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Structural composition and diversity of Scarab beetle communities in different ecosystems of South Karnataka

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Abstract
Scarab beetles form one of the most abundant and diverse taxon performing significant ecological roles in the ecosystems. Their relative distribution in terms of functionality is little known. The present study was attempted to understand the structure and relative composition of two major functional groups of scarabs collected from light traps in six different ecosystem types located in the coastal region, Puttur, Karnataka during April to July 2015. A total of 56 scarab species were recovered during the study. Among them, 34 belonged to phytophagous and 22 species belonged to non-phytophagous groups. In all the ecosystem types, the sub-family Melolonthinae (18) and Aphodiinae (9) were found be the most speciose and abundant taxa among the two functional groups considered. However, proportional distributions of the functional groups were nearly equal in all the ecosystems. Bray-Curtis similarity index showed that natural ecosystem and its combination with agro-ecosystem were closely related compared to different agro-ecosystems alone considered under the study.

Keywords: Scarabaeidae, community structure, functional guilds, diversity, agro-ecosystem

Introduction

Insects are incredibly diverse in nature comprising two thirds of the known species of the World. Order Coleoptera is the most prolific among all organisms with over 400,000 species [1]. Super-family Scarabaeoidea is the large and cosmopolitan taxon consisting of nearly 10 percent of all beetles in the world and exhibits great diversity in the tropics [2]. Scarabs function as scavengers, plant feeders, earth movers, pollinators, predators [3] besides being known habitat health indicators [4]. Many of them are also important pests of crops, as both adults and larvae [5]. Despite their varied ecosystem functions, surprisingly, only the pestiferous scarabs and dung beetles have got more attention. As a result, studies on the ecological aspects of scarab community as a whole remains less studied in the varied Indian ecosystems.

In principle, although, the scarabaeoids have varied ecological roles, these can be broadly categorized into phytophagous and non-phytophagous guilds [6]. Due to their abundance and significant ecological roles, the structure and composition of scarab community is expected to determine the nature of the ecosystem [7]. As a basic step towards understanding the ecological functions of the scarabs as a whole, it is necessary to understand their community structure. Therefore, we attempted to understand the community structure and composition of scarabs in different ecosystems that includes natural ecosystem, agricultural ecosystem and combinations of both. As a first step, the aim was to understand the relative composition of phytophagous and non-phytophagous scarabs in different types of ecosystems.

The present study was aimed at understanding (1) the relative diversity and composition of phytophagous and non-phytophagous scarabs in different ecosystems; (2) relationship between species diversity of the two functional communities and (3) also to check whether the composition of the communities varies with the ecosystem types.

2. Materials and methods

2.1. Study area

Scarab beetles were sampled in six different ecosystems of Puttur taluk (coastal zone of Karnataka, India) during the months of April-July, 2015. The ecosystems represented perennial agro-ecosystems, natural forests and combinations of both (Table 1 & Fig 1). A funnel and baffle type of light traps fitted with 165 W (Philips) mercury vapour lamp were operated for 12 hours starting from 6 pm to 6 am the next day in each ecosystem. The collected specimens were stored in 100 percent alcohol till they were processed.

Table 1: List of locations and respective ecosystems sampled for scarab beetles in Puttur taluk, Karnataka, India

Location	Ecosystem type	Longitude; Latitude; Altitude (M above MSL)
Kudipady	Cashew + Areca+ Village forest (CG+AG+VF)	12.764°N; 75.161°E; 106
Koila	Areca + Coconut plantation (AG+CG)	12.809°N; 75.301°E; 93
Belinele	Reserve forest (semi evergreen) +Coconut plantation (SEF+CG)	12.715°N; 75.568°E; 128
Gundya	Reserve ever green forest (EGF)	12.824°N; 75.568°E;139
Kaniyoor	Areca plantation (AG)	12.719°N; 75.352°E; 39
Odya	Cashew plantation (CG)	12.647°N ; 75.171°E; 112

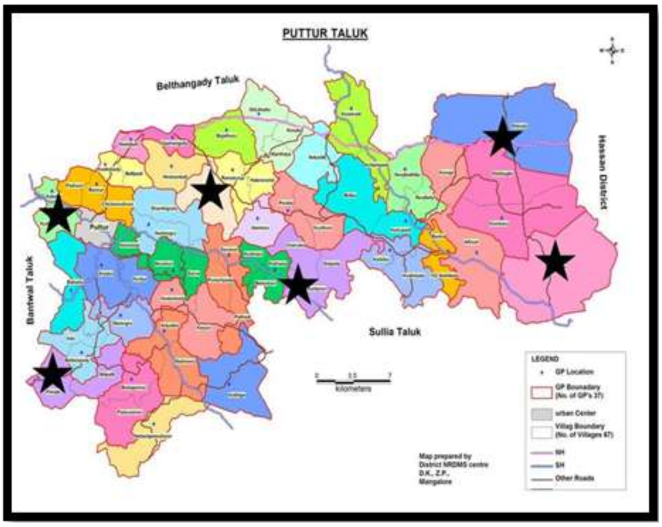

Fig 1: Sampled locations (indicated by stars) the map of Puttur Taluk, Karnataka

Fig 2: light trap fitted with Mercury vapour lamp

2.2. Method of processing and classification of the samples

Light traps catch a wide variety of insects. The specimens were filtered out and air dried. Then the scarabs were sorted out from the collections. All scarabs were then washed in soap water, air dried and sorted into different morpho-types. Uniformity of the morpho types were ascertained and then their numbers were recorded. A set of representatives of each of the morpho type were mounted suitably, labeled and oven dried. Properly dried specimens were transferred to a storage cabinet. Efforts were made to identify each of the morpho-type to at-least up to generic level using available literature such as the Fauna of British India volumes on scarabs [8-11].

Members of the super-family Scarabaeoidea exhibit a wide range of food habits. Therefore, considering these variations in food and living habits, a number of functional groups may have to be recognized among the scarabs. As biology of many non-phytophage scarabs is poorly understood, in order to overcome this difficulty of classification, the scarabaeoid beetles were classified into two broad functional groups for purposes of the present study. One of them is the phytophagous group that included the species belonging to subfamilies Rutelinae, Melolonthinae and Dynastinae. These species also have high economic concern. The non-phytophagous group comprised of members belonging to different families of scarabaeoidea such as Scarabaeidae, Bolboceratidae, Hybosoridae, Lucanidae, and Passalidae. Among the Scarabaeidae, members of the subfamilies, Scarabaeinae, Orphninae and Aphodiinae were grouped as non-phytophagous species [6].

2.3.Method of data Analysis

Diversity of every ecosystem and functional groups were calculated using Shannon-Weiner index and the Simpson Index which are widely used to quantify the heterogenity of the ecosystem [12].

Simpson Index was calculated using the formula :

$$D = 1 - \sum pi^2$$

Where, D= Simpson's index of diversity, pi= proportion of individuals of species i in the community, where, pi=Si/N=Number of individuals in the i^{th} species and N is the total number of individuals of all species collected.

Shannon-Wiener Index was calculated using the formula

$$H' = -\sum pi * (\ln pi).$$

Pearson's correlation was used to understand the relation between the functional groups. Bray-Curtis Index was calculated to understand the similarity between the ecosystems based on composition of species. Tabulations and graphs were prepared using PAST and MS excel office (version 2010).

3. Result

3.1. Species richness and abundance in different ecosystems

A total of 645 scarab beetles belonging to 56 species were collected during the study from six ecosystem types. These were composed of most dominant family Scarabaeidae (53 species), and other families *viz;* Lucanidae, Hybosoridae and Bolboceratidae were represented by single species each. The family Scarabaeidae was composed of six subfamilies of which Melolonthinae (18 species) was dominant taxon followed by Rutelinae (11 species), Scarabaeinae (8 species), Aphodiinae (9 species) and other subfamilies *viz;* Dynastinae (2 speices), and Orphninae (2 species) were represented by less number of species. However, Subfamily Aphodiinae was more abundant followed by Melolonthinae, Rutelinae and Scarabaeinae. Distribution of species and their abundances into different taxonomic groups are represented in the Table 2.

Table 2: Relative abundance and species richness of scarabaeoid beetles into different taxa collected during the study period (numbers in the parentheses denote species richness and * indicates phytophagous taxon)

	Kudipady	**Koila**	**Belinele**	**Gundya**	**Kaniyoor**	**Odya**	**Total**
Scarabaeidae							
Rutelinae*	2 (2)	3(3)	2(2)	4(3)	1(1)	13(3)	25(11)
Melolonthinae*	20(11)	9(7)	6(3)	32(12)	12(3)	12(5)	91(18)
Dynastinae*	0	2(1)	1	0	0	0	3(2)
Scarabaeinae	6(3)	4(4)	3(2)	7(4)	0	2(2)	22(8)
Aphodiinae	165(2)	85(4)	35(2)	180(8)	15(3)	11(3)	491(9)
Orphninae	2(2)	0	0	4(2)	0	2(2)	8(2)
Lucanidae	0	0	0	2(1)	1(1)	0	3(1)
Hybosoridae	1(1)	0	0	0	0	0	1(1)
Bolboceratidae	1(1)	0	0	0	0	0	1(1)
Total	179(22)	96(19)	42(10)	202(30)	25(18)	33(15)	645(56)

Highest species richness and abundance were observed from Gundya (30 species and 229 individuals) followed by Kudipady (22 species and 179 individuals) and Koila (19 species and 96 individuals). The lowest richness and abundance were recorded from Kaniyoor (8 species and 29 individuals). However, both Shannon- Wiener and Simpson's diversity indices showed highest value for Odya (2.49 and 0.89) followed by Gundya (2.02 and 0.75) and also, comparatively low value for Kudipady (1.47 and 0.64) where species richness was considerably higher compared to Odya (Table 3).

Table 3: Representation of total and functional guild richness and diversity of Scarabaeoid community by locations

Location	**Particular**	**Kudipady (CG+AG+VF)**	**Koila (AG+CG)**	**Belinele (SEF+CG)**	**Gundya (EGF)**	**Kaniyoor (AG)**	**Odya (CG)**	**Total**
All	Species	22	19	10	30	8	15	56
	Numbers	197	103	47	229	29	40	645
	S I *	0.64	0.49	0.46	0.75	0.73	0.89	0.74
	S-W I	1.47	1.36	1.15	2.02	1.6	2.47	2.09
Non –phytophagous scarabs	Species	9	8	4	15	4	7	22
	Numbers	175	89	38	193	16	15	526
	S I*	0.55	0.33	0.19	0.66	0.41	0.8	0.61
	S-W I	0.97	0.75	0.44	1.44	0.82	1.74	1.30
Phytophagousscarabs	Species	15	13	8	17	6	10	34
	Numbers	59	42	25	94	32	60	119
	S I *	0.77	0.76	0.75	0.77	0.72	0.76	0.92
	S-W I	1.95	1.87	1.66	1.98	1.46	1.76	3.03

S I : Simpson's Index and S-W I : Shannon Weiner Index

3.2. Distribution of functional groups in the different ecosystem types

Species composition and distributions of the functional groups in five ecosystems were studied. Of the 56 scarab species collected as many as 34 were classified as phytophagous while, 22 were non-phytophagous species. However, in each of the ecosystem, the sub-families Melolonthinae (18 species) and Aphodiinae (9 species) were more speciose and abundant taxa belonging to phytophagous and non-phytophagous groups, respectively. Combined phytophagous scarab diversity from all the six ecosystems was more (D=0.92; H'=3.03), although less abundant (119) compared to non-phytophagous scarabs (D=0.61; H'=1.30) which were more abundant (526). Thus, clearly suggesting a greater mean per capita representation of non-phytophagous species in the six ecosystems.

3.3. Relationship between species diversity of the two functional communities

In each ecosystem type there were more phytophagous species compared to non-phytophagous species collected (Table 2.) Approximately, 60 percent of the species belonged to phytophagous and 40 percent was found to be non-phytophagous group in all the ecosystem types implying that proportional distribution of both phytophagous and non-phytophagous scarabs were more or less equal in the six ecosystems examined (Fig. 3).

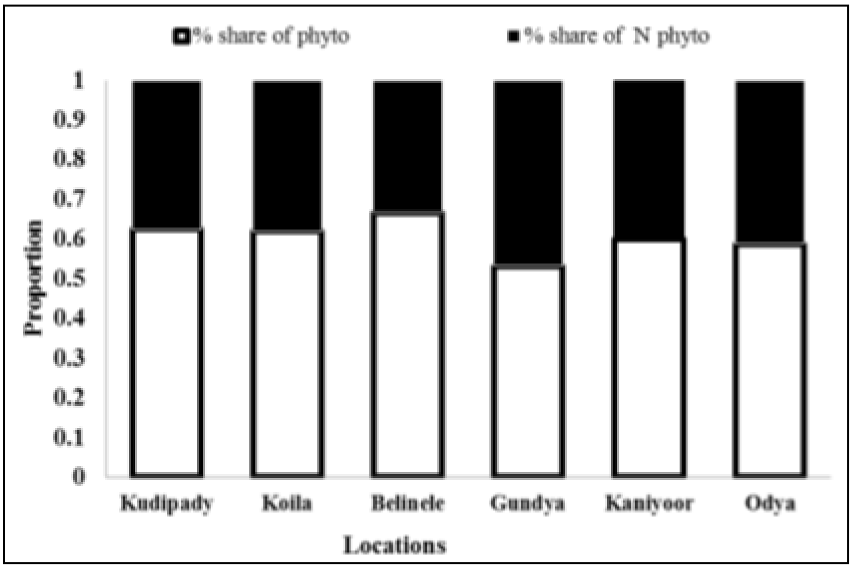

Fig 3: Proportional distribution of scarab beetles by number of species of functional guilds in different ecosystem types

A further examination of this aspect indicated significant positive linear correlation between numbers of species of the two functional communities, irrespective of the total diversity of all scarabs (R^2=0.852, p>0.01, Fig. 4) in the six ecosystems. Similar trend was not previously observed.

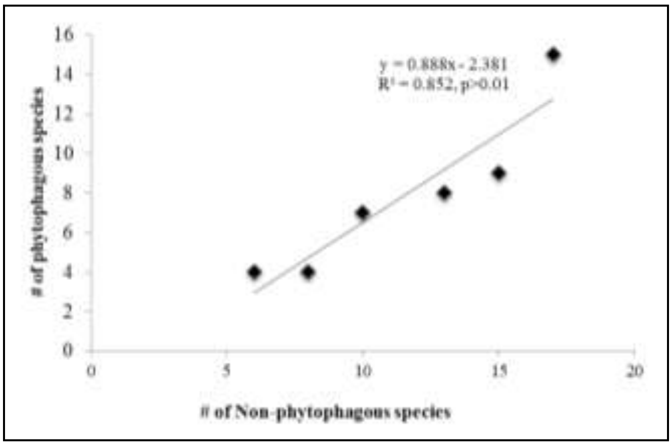

Fig 4: Relationship between numbers of species of non-phytophagous and phytophagous scarabs

3.4. Similarity of the ecosystem types by species composition

Among the four families of scarabs, the family Scarabaeidae was dominant and common to all six ecotypes and Families Hybosoridae, Bolboceratidae were unique to Kudipady (CG+AG+VF) and the family Lucanidae was recovered only from Gundya (EGF) and Kaniyoor (AG). Among the Subfamilies under the Scarabaeidae, *viz;* Aphodiinae Scarabaeinae, Rutelinae and Melolonthinae were found to be common in all the ecotypes. The subfamily Dynastinae was unique to Koila (AG+CG) and Belinele (SEF+CG). Bray-Curtis similarity index showed that scarab compositions were more similar between Areca Garden and Semi-Ever Green Forest in combination with Cashew Garden. Subsequently, Ever green Forest and Cashew garden in combination with Areca garden and Village Forest was found to have similar species composition. Thus, Areca ecosystem in combination with any of the natural ecosystems was similar and in contrast, cashew agro-ecosystem showed distinct scarab composition (Fig. 5).

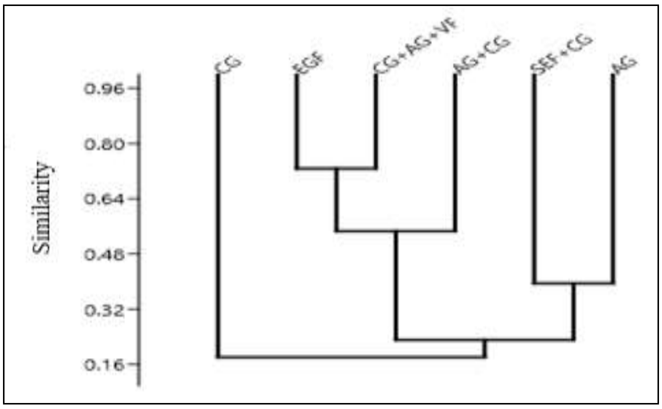

Fig 5: Bray-Curtis similarity between the ecosystems by species of scarabs caught.

Based on the number of times any species appeared in different ecosystem types, proportion of unique species and shared species were calculated. A Minimum of 60 percent of the phytophagous scarabs species were represented only in one of the ecosystem, 20 percent of the species shared by any two of the ecosystems and the other 20 percent species were recovered from more than two ecosystems. A Similar trend was observed in case of non-phytophagous beetles and the two distributions did not differ (K.-S.test; D=0.333; P>0.895) (Fig. 6).

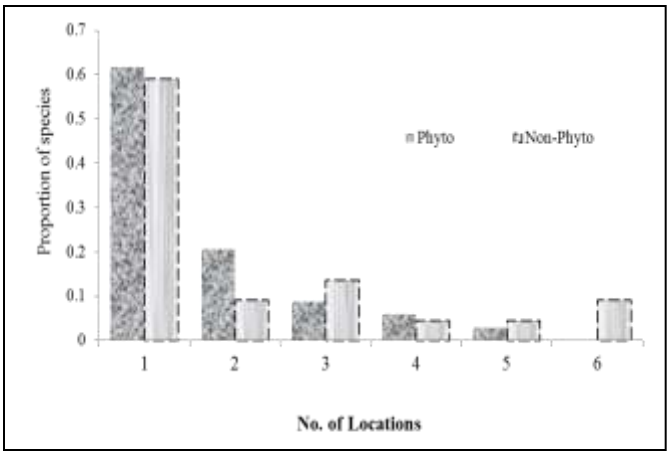

Fig 6: Proportional distribution of species recovered by number of ecosystem types considered under the study

4. Discussion

This study resulted in comprehending the diversity and scarab composition in the coastal region, Puttur, Karnataka during pre-monsoon months of the year 2015. Earlier studies conducted by several workers [13-17] concentrated on either preparation of inventory of the scarabs of particular area or management of economically important scarab species. Thus, studies were lacking on the effect of habitats on scarab species composition in different ecosystem types along southern west coastal region of India. Our study supports findings [15-19] that, phytophagous scarabs are more diverse and speceose compared to the non-phytophagous beetles in any ecosystem types. The phytophagous insects represented 50-60 percent in any community due to the fact that plant diversity would provide more opportunity for adaptive radiation [20]. However, sub-family Scarabaeinae being one of the largest taxon in non-phytophagous groups [7] showed comparatively low richness in the present survey, perhaps due to sampling bias. Dung beetles have an ability to segregate both spatially and temporally, thus perhaps, their representations in the samples is relatively poor [21]. It is also possible that the relative proportion of diurnal and nocturnal species may vie in favour of diurnal species thus limiting the better sampling of Scarabaeinae.

Diversity across the ecosystem types showed higher values for the Cashew agro-ecosystem compared to Ever Green forest, though species richness was higher in the latter. This is due to the inherent property of diversity indices to integrate both the diversity components *viz;* richness (number of species) and evenness (distribution of individuals in to species) into a standardized single value [12]. However, this would also suggest that agricultural systems act as the ‘ectozone’, which supports fauna from both the ecosystems due to edge effect resulting in greater diversity [22] of scarabs. This study also reveals that each of the ecosystems considered were unique in the vegetation composition supporting unique fauna suggesting highly restricted distribution pattern of scarabs in general and also uniqueness of the ecosystem to support different composition of the scarabs [23]. This is corroborated by the fact that nearly 60 % of the species are found in a single ecosystem. Scarab composition in Areca agro-ecosystem was more similar to natural ecosystem than cashew agro-ecosystem. This might be due to the fact that areca gardens have minimal management impact in terms of use of insecticides along the West Coast [17]. Cashew garden on the other hand are periodically treated with insecticides [24] limiting the distribution of many sensitive species [25]. Thus management impact seems to be the primary reason that is influencing the general composition of scarabs in agricultural ecosystems and the relatedness of the ecosystems in terms of composition. More detailed studies with year round samplings might provide a better picture of the observed findings.

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