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

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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 patterns during a day based on which they are divided into temporal guilds (Feer and Pincebourde, 2005). Diel periodicity studies commonly distinguish two major groups of dung beetle species, nocturnal and diurnal (Krell et al. 2003; Krell-Westernerwalbesloh 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 Thrisur district, to the south (Ali, 1999). The study was carried out in Kaikatty in Nelliampathi, located at 10° 31’N and 76° 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 50 m apart in each of the two habitats during each collection effort. The traps in forest and agriculture habitats were separated by a distance of 100 m. The trap contents were collected at 12 h intervals (6:00-18:00 h and 18:00-6:00 h) 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
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; Lathe 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. ulterior* which were absent in forest and present in agriculture habitat with preference towards ruminant herbivore dung (Hanski and Cambeforth, 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 guamal patches with secondary successions in Guatemala (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...
Rollers though the second most dominant guild in Nelliyampathi forest was absent from agriculture habitat. Rollers require firm (less liquid) dung than the tunneler because of the need to make them into balls (Halfpenny 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 understorey 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 (Nielson, 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 Cambeafort 1991; Krell et al., 2003; Krell-Westerwalbeslokh 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 Nelliyampathi 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 (Halfpenny et al., 1992), Mexico (Horgan, 2002) and Colombia (Escobar, 2004). Diurnal beetles were smaller in size than nocturnal and generalist species (Cambeafort, 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 (Cambeafort 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 Cambeafort, 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.

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**Fig. 1:** A. Map showing South Western Ghats; Habitats under study in Nelliampathi. B. Semi-evergreen forest. C. Agriculture habitat.
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 ampicoma     | 1   | 3   | G              | T                | S    |
| 9   | Onthophagus andrewesi    | 8   | 12  | 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 daisoni       | 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 simicus    | 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) |
|-----------------------------|-----------------------|-------------------------------------|
|                             | H        | DF | P   | T-R | R-Dw | T-Dw |
| Functional guild            |          |    |     |     |      |      |
| Agriculture habitat         | 19.569   | 2  | < .001 | < .001 | .042 | .003 |
| Forest habitat              | 21.629   | 2  | < .001 | .126 | .005 | .007 |
| Temporal guild              |          |    |     |     |      |      |
| Agriculture habitat         | 65.842   | 2  | < .001 | < .001 | .001 | < .001 |
| Forest habitat              | 49.891   | 2  | < .001 | < .001 | .001 | .053 |
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.
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.