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Diversity and community structure of dung beetles (Coleoptera: Scarabaeinae) associated with semi-urban fragmented agricultural land in the Malabar coast in southern India

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Abstract: An evaluation of the diversity and community structure of dung beetles associated with semiurban agricultural land in the Malabar coast of southern India revealed that urbanization has led to decreased diversity compared to regional forests, and has affected the community status of dung beetles. However, contrary to expectations, species richness was observed to be equivalent to rural agricultural fields in the region. Low abundance of prominent agricultural habitat species indicates that the study area has changed as a result of habitat modification/urbanization, and the prevailing conditions are not ideal for the establishment of the most common species in agriculture belts. Prominence of two less common species, *Tiniocellus spinipes* and *Caccobius vulcanus,* indicates these generalist urban adaptable (synanthropic) species have become increasingly widespread and locally abundant. The low abundance of tunnelers and rollers is attributed to fragmentation of the urban agricultural belt, low mammalian diversity and dung availability, and the hard nature of the laterite soil in the Malabar coast region.

Keywords: Dung beetles, fragmentation, Malabar coast, southern India, *Tiniocellus spinipes,* urbanization.

INTRODUCTION

Destruction and deterioration of natural habitats associated with urbanization has led to dramatic changes in the biotic structure and composition of ecological communities. Observations include decreased abundance and diversity, disappearance or replacement of indigenous species by non-natives (Blair 1996, 2004; La Sorte & Boecklen 2005) and habitat specialists (Magura et al. 2010), and local extinctions (Raupp et al. 2010). In many places, although highly modified and disturbed, small urban fragments of agricultural lands in the midst of urban environments have been identified as an important source of native biodiversity (Gaston et al. 2004). The different fauna found in small urban fragments may be a consequence of any of a number of pressures associated with fragmentation and urbanization, including increased anthropogenic disturbance, reduced area, loss of hosts, invasion of new species and release of natural enemies (Yahner 1988). Such areas can provide ephemeral or more permanent habitats for species, dispersal corridors or resting places for migrating organisms (Gaston et al. 2005). Therefore, it is important to document the status of biodiversity prevailing in other areas to identify the level of biodiversity still left in urban areas and characterize the remaining elements of the original biota (e.g. are they specialist or generalist). In the present effort we aim to determine the community structure of dung

beetles in a small isolated agricultural land in the midst of urban settlements in the coastal Malabar region.

The Malabar coast moist deciduous forests ecoregion—hereafter referred as MCF—was a swath of lush tropical evergreen forest that extends along the Western Ghats mountains and the Arabian Sea. MCF represents an extreme example of deforestation in the Western Ghats, having undergone major ecological transformations over the last 100 years (Nair 1991; Wikramanayake et al. 2002). MCF has lost more than 95% of its original vegetation to deforestation during the British rule (Colonial period), cash crop cultivation during the post Colonial period and recent urbanization. Currently, due to the recent wave of urbanization, the agricultural lands are being transferred into urban jungles at alarming rates in the MCF. It is certain that the remaining original biota that took shelter in these pockets will be lost soon. No records exist about the impact of anthropogenic activity on biodiversity in the region and hence we lack crucial historical documentation of the natural communities in MCF which would remain as an important source of information for measuring species extinctions in the area (Brook et al. 2003). The present effort aims to gather data on the composition and guild structure of dung beetle assemblage associated with a fragmented agricultural landscape in the midst of an urban environment in Kozhikode region in the MCF. We selected dung beetles because they showed significant changes in species composition and community assemblage following forest fragmentation and habitat disturbances (Nichols et al. 2007), making them excellent biodiversity indicators for examining the responses of species communities to anthropogenic disturbance (Gardner et al. 2008a,b). We propose that the regional dung beetle fauna might not have been affected by urbanisation, disappearance of native mammals and an unchanged native assemblage with high diversity and abundance exists in the region.

MATERIALS AND METHODS

Study area

Selected study site was an open agricultural field ($11^0$15'N & $75^0$48'E) of predominantly coconut plantation with the intervening grasslands close to Devagiri College campus, Kozhikode used for cattle and sheep grazing. Annual temperature 24–32 ^{0}C; relative humidity 40–80 %; average rainfall 750–1500 mm/year which occurs mostly in the wet months of June to November (CWRDM 2008-09).

Sampling

Dung beetles were collected using dung baited pitfall traps of the bait-surface-grid type on a seasonal basis during southwest monsoon (June–August), northeast monsoon (September–November), presummer (December–February) and summer (March–May) periods from June 2008 to May 2009. Pit fall traps were made of plastic basins, 10cm in diameter and 15cm deep and a mixture of water-formalin-liquid soap mixture were used as preservative. The basins were buried with their rim in level with the surrounding substrate and each trap was topped with a plastic plate supported on iron bars to prevent desiccation during sunny days and inundation during the periods of rain. Two hundred grams of fresh cow dung was placed on a wire grid between the basin and the tray. Ten such traps at 50m intervals along a linear transect were placed following the standardized dung-beetle sampling design of maintaining a minimum distance of 50m between traps to minimize trap interference (Larsen & Forsyth 2005). Beetles were collected at 0600 and 1600 hr each day. Both diurnal and nocturnal collections were made separately.

Beetles were identified to species levels using taxonomic keys available in Arrow (1931), Balthasar (1963) and by comparing with the verified specimens. After identification, specimens were deposited in the insect collections of St. Joseph's College, Devagiri, Kozhikode. The species were sorted into three functional guilds - dwellers (endocoprids), rollers (telecoprids) and tunnelers (paracoprids) following Cambefort & Hanski (1991) and three temporal guilds (noctural/diurnal/generalists) following Krell et al. (2003). Species that were present during all seasons with >10% abundance were treated as major groups, <10% were treated as minor groups and singletons as rare groups. Based on size, dung beetles are classified into small beetles (with size 5mm and less) and large beetles (5.1 and 30 mm).

Data analysis

Diversity (Magurran 2004) was estimated using Shannon–Weaver diversity index (Shannon & Weaver

1949), evenness with Simpson's evenness index (Simpson 1949) and richness with Margalef's species richness index (d). Data used for statistical analysis were tested for normality with GRETL open source software version 1.1 (Cottrell 2006). Significant levels of variation in the overall and species-wise abundance with seasons were tested with Kruskal-Wallis followed by Mann-Whitney U test (Weiss 2007). All statistical data analyses were done with Mega Stat Version 10.0 software (Orris 2005) and diversity analysis with Primer v5.2.9 software.

RESULTS

Species richness and diversity

A total of 519 dung beetles representing 26 species, belonging to eight genera and five tribes were recorded. Assemblage consisted of three major species, 17 minor and six rare species. *Tiniocellus spinipes* (44.89%) and *Caccobius vulcanus* (17.92%) dominated the assemblage (Image 1). Large and small size beetles varied in abundance (Kruskal-Wallis test, H = 8.64, df = 1, P<0.05). Small sized beetles represented by 10 species (67.83% of total abundance) dominated the assemblage over the large sized beetles represented by 15 species (Table 1). The diversity (H) was 2.015, Margalef species richness index value (d) was 9.75,

Table 1. Abundance (mean±SD), percentage composition, seasonality, temporal and functional guild of dung beetle assemblage in the fragmented urban agricultural habitat during the 2008–09 period.

	Species	Mean±SD	%	Seasonality	Temporal guild	Functional guild
1	*Tiniocellus spinipes* * @	5.83±6.91	45.87	S	Di	D
2	*Caccobius vulcanus* * #	2.33±3.55	18.31	S	N	T
3	*Tibiodrepanus setosus* * #	1.20±2.10	9.45	AS	Di	D
4	*Onthophagus ensifer* @	0.48±0.91	3.74	S	N	T
5	*Onthophagus falsus* @	0.48±0.91	3.74	S	N	T
6	*Paracopris signatus* @	0.40±0.81	3.15	S	N	T
7	*Onthophagus insignicollis* #	0.30±0.76	2.36	S	G	T
8	*Ochicanthon murthyi* #	0.28±0.88	2.12	AS	N	R
9	*Caccobius meridionalis* #	0.25±0.59	1.97	AS	G	T
10	*Onthophagus centricornis* #	0.20±0.56	1.57	AS	G	T
11	*Onthophagus fasciatus* @	0.18±0.45	1.38	AS	G	T
12	*Onthophagus malabariensis* #	0.18±0.50	1.38	AS	Di	T
13	*Onthophagus kchatriya* @	0.15±0.43	1.18	S	Di	T
14	*Sisyphus neglectus* @	0.13±0.46	0.98	S	Di	R
15	*Onthophagus duporti* @	0.13±0.40	0.98	AS	G	T
16	*Onthophagus bifasciatus* @	0.10±0.30	0.79	AS	N	T
17	*Sisyphus longipes* #	0.08±0.27	0.59	AS	Di	R
18	*Onthophagus cervus* @	0.08±0.27	0.59	AS	G	T
19	*Onthophagus unifasciatus* @	0.05±0.22	0.39	AS	Di	T
20	*Onthophagus dama* @	0.05±0.32	0.39	AS	G	T
21	*Paracopris davisoni* @	0.03±0.16	0.20	AS	G	T
22	*Oniticellus cinctus* @	0.03±0.16	0.20	AS	G	D
23	*Onthophagus pygmaeus* #	0.03±0.16	0.20	AS	Di	T
24	*Onthophagus favrei* @	0.03±0.16	0.20	AS	Di	T
25	*Onthophagus madoqua* #	0.03±0. 16	0.20	AS	Di	T
26	*Onthophagus turbatus* @	0.03±0.16	0.20	AS	N	T

N - nocturnal; Di - diurnal; G - generalist; * - major species; S - seasonal; AS - aseasonal; # - small species; @ - large species; D - dweller; T - tunneler; R - roller

Image 1. Two dominant species (a) *Tiniocellus spinipes* and (b) *Caccobius vulcanus* present in the fragmented urban agricultural habitat during 2008–09 period.

dominance index value (λ) was 0.24 and evenness (1-λ) was 0.751. Rank of each species based on relative abundance is represented in Fig. 1.

Functional and temporal guild composition

Dwellers were the most abundant guild (53.75%) with *T. spinipes* and *Tibiodrepanus setosus* as dominant species followed by tunnelers (41.42%) and rollers (3.85%) (H=53.46, df=2, P<0.05). Tunnelers, represented by 20 species (76.92%) were the most speciose guild followed by rollers and dwellers represented by three species each (11.53%) (Table 1). Six species were nocturnal, five were diurnal and 15 were generalists. Diurnal guild dominated the assemblage followed by nocturnal and generalist (H=20.01, df=2, P <0.05) (Table 1).

Seasonality

Highest abundance was recorded during southwest season followed by northeast and summer season (H=45.33, df=3, P<0.05). Among the three guilds, tunnelers were seasonal (H=3.81, df=3, P <0.05) with high abundance during southwest monsoon period followed by northeast monsoon, summer and presummer periods. Dwellers (H=4.39, df=3, P >0.05) and rollers (H=11.42, df=3, P >0.05) did not show any seasonal variation. Eight species (one roller, one dweller and six tunnelers) showed seasonal variation in abundance (Table 2).

DISCUSSION

Evaluation of the diversity and community structure of the dung beetles associated with the semi-urban agricultural lands revealed that urbanization does cause a decrease in dung beetle diversity compared to regional forests and has affected the community status of dung beetles. However, contrary to the expectations, species richness was in par with the rural agrifields in the region. Following patterns, namely, (1) dominance of the community by two species (*T.*

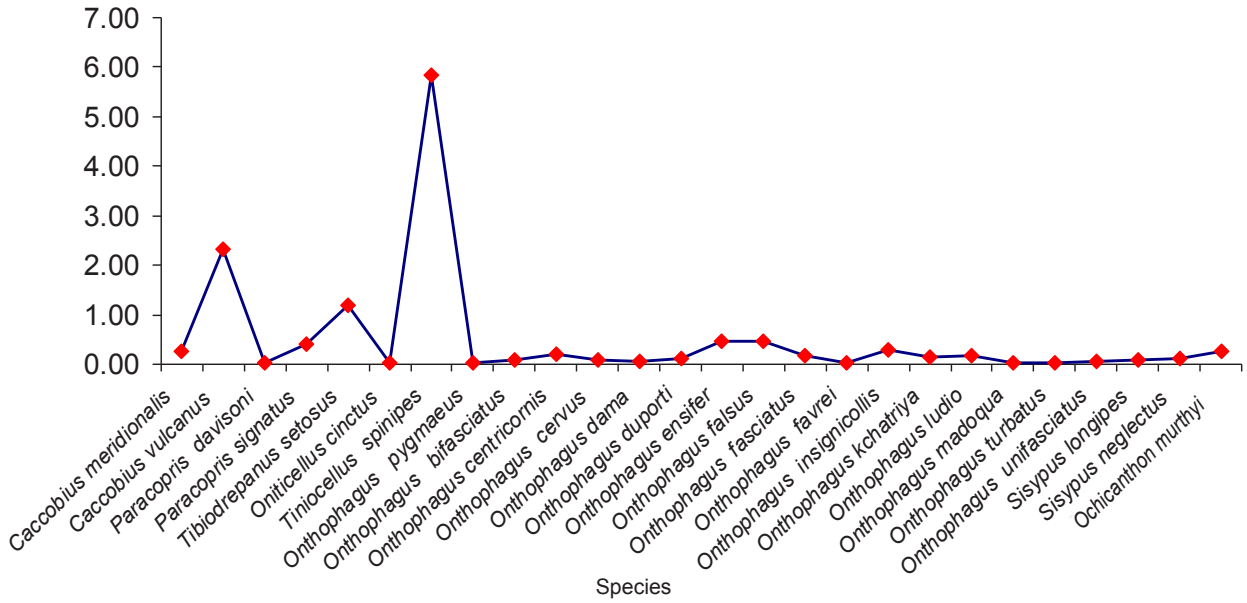

Figure 1. Rank abundance plot of dung beetles in the fragmented urban agricultural habitat during 2008–09 period.

Table 2. Results of Kruskal-Wallis and Mann-Whitney tests of overall and individual seasonal abundance of dung beetle assemblage in the fragment urban agricultural habitat during 2008-09 period.

		Kruskal-Wallis			Mann-Whitney p-value					
		H	DF	p- values	S - PS	S - SW	S - NE	PS - SW	PS - NE	SW - NE
	Abundance	20.97	3	<0.05	>0.05	<0.05	<0.05	<0.05	<0.05	>0.05
	Species									
1	*Caccobius vulcanus*	14.24	3	<0.05	<0.05	>0.05	>0.05	<0.05	<0.05	>0.05
2	*Paracopris signatus*	18.56	3	<0.05	>0.05	<0.05	>0.05	<0.05	>0.05	<0.05
3	*Tiniocellus spinipes*	19.67	3	<0.05	<0.05	<0.05	>0.05	>0.05	<0.05	<0.05
4	*Onthophagus ensifer*	27.76	3	<0.05	>0.05	<0.05	>0.05	<0.05	>0.05	<0.05
5	*Onthophagus falsus*	8.96	3	<0.05	>0.05	<0.05	>0.05	<0.05	<0.05	>0.05
6	*Onthophagus insignicollis*	11.30	3	<0.05	>0.05	<0.05	>0.05	<0.05	>0.05	>0.05
7	*Onthophagus kchatriya*	9.69	3	<0.05	>0.05	<0.05	>0.05	<0.05	>0.05	>0.05
8	*Sisyphus neglectus*	9.47	3	<0.05	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05

spinipes and *C.vulcanus*) recorded rarely from the moist forests and agrifields, and the record of five rare forest specialist species *Ochicanthon murthyi*, *Onthophagus insignicollis, O. kchatriya, O. duporti* and *Oniticellus cinctus* (Arrow 1931; Sabu 2011) and (2) low abundance of prominent species in the regional agrilands and forests namely *Caccobius meridionalis, Onthophagus dama, O. turbatus, O. falsus* and *O. fasciatus* (Sabu 2011) were observed.

Community structure of the assemblage was highly uneven with the dominance of two species (*T. spinipes* and *C. vulcanus*). Uneven distribution of species is relatively common in unstable environments and point towards extreme disturbance (Magurran 2004). *Tiniocellus spinipes* and *C. vulcanus* are rare in the agriculture and forest belts of the Western Ghats, and the most abundant species are *Caccobius meridionalis, Onthophagus dama, O. turbatus, O. falsus* and *O. fasciatus* (Sabu 2011). Low abundance of these prominent agri habitat species indicates that the study region has changed as a result of the habitat modification/urbanization and the prevailing conditions in the study region is not ideal for the establishment of even the most common and hence the most adapted species in the agriculture belts. Two dominant species in the study region namely *T. spinipes* and *C. vulcanus* are the prominent species in the open semi-arid dry north western part of the Indian subcontinent with a long history of habitat modification (Arrow 1931; Balthasar 1963; Mittal 2005; Kakkar & Gupta 2010). Higher abundance of two species common in the open and dry belts in northern India and low abundance in the moist regional forest and agri belts indicate them to be heliophilic, open habitats adapted and disturbance tolerant species. Dominance of such heliophilic, dry habitats species in the moist study region indicates that the study region underwent extreme modifications and the utility of these two species can be seen as indicators of habitat change in the MCF in general. Cosmopolitan distribution and common occurance of *T. setosus* in the forests and agribelts in the moist Western Ghats (Sabu 2011) and in the present study MCF site which is an isolated urban agribelt indicates that *T. setosus* is a generalist species with capacity to persist in a wide array of habitat types. Distinctly low representation of forest specialist species supports the 'habitat specialist hypotheses' (Magura et al. 2008), which suggested that 'species richness of forest specialists should decrease from the rural areas to the urban ones and different elements of an assemblage will react differently, because the specialists are expected to decrease with urbanization while the generalist species could be favored (Magura et al. 2004). Results indicate that *T. spinipes* and *C. vulcanus* the generalist urban adaptable (synanthropic) species adapted to the modified urban habitats that have become increasingly widespread and locally abundant. It is likely that these two species may have become increasingly wide spread and locally abundant in different urban regions in the Malabar coast region and are likely to proliferate further in the region at the cost of other species. This type of homogenization of the taxonomic composition

is a major negative consequence of urbanization world wide (Magura et al. 2010).

In total contrast to the dry habitat dwelling species, occurrence of *Ochicanthon* species, a rare primitive old world dung beetle species present in moist forest patches (Krikken & Huijbregts 2007; Latha et al. 2011) is unexpected. Its presence indicates that the recent habitat modifications in the Western Ghats have not wiped out these relict old world dung beetles (primitive groups) from the agrilands. Similar record of the following rare species namely *Onthophagus insignicollis, O. kchatriya, O. duporti* and *Oniticellus cinctus* in the moist Western Ghats indicate that these species represent the sink population of a larger pool of the source, i.e. the native dung beetle population. It is possible that the fragmented agri habitats in the region is a safe microhabitat for such rare species *(Onthophagus malabariensis, O. unifasciatus, O. pygmaeus, Ochicanthon murthyi)* (Magura et al. 2004; Elek & Lövei 2007) till the gradual disappearance of such habitats.

No record of the large species belonging to the genera *Gymnopleurus, Catharsius* and *Heliocopris* in the assemblage indicates that they might have vanished from the region. It could be due to the inability of large dung beetles to withstand dessication and the low survival chance of their larvae in dry soil conditions (Chown 2001). Since the present study was confined to a single site, studies in other similar sites in the region are necessary to establish whether the disappearance of large beetles is a widely applicable pattern.

Dominance of tunnelers in forest and agri habitats, and the higher abundance of the cosmopolitian *T. setosus* is typical of dung beetle assemblages in the Western Ghats (Sabu et al. 2006, 2007; Vinod & Sabu 2007) and across the globe (Cambefort & Walter 1991; Andresen 2005). Disappearance leads to the question whether dominance of dweller guild with *T. spinipes* as prominent species is a feature of extremely disturbed habitats in the moist western slopes of the Western Ghats and Malabar coast region. Distinctively high abundance of dwellers over tunnelers and rollers is arising from the unequal abundance of *T. spinipes*. Similar dominance of dwellers with another species (*T. setosus*) is reported from regions with high dung pad availability as in the elephant dung rich Wayanad forests in the Western Ghats (Vinod 2009) and is attributed to the abundance of elephant/gaur and the resulting dung pad abundance. However there is no record of dominance of dwellers in the agri belts in the Western Ghats. High abundance of dwellers in an agribelt with low dung availability and mammalian diversity is attributed to the low abundance of other guilds (tunnelers/rollers) and the hard nature of the laterite soil in the Malabar coast region which do not favour the population build up of other guilds.

Occurrence of two dominant species *T. spinipes* (diurnal) and *C. vulcanus* (nocturnal) with distinctly contrasting pattern of temporal resource utlilisation patterns as prominent species could be an adaptive strategy for efficient resource partitioning to avoid competition for resources. Such perfect temporal resource partition of the two prominent species could be a major factor that leads to the decline in the abundance of other species. Overall abundance showed distinct seasonality with high abundance during southwest monsoon followed by northeast and summer season. Peak in abundance is linked to the single species dominance of *T. spinipes* which was the most abundant species during southwest monsoon. It is likely that softening of the lateritic soil during the rainy periods could be favouring the abundance of both tunnelers and dwellers. Seasonality of tunnelers, which was the only guild showing seasonality in the region, is additional proof to this assumption.

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