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Diversity and richness of dung beetles (Coleoptera: Scarabaeidae) in three different habitats of Udaipur Region, Rajasthan

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Abstract
The present study provides a comprehensive understanding of dung beetle diversity, richness and its evenness in three distinct habitats of Udaipur, Rajasthan. During the study period, a total of 1226 dung beetles of 34 Species belonging to 7 different subfamilies and 21 genera were recorded and identified from three different habitats. The research highlighted that Habitat-1 (forested ecosystem) demonstrated the highest dung beetle diversity and richness with 772 individuals of 34 species. Habitat-2 (agriculture area) showed moderate diversity and richness with 293 individuals from 25 species, while, Habitat-3 (urban area) had the lowest dung beetle diversity and richness, with only 162 individuals from 21 species. Dung availability of mammalian species and anthropogenic disturbance mainly influence the dung beetle diversity and richness.

Keywords: Agriculture, anthropogenic, ecosystem, evenness, forest, index, urban

Introduction
Dung beetles belong to Scarabaeidae Family of superfamily Scarabaeoidea, which is one of the largest superfamilies of the order Coleoptera. It constitutes cosmopolitan and very diverse group comprising of nearly 27,800 species worldwide (Ratcliffe and Jameson, 2004) [14]. The family Scarabaeidae is divided into 43 subfamilies, 118 tribes and 94 subtribes (Smith, 2006) [20].

The key ecosystem functions mainly performed by dung beetles (Coleoptera: Scarabaeidae) are nutrient cycling, bioturbation, secondary seed dispersal, parasite suppression, etc. (Badenhorst *et al*., 2018; DeCastro-Arrazola *et al*., 2020) [2, 4]. Dung beetles can be grouped in three main functional groups according to their feeding and nesting strategies (Doube, 1990) [5]: (1) telecoprids (or rollers) that make a ball with the food resource and relocate part of the dung horizontally and vertically; (2) paracoprids (or tunnelers) that dig tunnels in the soil underneath the dung and relocate vertically part of the dung on the ground; and (3) endocoprids (or dwellers) that live inside the dung pile or in the dung-soil interface.

Ecosystem dynamics, functioning, and productivity are enhanced by diversity, which corresponds to the number of species and also to the number of functional groups that play different ecological roles (Tilman *et al*., 2014: Slade *et al*., 2019: Noriega *et al*., 2021) [9, 17, 21]. Furthermore, increments in functional diversity and species richness generate positive responses in ecosystem functionality (Pasari *et al*., 2013) [11], while some ecosystem functions and services disappear in areas with low diversity (Slade *et al*., 2014) [18]. However, much of the information available on the relationship between diversity and ecosystem functioning are based on correlational rather than experimental approaches, and on the use of indirect measurements (Noriega *et al*., 2018) [8], which limits our understanding of the impact of global changes on ecosystem functioning. Therefore, field and/or laboratory experiments are essential to obtain direct quantifications of both diversity and ecological processes.

The recent studies provide the initial information on the Scarabaeidae fauna of the Indian subcontinent (Valiya & Gohil, 2023; Rajagopal *et al*., 2023) [13, 22] and the present study aims to investigate the Scarabaeidae diversity in three different habitats of Udaipur region, Rajasthan.

Materials and methods
Study site
Survey of three different habitats e.g.- forested ecosystem (24.52278° N, 73.71856° E), agroecosystem (24.58437° N, 73.71287° E) and urban area (24.59544° N, 73.69452° E) was done for dung beetles sampling in Udaipur region. The study was carried out for one year from October 2022 to September 2023.

Photography
In most of cases dung beetles were captured by camera (Canon EFS 18-55mm camera attached with Raynox DCR-250 Super Macro-Snap lens and Samsung M31Mobile macro camera).

Collection and identification
Dung beetles were collected using dung-baited pitfall traps and light traps during the field survey.

The dung beetles were identified by using already standardized (Sathiandran *et al*., 2015 and Thomas & Sabu, 2018) [1, 15] identification manuals and with the help of ZSI expert.

Data analysis
Indices used for the data analysis was the Shannon-Weiner diversity index (H) for Diversity (1949), Pielou's index (E) for Evenness (Pielou, 1966) [12] and Margalef's index (R) for Richness (Margalef, 1958) [7]. All statistical calculations were done on PAST 4.03 software.

Results and Discussion
1226 specimen count of 34 Species of dung beetles was recorded from October 2022 to November 2023 from three different habitats of Udaipur region, Rajasthan. This study indicated 34 Species of family Scarabaeidae belonging to 7 different subfamilies and 21 genera recorded and identified from three different habitats (Table-1). The seven different subfamilies are Aphodiinae, Cetoniinae, Dynastinae, Eumolpinae, Melolonthinae, Rutelinae and Scarabaeinae.

Among these Scarabaeinae represented maximum species (15) from 9 different genera, followed by Rutelinae with 6 Species, Melolonthinae with 5 species, Cetoniinae with 3 species, Aphodiinae with 2 species, Dynastinae with 2 species and least for Eumolpinae with 1 Species. Our results are in accordance with previous evidence suggesting that Scarabeinae is the most diverse sub-family (Figure-1) of Scarabaridae family (Valiya & Gohil, 2023; Rajagopal, 2023) [13, 22].

Habitat wise maximum number of individuals were recorded from Habitat-1 (772 individuals of 34 species), followed by Habitat-2 (293 individuals of 25 species) and least from habitat-3 (161 individuals of 21 species), and Shannon (H) index for diversity is 3.279 for Habitat-1 followed by 3.052 for Habitat-2 and least (2.928) for habitat-3. Margalef's index for richness is 4.946 for Habitat-1, 4.223 for Habitat-2 and 3.971 for habitat-3, while Pielou's index for eveness is 0.781 for Habitat-1, 0.852 for Habitat-2 and 0.889 for habitat-3 (Table-2) demonstrating Habitat-1 (forested area) to be most diverse and species rich area for Scarabaeidae fauna in Udaipur region. This is probably due to massive amounts of faeces from herbivores in forested area. The evenness index is the lowest in forested region as compared to the agriculture and urban area indicating that a fewer number of species dominate among the diverse species in the forested area.

It is also pointed that the habitat heterogeneity is a probable source of species that may be moving using the dominant vegetation matrix and affecting local diversity (e.g., Gilroy *et al*., 2014; Beiroz *et al*., 2018) [3, 6]. Although, anthropogenic disturbances produce generalized ecological changes that alter the natural dynamics of communities at different levels and these changes are responsible for changes in the diversity and structure of communities (Slade *et al*., 2011) [19]. Previous studies suggested that higher dung availability and low anthropogenic disturbance in forests is clearly associated with higher dung beetle richness, abundance, and functional diversity (Noriega *et al*., 2021) [10].

Table 1: Checklist of Dung beetles species observed during the research

Sr. No.	Sub-Family	Species name (Scientific name)	No. of Individuals		
			H-1	H-2	H-3
1	Aphodiinae	*Aphodius fossor* (Linnaeus, 1758)	14	8	0
2	Aphodiinae	*Aphodius spp.*	22	12	7
3	Cetoniinae	*Cetonia* spp.	24	11	7
4	Cetoniinae	*Oxycetonia jucunda* (Falderman, 1835)	22	9	5
5	Cetoniinae	*Oxycetonia versicolor* (Fabricius, 1775)	26	14	11
6	Dynastinae	*Heteronychus arator (*Fabricius, 1775)	12	6	0
7	Dynastinae	*Xylotrupes ulysses* (Guérin-Méneville, 1830)	3	0	0
8	Eumolpinae	*Chrysochus cobaltinus* (Leconte, 1857)	46	22	5
9	Melolonthinae	*Apogonia ferruginea* (Fabricius, 1781)	28	6	8
10	Melolonthinae	*Holotrichia lata* (Brenske, 1892)	12	0	0
11	Melolonthinae	*Holotrichia* spp.	17	4	4
12	Melolonthinae	*Phyllophaga* spp.	28	13	9
13	Melolonthinae	*Phyllophaga obsoleta* (Blanchard, 1851)	19	9	7
14	Rutelinae	*Adoretus ictericus (*Burmeister, 1844)	24	4	7
15	Rutelinae	*Adoretus spp.*	6	0	0
16	Rutelinae	*Anomala ruficapilla (*Burmeister, 1855)	8	0	2
17	Rutelinae	*Anomala bengalensis* (Blanchard, 1851)	26	12	4
18	Rutelinae	*Anomala* spp.	4	0	0
19	Rutelinae	*Chrysina lecontei (*Horn, 1882)	23	7	0
20	Scarabaeinae	*Dichotomius* spp.	32	17	11
21	Scarabaeinae	*Digitonthophagus bonasus* (Fabricius, 1775)	14	0	4
22	Scarabaeinae	*Digitonthophagus gazella* (Fabricius, 1787)	11	4	2
23	Scarabaeinae	*Copris numa* (Lansberge, 1886)	32	15	11
24	Scarabaeinae	*Copris* spp.	24	11	7
25	Scarabaeinae	*Ateuchus* spp.	9	0	0
26	Scarabaeinae	*Gymnopleurus cyaneus* (Fabricius, 1787)	22	4	0
27	Scarabaeinae	*Gymnopleurus miliaris* (Fabricius, 1775)	76	27	13
28	Scarabaeinae	*Heliocopris bucephalus* (Fabricius, 1775)	4	0	0
29	Scarabaeinae	*Heliocopris gigas* (Linnaeus, 1758)	5	0	0
30	Scarabaeinae	*Onthophagus spp*	74	26	12
31	Scarabaeinae	*Onthophagus lemur* (Fabricius 1781)	28	13	7
32	Scarabaeinae	*Onthophagus tweedensis* (Blackburn, 1903)	24	14	4
33	Scarabaeinae	*Onitis siva* (Gillett, 1911)	46	22	14
34	Scarabaeinae	*Scarabaeus erichson* (Harold, 1867)	7	3	0
		Total	772	293	161
		Grand total = 1226			

Table 2: Diversity indices for different Habitat

Diversity indices	Habitat-1	Habitat-2	Habitat-3
Taxa (S)	34	25	21
Shannon-Weiner diversity index (H)	3.279	3.059	2.928
Pielou's Evenness index (E)	0.781	0.852	0.889
Margalef's Richness index (R)	4.946	4.223	3.971

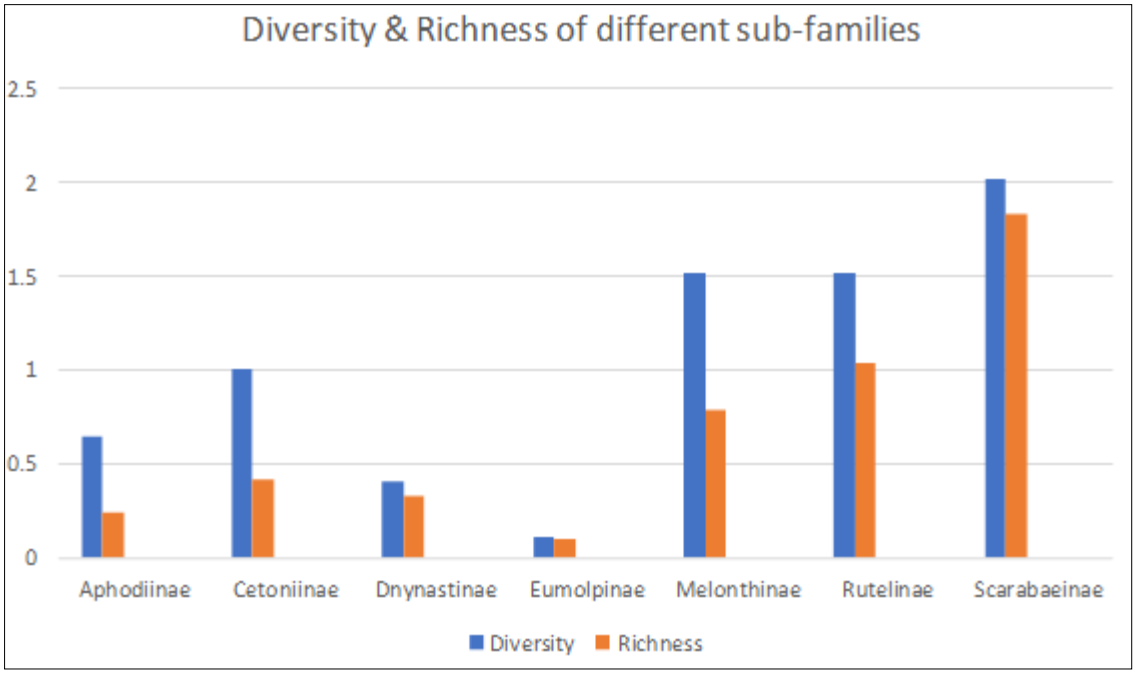

Fig 1: Diversity and Richness of different sub-families of Scarabaeidae family in all three habitats.

Conclusion

Dung beetles play a critical role in breaking down manure, loosening the soil and transporting the nutrients to the subsoil, which in turn improves the soil structure and the ability of the soil to hold water. During the feeding process, the dung beetles manipulate the faeces thereby bringing about seed dispersal and also the suppression of parasites in the soil. The forested ecosystem had highest dung beetle diversity and richness, while urban area had lowest diversity. But the result was just opposite for evenness because habitat-3 represented maximum evenness and habitat-1 minimum. Sub-family Scarabaeinae had highest diversity and Eumolpinae was represented least across all three habitats. Overall, 1226 specimen of 34 species indicate that the Udaipur region is extremely diverse and rich in fauna of Scarabaeidae.

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