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Diversity, faunal composition and conservation assessment of dung beetles (Coleoptera: Scarabaeidae) in two reserve forests of Haryana (India)

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As dung beetles perform vital service to ecosystem, their recent decline in open grassland and agro-ecosystem in North-West India warranted monitoring of lost taxa in the nearby protected woodland areas. Accordingly, two dry subtropical reserved forests, Sonti and Seonsar, 70 km apart, in Haryana were undertaken to explore the species richness, abundance, diversity and seasonality in dung beetles for two years.

A total of 33 species only, 32 (4673 individuals) from Sonti and 24 (1248 individuals) from Seonsar, from 16 genera and three subfamilies were obtained in the total period. Though species richness was higher in Sonti forest, the diversity was higher in the larger Seonsar forest. *Sisyphus neglectus* Gory (3106 individuals) was the most dominant species in both the forests, more exceptionally in Sonti forest. All the faunal components, namely, species composition, diversity and abundance were found varying in every successive catch at both sites showing seasonal effect. Species diversity peaked in April and September-October in Sonti forest and from May to August in Seonsar. Most of the catches though comprised of all the three functional groups, *i.e*., rollers, tunnellers and dwellers, their mutual proportions were varying.
Several dung beetle species, especially rollers, imperiled in recent times in adjoining urban landscape, were recovered in plenty from the two forests, including a new species *Garreta sylvestris* Mittal. Evidently these natural habitats amidst anthropically disturbed areas were serving as refuge for the lost and depleted dung beetle fauna around raising hopes for the conservation of vulnerable fauna in North-West India.
Keywords: monitoring, endangered fauna, dung rollers, woodland, protected areas, conservation, habitat loss.

Les bousiers sont essentiels au maintien de l'écosystème. Leur récent déclin dans les prairies ouvertes et dans l'agro-écosystème au nord-ouest de l'Inde justifie la surveillance des taxons disparus dans les forêts protégées. En conséquence, deux forêts sèches subtropicales classées, Sonti et Seonsar, à 70 km de distance, dans l'Haryana, ont été explorées durant deux ans afin de déterminer la richesse en espèces, l'abondance, la diversité et la saisonnalité des bousiers.

Un total de 33 espèces, 32 (4673 individus) retrouvées à Sonti et 24 (1248 individus) à Seonsar, appartenant à 16 genres et 3 sous-familles, a été dénombré durant cette période de 2 ans. Bien que la richesse en espèces soit plus élevée dans la forêt de Sonti, la diversité est plus importante dans la forêt de Seonsar. *Sisyphus neglectus* Gory (3106 individus) est l'espèce dominante dans les deux forêts, particulièrement à Sonti. Sur les deux sites, tous les composants faunistiques, à savoir la composition des espèces, la diversité et l'abondance, varient entre chaque collecte, montrant alors un effet saisonnier. La diversité des espèces culmine en avril et en septembre-octobre dans la forêt de Sonti et de mai à août à Seonsar. La plupart des collectes étaient composées de trois groupes fonctionnels, nommés les rouleurs, les fouisseurs et les résidents, dans des proportions variables.
Plusieurs espèces de bousiers, en particulier les rouleurs, en voie de disparition dans le paysage urbain adjacent, ont été retrouvées en abondance dans ces deux forêts. Une nouvelle espèce, *Garreta sylvestris* Mittal, a également été

découverte. Ces habitats naturels, n'ayant subi aucune contrainte anthropique, servent de refuge pour les bousiers et présument une conservation de la faune vulnérable au nord-ouest de l'Inde.
Mots-clés: surveillance, faune en voie de disparition, rouleurs, forêt, zones protégées, conservation, perte d'habitat.

1. INTRODUCTION

Dung beetles are a well defined group both taxonomically and functionally. They are ecologically significant component of tropical biota and play a key role in several ecosystem processes (Halfter & Matthews, 1966; Hanski & Cambefort, 1991a). Natural systems suffer because of their loss (Larsen *et al*., 2008). Since dung beetles are responsible for relocating dung in most terrestrial ecosystems, they play an important part in nutrient recycling, soil upturning and its water holding capacity (Mittal, 1993; Tyndale-Biscoe, 1994). Because of their sensitivity to environmental changes, particularly to deforestation, dung beetles become an important focal taxon for understanding interactions between anthropic disturbances and community structure, and work as bioindicators of ecosystem health (Klein, 1989; Halfter *et al.,* 1992; Favila & Halfter, 1997; Spector & Forsyth, 1998; Barragan *et al*., 2011). Dung beetles can also be used as model systems for improving our general understanding of broad evolutionary and ecological processes (Simmons & Ridsdill-Smith, 2011). They are extremely important element in forest ecology also, not only for incorporating large amount of faecal matter into the soil but in terms of seed dispersal abilities also (Hanski & Cambefort, 1991a; Vulinec, 2002; Quintero & Roslin, 2005). Up to 90 % of the seeds defecated on soil surface might be destroyed by rodent and other seed predators if not buried by dung beetles (Estrada & Coates-Estrada, 1991).

Forest dung beetle fauna has been studied in different parts of world (Halfter & Matthews, 1966; Hanski & Cambefort, 1991a). Species richness of dung beetles in tropical forest of south-east Asia, Africa and South America has been compared by Hanski & Cambefort (1991b). The dung beetles response to tropical forest modification and fragmentation has been analyzed by Nichols *et al.* (2007). In Oriental region, mainly in south-east Asia, there has been several studies on wet tropical rainforest and now some 450 species of Scarabaeidae, majority of them belonging to *Onthophagus* (324 species), are known from the archipelago (Hanski & Krikken, 1991). Davis *et al.* (2001) worked on the forests of northern Borneo, and Boonrotpong *et al.* (2004) in southern Thailand recorded about 20 species from primary and secondary forests and found their composition influenced by forest structure, native animals and physical factors, but without any seasonal effect on species diversity. With 28 species from Sulawesi (Indonesia), Shahabuddin *et al.* (2010) found more species richness, abundance and biomass in natural forest than open areas. On Indian subcontinent, particularly in north India, there is dearth of such studies. Dung beetles are known to be influenced strongly by vegetation cover and soil type (Nealis, 1977; Doube, 1983; Barragan *et al*., 2011) and the structure and distribution of dung beetle communities can be determined by the physical structure of forest (Davis, 1993; Davis & Sutton, 1998; Vulinec, 2008).

Recent decline (Mittal, 2005) of dung beetles in urban and cropland mosaic of Haryana, and the resulting fall in their eco-function in nature, made it imperative to look for these endangered taxa in less anthropically disturbed areas. It was very crucial to know whether the taxa were permanently lost or still retrievable from more natural habitats in the surroundings. Accordingly, the protected forests in the vicinity, hitherto mostly unexplored, were then undertaken to discover, along with their own, the fauna recently disappeared from cropland-grassland habitat around and possibly taken shelter or still sustaining in contiguous woodland areas supposed to be with less human interference. To begin with, two reserved forests around Kurukshetra (Sonti and Seonsar) were selected for the present surveys to record dung beetle species richness, abundance, diversity and seasonality, with particular interest to the fauna which had become scarce in open plains recently. The occurrence of dung beetle fauna in the two forests was evaluated in contrast to open urban landscape and also to each other in the light of their physical structure and other conditions. Whether these woodland areas, thought to be comparatively undisturbed, could serve as refuge for the conservation of vulnerable fauna around, had also been examined.

2. MATERIALS AND METHODS

2.1. Study Area

Two reserved forest sites, Sonti and Seonsar (Saraswati Wildlife Sanctuary) of Haryana selected for the present study are 70 km apart almost on the same latitude. Seonsar forest is situated at 29°58′00″N & 76°28′10″E, 50 km west of Kurukshetra and is a dry deciduous subtropical forest. The total area of the forest is about 11000 acres and is the third largest forest of Haryana. Seonsar forest is comparatively dense and with a canopy at places formed by kikar (*Acacia nilotica* (L.)), vilayeti kikar (*Prosopis juliflora* Swartz), dhaak (*Butea monosperma* (Lam.)) and safeda (*Eucalyptus tereticornis* Smith). The other main trees present there are peepal (*Ficus religiosa* L.) and shisham (*Dalbergia sissoo* Roxb.), etc. Understorey is formed by a variety of shrubs and herbs. There are some open cut out areas also here and there. Mammalian fauna in the forest comprises chinkara (*Gazella bennettii* Sykes), hyaena (*Hyaena hyaena* L.), jackal (*Canis aureus* L.), jungle cat (*Felis chaus* Güld.) and nilgai (*Boselaphus tragocamelus* Pallas). Monkeys (*Macaca mulatta* Zimmermann) are the most common animals. A few villages are also situated inside the forest area along with their cattle.

The Sonti reserve forest is situated at about 20 km east of Kurukshetra at 29°59′00″N & 76°59′15″E. This is comparatively a small area of about 475 acres only and about 1/3 part of it is experimentally cultivated with eucalyptus trees. In the remaining more than half of natural forest, the other trees are mainly teak (*Tectona grandis* L.), kikar (*Acacia nilotica*), vilayeti kikar (*Prosopis juliflora*), neem (*Melia azadirachta* L.) and arjun (*Terminalia arjuna* Roxb.). Kronda, beri, hins and neelbadi are the shrubs found there. The mammalian fauna here also is dominated by antelope nilgai (*Boselaphus tragocamelus*) and monkeys.

2.2. Sampling Methods

Dung beetles were sampled by using baited pitfall traps. The traps were made up of a tin can of about one liter capacity with a funnel of the same diameter hanging inside from its mouth. A round tin plate fixed at the top of funnel, with an inch gap all around for dropping of beetles, was used for placing bait (Figure 1). Each trap was buried up to its rim in ground and baited with about 300 g of fresh cattle dung for 24 h. For every sample, catches were pooled from five such traps spread over an area covering all possible microhabitats at the site. Trapping interval of 10 days was kept to record temporal changes in every assemblage. Collections were made throughout their active season from April to October in years 2008 and 2009.

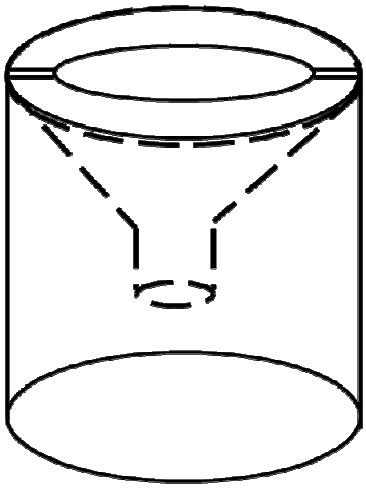

Figure 1: Bait trap used in sample collection (not to scale).

2.3. Data Analysis

Species diversity of the collected fauna was estimated with the help of Shannon-Wiener index:

$$H' = -\sum (n_i/N) \log_e (n_i/N) \qquad (n_i/N = p_i)$$

$$H' = -\sum p_i \log_e p_i$$

(p_i is the proportion of i^{th} species and $\log_e$ is the natural logarithm)

and evenness index (Pielou, 1974):

$$J' = H'/H_{max} = H' / \log_e S$$ (S = number of species).

Dominance was calculated by Simpson (1949) index of dominance:

$$D = \sum(n_i/N)^2 = \sum(p_i)^2.$$

3. RESULTS AND DISCUSSION

A total of 5921 individuals of dung beetles from 33 species of 16 genera and three subfamilies were captured during the entire study from both the sites. Sixteen genera were: *Garetta* Janssens, *Gymnopleurus* Illiger, *Sisyphus* Latreille, *Onitis* Fabricius, *Euoniticellus* Janssens, *Tiniocellus* Péringuey, *Oniticellus* Dejean, *Tibiodrepanus* Krikken, *Catharsius* Hope, *Copris* Müller,

Caccobius Thomson, *Digitonthophagus* Balthasar, *Onthophagus* Latreille, *Proagoderus* Lansberge from Scarabaeinae, *Aphodius* Illiger from Aphodiinae, and *Hybosorus* Macleay from Hybosorinae. Species richness was higher at Sonti forest with 32 species out of the total of 33 available from both the places. From Seonsar forest, only 24 species were available, with 23 species common to both sites. All species of three genera, *Catharsius* (*molossus* (L.) 1758 and *pithecius* (F.) 1775), *Copris* (*signatus* Walker 1858) and *Hybosorus* (*illigeri* Reiche 1853 and *orientalis* Westwood 1845), and some of *Onthophagus* (*quadridentatus* (F.) 1798; *ramosellus* Bates 1891; *sternalis* Arrow 1931; *ramosus* (Wiedemann) 1823), were recorded from Sonti forest only, and *Oniticellus cinctus* (F.) 1775 found restricted to Seonsar forest only (Table 1).

Abundance too was higher at Sonti forest, especially because of one species (*Sisyphus neglectus* Gory, 1833). Out of total 5921 individuals, 4673 were collected from Sonti forest and 1248 from Seonsar. Of all species, *S. neglectus* (3106) was most abundant. Other common species were *Tiniocellus spinipes* (Roth) 1851 (675), *Gymnopleurus miliaris* (F.) 1775 (444), *Digitonthophagus gazella* (F.) 1787 (252), *Onthophagus mopsus* (F.) 1792 (229), *D. bonasus* (F.) 1775 (157), *G. parvus* (Macleay) 1821 (148) and *Caccobius ultor* (Sharp) 1875 (141). A little less frequent were, *Garreta sylvestris* Mittal 2011 (105). *O. spinifex* (F.) 1781 (94), *C. vulcanus* (F.) 1801 (72), *Onitis virens* Lansberge 1875 (54), *Onthophagus fasciatus* Boucomont 1914 (53) and *O. quadridentatus* (50). However, some other species, namely, *Onitis subopacus* Arrow 1931 (35), *Tibiodrepanus setosus* (Wiedemann) 1823 (35), *Catharsius pithecius* (27), *Proagoderus amplexus* (Sharp) 1875 (26), *Copris signatus* (25), *Onthophagus ramosellus* (25), *Gymnopleurus gemmatus* Harold 1871 (22), *Onitis philemon* F. 1801 (22), *Aphodius lividus* (Olivier) 1789 (22), *G. cyaneus* (F.) 1798 (20), *Onthophagus sternalis* (17), *A. moestus* F. 1801 (14), *Euoniticellus pallens* (Olivier) 1789 (13), *O. ramosus* (12), *Hybosorus illigeri* (9), *O. unifasciatus* (Schaller) 1783 (7), *H. orientalis* (5), *Oniticellus cinctus* (3) and *Catharsius molossus* (2) were scarce.

In first year, a total of 927 individuals only belonging to five genera and 13 species were captured from both the sites. The species richness was higher at Seonsar forest with 12 species (415 individuals) in comparison to Sonti with only nine species (512 individuals). In the second year, a total of 4994 individuals from 16 genera and 31 species were collected, 4161 individuals from 30 species from Sonti area and 833 individuals of 23 species from Seonsar. This was because of *S. neglectus* (2679) and *Tiniocellus spinipes* (628), two dominant species in Sonti forest throughout season. *S. neglectus* was more abundant on monkey dung.

The overall species diversity (Shannon-Wiener index) in dung beetle fauna was higher at Seonsar forest (H′=2.469) than Sonti (H′=1.619). Evenness was also higher at Seonsar forest (J′= 0.776) than Sonti (J′= 0.467). Low evenness value in Sonti forest was because of the high dominance mainly of *S. neglectus* and to some extent of *T. spinipes*, resulting in overall higher dominance (D=0.407) in Sonti forest than Seonsar (D=0.128). During first year, however, the differences in species diversity, evenness and dominance were not much. In Seonsar the values were H′=1.899, J′= 0.764 and D=0.218, whereas in Sonti these were H′=1.760, J′=0.801and D=0.238. But the real difference in the values of these indices between two forests was in the second year when the two dominant species were at their peak abundance in Sonti. Diversity (H′=2.591) and evenness (J′=0.815) at Seonsar though were highest in comparison to Sonti (H′=1.490, J′=0.438) but the dominance obviously was maximum at Sonti (D=0.440) in contrast to minimum of Seonsar (D=0.108) (Tables 2-3). Seasonal peaks in species diversity in the two forests also differed, which was twice in Sonti forest in April and September-October, and a spread one throughout from May to August in Seonsar.

Though species composition was at variance in every catch, the assemblages from each site were mostly comprised of all the three functional groups of dung beetles, *i.e*., rollers, tunnellers and dwellers. Nevertheless, their proportion was varying in every catch. Some rollers species (*G. miliaris* and *G. cyaneus*) were more frequent at Seonsar forest, while one other (*G. parvus*) in Sonti forest. Another dung roller, *S. neglectus*, however, turned up in extraordinary large proportion (92.46 %) in second year in Sonti forest only (Table 1). Its total number in pooled collection was more than the total number of all other species together. Among tunnellers, the species of *Catharsius* and *Copris*, were found

restricted to Sonti forest only, whereas three species of *Onitis* and the only species of *Oniticellus* were more prevalent in Seonsar. Various species of *Onthophagus* and its sister genus *Caccobius* were by and large more dominant in Sonti fauna. Among two species of *Aphodius* from the dwellers family Aphodiinae, while *moestus* was more abundant in Seonsar forest, *lividus* was rather equally distributed in both the forests. *Hybosorus* species from Hybosorinae were caught exclusively from Sonti forest.

In this region, seasonality also had a very profound effect on the occurrence of dung beetles and accordingly their availability was found varying, with high abundance in wet summer (July-August). There was a possible correlation of seasonal changes of temperature and rainfall with assemblages of dung beetles (Radtke *et al*., 2008). Lack of rainfall during collection period, as happened in present case, had an effect on the relative capture rate (Schiffler, 2005).

Apparently the turnout of dung beetles (species richness and abundance) from the two forests was lower than expected. In second year, the species number and abundance, almost double than the first year (minus two highly abundant species from Sonti forest), seemed rather more typical, which might be because of favourable seasonal factors, and the same factors perhaps were responsible for the outburst of *Sisyphus neglectus* (3106 individuals), alone contributing 52.45 % of all individuals. Species richness was higher in smaller fragmented Sonti forest, though diversity (H′) was higher in the large Seonsar forest. Generally dung beetle abundance, species richness and diversity were higher in large forest fragments (100-150 ha) and natural reserves than in smaller ones (10-50 ha) (Philip, 2009). Klein (1989) also observed that the small forests fragments had a fewer and smaller beetle species and lower population than intact forest. But in the present study the smaller Sonti forest not only had higher number of species but the large-sized species, which were more vulnerable in open habitat around, also were found confined to it. The results were not supportive of the observation of Estrada & Coates-Estrada (2002) also that continuous forest fragments were the richest habitat in dung beetle species and small forest fragments were less diverse. The higher species richness in the smaller Sonti forest, further divided into smaller fragments due to human managements, might be because of more microhabitats available to them. But at the same time the low evenness might also be the result of altered forest structure, favourable to some species and changing the inter-se abundance ratio lowering evenness (J′) and diversity (H′). The fauna at Seonsar was more even due to less drastic changes in vegetation structure.

The species richness also depended on the degree of anthropic disturbances (Arellano *et al*. 2005). In both the forest under observation, some degree of human interferences might also be responsible for the lower turn out of species. Inside Seonsar forest human habitations had affected the physical nature of forest around them and at Sonti forest the disturbance was because of cultivating only *Eucalyptus* trees at the cost of natural forests. The species richness in the part under a monoculture *Eucalyptus* tree cover was found quite low in comparison to dense natural forest fragment, showing that altered conditions, particularly in vegetation cover, made a difference (Peck & Forsyth, 1982; Doube, 1983; Cambefort & Walter, 1991; Hill, 1996; Estrada & Coates-Estrada, 1999; Barragan *et al.*, 2011). The differences in vegetation and physical structure of two forests were responsible for the differences and some specificity to some extent in their fauna.

The presence of dung producing mammals also contributes to the dung beetles relative abundance and diversity (Cambefort & Walter, 1991). The low population of large mammals here also might be another reason for the low turnout of dung beetles. Though dung beetles sometimes show preference for different food materials (Gordon & Cartwright, 1974; Mittal, 1986; Doube, 1991; Mittal & Bhati, 1998), many species here exhibited very little discrimination and majority of them were found to utilize several types of dung depending on its availability. During present investigations though the main mammalian dung available in two forests was of monkeys and nilgais, the beetle fauna was equally attracted to cattle dung, used as bait also. Though monkeys were present in plenty in both the forests, but some species (*S. neglectus* and *T. spinipes*) liking their excreta were found in extraordinary large proportion in Sonti forest only, that too only in one season, meaning thereby that some other local factors, along with populational and phenological, also played a role in such cases.

Since no earlier authentic data on dung beetle fauna of these two forests existed (except some observations on Sonti by Singh, 2007), the present records from the two forests would serve as baseline data for any future monitoring. As stated above, there might have been various local reasons for the present low species diversity and abundance, but by far the main reason for this seemed to be the overall decline of dung beetles in the region, because of their habitat loss around urban and rural areas and altered food quality (Mittal, 2005). The woodland areas in Haryana too, although under the Act of protection, were not without their share of human disturbances.

The region in the recent past had witnessed a large number of dung beetle species, and since 1972, Mittal (1981, 1999, 2000, 2005) had reported from the contiguous areas some 136 species (from 26 genera and 8 subfamilies). Though the present investigations were limited in space and time, but, nevertheless, sufficiently reaffirm the continuous declining trend in the dung beetle fauna of the area. Members of several small subfamilies, *e.g*., Dynamopodinae, Chironinae, Orphninae, and the important one Geotrupinae, very frequent in 1970s and -80s, but started declining in 1990s, were altogether missing during present surveys of protected forest areas too. Two hybosorine (*Hybosorus*) species were available only from one forest, *Phaeochrous* Castelnau being totally absent. From Aphodiinae only two species of one genus were available against 20 species from three genera available in 1970s and -80s. From main subfamily Scarabaeinae also, a large number of species either have totally disappeared or declined drastically. Some large-sized species (such as of *Heliocopris*, *Copris*, *etc*.) were the first to go from the plains open habitat around (Mittal, 2005) and were not recovered from these protected woodland as well. Other genera, *Catharsius* with large species and *Onitis* to some extent, were available but in very low numbers, the former with two species against five and latter with three species against seven recorded earlier from the area. Genus *Phalops* was also found absent, which had earlier been recorded mostly from woody areas. Likewise, *Chironitis* and *Liatongus* were also missing. Two speciose genera *Caccobius* and especially *Onthophagus* were also represented by a few number of species only, former with two against nine available earlier from north-west India and the latter with eleven against fifty.

But, nevertheless, there were species which had recently disappeared totally from the urban and cropland area around here could still be found sustained in the forest area. In addition to some species of dung rollers (*Gymnopleurus miliaris, G. parvus, G. gemmatus, G. cyaneus, Sisyphus neglectus*, *etc*.), a few large-sized species (*Catharsius molossus* and *C. pithecius*) and some other species of *Onthophagus* (*sternalis, fasiatus, unifasciatus, ramosus, amplexus*), *Caccobius* (*ultor* and *vulcanus*) and *Tibiodrepanus setosus* were found existing in the forest area. *Copris signatus* was recorded for the first time from the region (Sonti forest), which had earlier been reported from south India only. The finding of dung rollers (particularly very abundant *S. neglectus*), including a new species (*Garreta sylvestris* Mittal), an important functional group of dung beetles, together with several other species, do raise some hope that if the anthropic activities are contained and forests are genuinely protected, these may harbour and give shelter to more of such fauna which have recently become vulnerable in cropland and urban landscape, where degradation of dung beetles habitats have now become inevitable because of unchecked urbanization, industrialization and agricultural mechanization.

To reaffirm the contention that protected woodland areas can support more of such endangered taxa, a couple of additional sample surveys were conducted in another reserve forest (Morni Hills) of Haryana (90 km north of Kurukshetra). Again the findings were very reassuring. Many species, including large-sized ones, which had disappeared from open plains for long now, *e.g*., *Heliocopris gigas, Catharsius molossus, C. sagax, C. pithecius, Copris repertus, C. surdus, Paragymnopleurus sinuatus* and *Onthophagus bengalensis*, were found flourishing there (more could be revealed from added surveys), establishing the fact that protected areas were the only hope and should remain as core area for any future conservation efforts. Since dung beetles are very important in enhancing nutrient cycling, soil aeration, parasite suppression and secondary seed dispersal, their conservation in rapidly shrinking habitats become indispensable, and which ultimately would depend on the conservation of protected areas maintaining enough number of large mammals.

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Table 1: Individual species contribution (%), mean per catch (mean ± sd) and relative occurrence of each species of dung beetles in two forests in two years (2008-09).

Species	Sonti Forest			Seonsar Forest		
	% contrib. each sp.	Mean per catch (N=42)	% occur /site	% contrib. each sp.	Mean per catch (N=37)	% occur /site
Garreta sylvestris	0.33	1.54±2.28	58.77	1.34	1.08±1.42	41.22
Gymnopleurus cyaneus	3.66	0.14±0.56	27.45	3.84	0.37±0.92	72.54
G. gemmatus	0.67	0.28±0.83	50.90	0.96	0.27±0.65	49.09
G. miliaris	6.59	2.78±5.02	23.94	31.41	8.83±11.03	76.05
G. parvus	5.35	2.26±3.54	61.24	5.09	1.43±1.97	38.75
*Sisyphus neglectus**	-	68.61±135.06	92.46	-	5.59±7.13	7.53
Onitis philemon	0.16	0.07±0.26	12.06	1.82	0.51±1.01	87.94
O. subopacus	0.62	0.26±0.82	28.88	2.30	0.64±1.08	71.12
O. virens	0.45	0.19±0.59	13.28	4.41	1.24±1.63	86.72
Catharsius molossus	0.11	0.45±2.62	100	0	0	0
C. pithecius	1.52	0.85±2.25	100	0	0	0
Copris signatus	1.40	0.59±1.66	100	0	0	0
Euoniticellus pallens	0.45	0.19±0.70	59.37	0.48	0.13±0.58	40.63
Oniticellus cinctus	0	0	0	0.29	0.08±0.36	100
Tiniocellus spinipes	35.40	14.95±24.87	92.17	4.51	1.27±2.19	7.83
Tibiodrepanus setosus	1.29	0.54±1.75	62.79	1.15	0.32±0.85	37.21
Caccobius ultor	7.21	3.04±6.10	89.67	1.25	0.35±0.89	10.32
C. vulcanus	3.55	1.50±4.04	86.20	0.86	0.24±0.68	13.79
Digitonthophagus bonasus	4.28	1.80±2.89	45.22	7.78	2.18±2.93	54.78
D. gazelle	5.97	2.52±4.27	39.00	14.02	3.94±3.71	60.99
Onthophagus fasciatus	2.48	1.04±2.92	81.25	0.86	0.24±0.68	18.75
O. mopsus	7.38	3.11±4.84	54.08	9.41	2.64±4.60	45.91
O. quadridentatus	2.81	1.19±4.91	100	0	0	0
O. ramosellus	1.40	0.59±2.30	100	0	0	0
O. ramosus	0.67	0.28±1.06	100	0	0	0
O. spinifex	2.87	1.21±3.27	51.05	4.13	1.16±1.95	48.95
O. sternalis	0.95	0.40±1.39	100	0	0	0
O. unifasciatus	0.16	0.07±0.46	41.17	0.38	0.10±0.51	58.83
Proagoderus amplexus	0.62	0.26±1.30	39.39	1.44	0.40±0.98	60.60
Aphodius lividus	0.67	0.33±1.57	55.00	0.96	0.27±0.76	45.00
A. moestus	0.05	0.02±0.15	5.40	1.25	0.35±1.00	94.59
Hybosorus illigeri	0.50	0.21±0.89	100	0	0	0
H. orientalis	0.28	0.11±0.50	100	0	0	0

* Because of high abundance (2899 individuals) of *S. neglectus*, more than the total of all other species together (1774), it is not included in % age share calculations. (N= no. of observations).

Table 2: Seasonal distribution (10-days interval) of species diversity, evenness and dominance of dung beetles in Sonti forest.

Months		Diversity indices								
		2008 N=21			2009 N=21			Pooled (2008+2009) N=42		
		H′	J′	D	H′	J′	D	H′	J′	D
April	1	1.160	0.816	0.369	1.362	0.760	0.311	1.742	0.837	0.223
	2	1.827	0.607	0.181	1.008	0.727	0.421	1.756	0.732	0.253
	3	1.653	0.852	0.226	1.560	0.975	0.349	1.889	0.760	0.198
May	1	1.735	0.969	0.184	0.606	0.338	0.721	0.841	0.365	0.654
	2	1.689	0.675	0.204	0.860	0.359	0.605	1.012	0.383	0.569
	3	1.828	0.939	0.175	0.924	0.401	0.609	1.211	0.436	0.536
June	1	1.454	0.747	0.338	0.956	0.353	0.650	1.138	0.402	0.587
	2	0.910	0.659	0.533	1.050	0.363	0.619	1.066	0.368	0.614
	3	1.148	0.828	0.352	0.818	0.320	0.686	0.849	0.331	0.661
July	1	1.157	0.719	0.387	1.017	0.489	0.514	1.336	0.608	0.364
	2	1.245	0.774	0.365	0.409	0.178	0.401	1.760	0.686	0.251
	3	1.244	0.833	0.328	1.376	0.855	0.306	1.594	0.819	0.280
Aug.	1	1.238	0.893	0.307	0.911	0.355	0.649	1.044	0.396	0.598
	2	1.086	0.991	0.340	1.128	0.490	0.549	1.215	0.506	0.522
	3	0	∞	1	1.302	0.626	0.383	1.307	0.629	0.363
Sept.	1	1.347	0.717	0.231	1.728	0.751	0.253	1.743	0.757	0.238
	2	1.193	0.741	0.413	1.968	0.947	0.151	1.882	0.905	0.178
	3	1.362	0.983	0.162	2.142	0.862	0.145	2.139	0.834	0.150
Oct.	1	0	∞	1	1.805	0.753	0.247	1.782	0.734	0.256
	2	0	∞	1	1.956	0.787	0.188	1.944	0.783	0.189
	3	0	∞	1	1.737	0.755	0.228	1.731	0.751	0.229
Total		**1.760**	**0.801**	**0.238**	**1.490**	**0.438**	**0.440**	**1.619**	**0.467**	**0.407**

(N= number of observations)

Table 3: Seasonal distribution (10-days interval) of species diversity, evenness and dominance of dung beetles in Seonsar forest.

Months		Diversity indices								
		2008 N=16			2009 N=21			Pooled (2008+2009) N=37		
		H′	J′	D	H′	J′	D	H′	J′	D
April	1	0.536	0.489	0.737	0.678	0.617	0.619	0.628	0.571	0.662
	2	1.162	0.838	0.357	1.151	0.642	0.439	1.531	0.736	0.290
	3	1.366	0.849	0.307	1.770	0.768	0.247	1.972	0.823	0.187
May	1	1.753	0.901	0.201	2.236	0.872	0.138	2.353	0.891	0.117
	2	1.716	0.957	0.190	2.011	0.784	0.208	2.161	0.798	0.178
	3	1.549	0.796	0.280	2.031	0.792	0.176	2.256	0.833	0.134
June	1	0.936	0.450	0.629	2.510	0.863	0.109	2.088	0.703	0.241
	2	1.720	0.827	0.227	2.300	0.871	0.134	2.308	0.832	0.148
	3	1.318	0.736	0.362	2.310	0.924	0.112	2.083	0.839	0.165
July	1	1.336	0.706	0.309	2.178	0.825	0.153	2.083	0.789	0.172
	2	1.152	0.831	0.354	2.079	0.867	0.154	2.064	0.804	0.179
	3	1.150	0.642	0.440	2.215	0.863	0.136	2.035	0.771	0.200
Aug.	1	1.277	0.921	0.306	1.895	0.862	0.191	1.637	0.745	0.196
	2	1.312	0.815	0.235	2.197	0.954	0.120	2.275	0.949	0.113
	3	0.849	0.772	0.506	1.777	0.909	0.195	1.705	0.820	0.256
Sept.	1	0	∞	0	1.098	0.682	0.472	1.098	0.682	0.472
	2	0.637	0.918	0.555	1.194	0.861	0.360	1.446	0.899	0.278
	3	0	∞	0	1.331	0.960	0.240	1.332	0.961	0.280
Oct.	1	0	∞	0	0.687	0.991	0.506	0.687	0.991	0.506
	2	0	∞	0	1.082	0.984	0.344	1.082	0.626	0.344
	3	0	∞	0	0.562	0.810	0.625	0.562	0.810	0.625
Total		**1.899**	**0.764**	**0.218**	**2.591**	**0.815**	**0.108**	**2.469**	**0.776**	**0.128**

(N= number of observations)