergreen forest and Agriculture habitat of Nelliampathi during the 2007-2008 study period

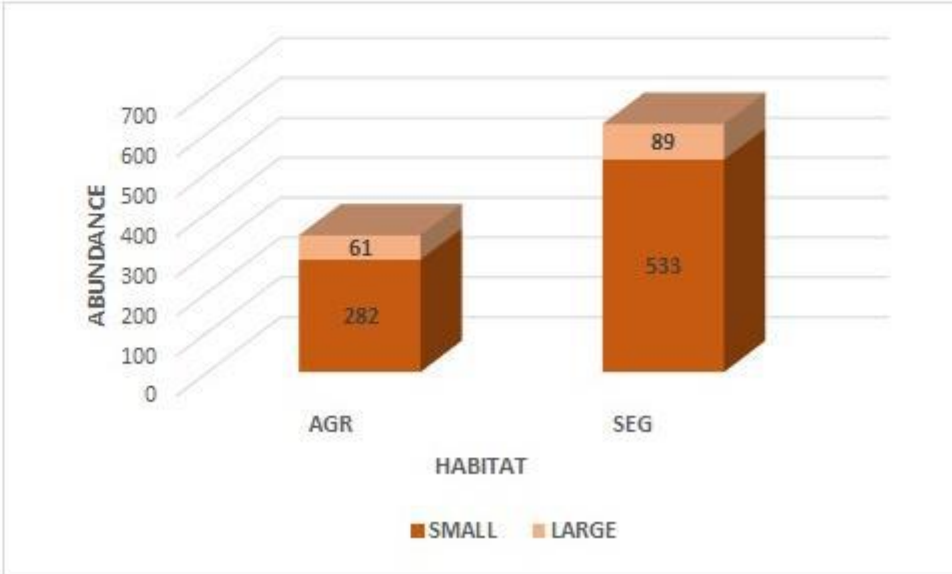

Fig.5: Abundance of large and small dung beetles in a Semi-evergreen forest and Agriculture habitat of Nelliampathi during the 2007-2008 study period