Entomology

A pilot survey on diversity and ecology of beetles across a habitat gradient from urban to agricultural ecosystem in Vadodara district (Gujarat), India: a comparative account

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Abstract

This survey on Coleopteran faunal diversity was done in Vadodara district during year 2001 to 2007, when the work on insect diversity in Gujarat was very sparse and Vadodara district, which is in the centre of Gujarat state, was devoid of knowledge of its insect diversity. This is the first comprehensive survey of order Coleoptera in Vadodara district. Coleopteran species are pests, pollinators and predators, which make them small but important chain of the ecosystem. Present study was undertaken to access the diversity, richness, relative abundance of Coleoptera and rate of change in species along a gradient, from one habitat to another in four different habitats of Agricultural fields (Rural), Community gardens, Fragmented habitats and Residential areas (Urban). 94 species, 77 genera from 25 families were identified. The result showed that the fragmented landscapes of urban areas had higher abundance and diversity of Coleopteran families as compared to agro- ecosystems of rural areas. *Coccinella septumpunctata* showed greatest species richness in urban communities whereas *Paederus fuscipes* was dominant in the agro ecosystems. The trophic structure consisted of 44.6 % herbivores, 25.5% carnivores, 15.9% detrivores, 1% algivore and 12.7% grubs-adult with different feeding habits. The revival of the habitats and maintenance of the 'green space' is the need of the hour.

Keywords: coleoptera, coccinellidae, urban ecosystem, agroecosystem, species diversity, abundance, fragmented habitats, trophic structure, feeding habit

Introduction

Studies based on insect diversity and their trophic structure were scarce from Vadodara and its surrounding during 2001 to 2007. No documentation has been made till now on beetle's species richness specifically from Vadodara city. About 40% (about 400,000 species) of all described insect species are beetles [1]. It is estimated that about 18,000 species of aquatic Coleoptera are roaming the earth at present. About 12,600 (70%) of these are already described [2]. About 15,088 species of coleopteran insects are known from Indian region [3]. Beetles occur in almost all part of the world, in terrestrial habitats from mountain tops to the intertidal shoreline, from the forest to the desert, in subterranean caverns and in freshwater habitats [4]. The Success of the group is due to the presence of hardened forewing, the ability to consume a wide variety of materials and holometabolia [5]. Beetles play a major role in most of the terrestrial and aquatic ecosystems as they perform ecological key functions. Predatory species, such as lady beetles, are important biological control agents of aphids and scale insects [6]. Carabid (Carabidae) and tiger beetles (Cicindellidae) are considered to be bioindicators due to their sensitivity to various changes in the natural environment [7].

We conceive an urban region as the lands and waters both embedded within and surrounding areas of intense urban land use. These lands include fragments of unbuilt land and remnant patches of natural habitat including parks and natural areas within or in periphery of urban lands. We include this variety of land within our concept of an urban region since these lands and the biota they harbour are likely to be affected by activities associated with the neighbouring urban lands. Urban environments are ecosystems that differ clearly from the natural environment in numerous factors of nature and intensity [7]. Under the conditions of the urban environment the parameters of climate change, the process of alkalization of the top soil layers and the accumulation of heavy metals, especially zinc, lead and copper as well as a considerable content of bitumen, are in progress [8]. The appearance of an urbanized landscape leads to the transformation of biocenoses, which are usually considerably natural. The city is a permanent part of the landscape, which creates different conditions for the organisms living in it than those of natural environments [9]. Observations of the structure of zoocenoses are an essential element of ecological monitoring which allows for evaluating and forecasting changes which occur in different habitats. Coleoptera are a convenient object for the collection of such data [7]. Not only the urban, but Vadodara's characteristic agricultural landscapes also needed to be explored for their beetle's species richness and habitat diversity. Agricultural systems not only occupy a dominant position in terms of land use but they also have broad ranging effects to ecosystem and society.

Studies on Coleopteran ecology and diversity have been carried out in certain parts of the country with more reports from Western Ghats of southern India [10] and Shivaliks of Himachal

Pradesh region in northeastern India [11]. Bio-diversity studies on insects have been taken up in Gujarat. Sabnis and Amin (1992) [12] recorded about 250 species of insects belonging to several orders from Narmada valley. Research on Abundance and Diversity of Butterflies in Vadodara city [13], role of biocontrol insects and their interaction with crops [14], diversity and species richness of ants [15] were given more importance.

Keeping this in view present work has been taken up. The main objectives of this study were:

a. To establish species composition of the beetles in the urban and agroecosystems of Vadodara district
b. To analyze richness and abundance of coleopteran species in various habitats
c. To assess changes in beetle diversity along a habitat gradient from one habitat to other
d. To study the feeding habit of coleopteran species.

Along with recording species richness of the study area, this research will point towards the potential of urban green spaces and agricultural fields to conserve a hyper diverse group like beetles. The list of beetles and the results presented in this study is the first step towards providing a data on Coleoptera from Vadodara, Gujarat.

We hope to continually grow the list of beetle's species, as we move towards a better understanding of the entomofauna of Gujarat.

Materials and methods

A. Attributes of selected study sites (Fig A1-2)

The study was conducted in Central Vadodara, which is located at 22o11' N and 73o07' E in Gujarat and 128 feet above sea level. The climate here is semiarid type characterized by dry and increasingly hot summer from end of February to June, Warm monsoon from July to September and a dry and cold winter from October to early February. July and August receive heaviest downpour. Temperature reaches to 44 degree C in summers to 13 degree C in winters. Relative Humidity is least 31% during winters to 92% during monsoon. Study sites were chosen based on accessibility and location within an eco-region. The Flora of this region can be specified as dry deciduous type. Four different types of habitats were selected on the basis of ecological factors, flora, type of soil, surrounding environment and anthropogenic activities, to get an insight of the best possible insect diversity. Study was conducted during the period from 2001 to 2007.

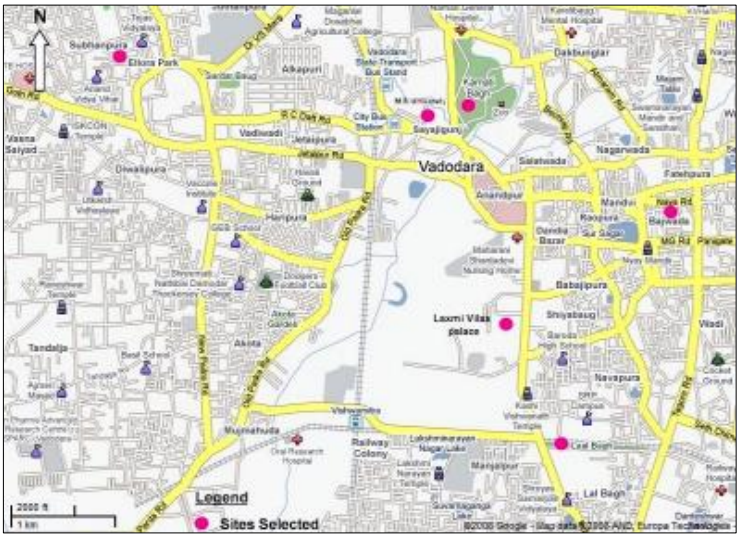

Fig A1: Map of Vadodara showing urban study sites

Fig A2: Map of Vadodara showing rural study sites

1. Rural site

Agricultural fields (AF)

Fields of Padra, Waghodia, Savli and Dabhoi were visited. All are in 30 Kms Radius surrounding main city of Vadodara. Crop plants like Cabbage, Spinach, Raddish, Paddy, Pigeon pea, Maize, Wheat, Cotton, Brinjal, Sugarcane and Castor are cultivated according to season. Least anthropogenic activity noted. Usage of chemical pesticide is prevalent. No pond or canal or any open permanent waterbody was present nearby any of the fields visited. Litter below peripheral trees and shrubs. Major vegetation on the hedges surrounding the agricultural fields are: *Mangifera indica, Azadirechta indica, Hibiscus rosa sinensis and Tamarindus indicus, Euphorbia neriifolia, Zizyphus mauritiana, Zizyphus oenoplia,Moringa oleifera, Caeselpenia crista, Tinospora cordifolia, Tinospora cordifolia,Calotropis procera, Opuntia elatior, Ipomea obscura*. Presence of cattle in surrounding areas.

2. Urban sites

a) Community gardens

Gardens in Vadodara have been set up for recreation and are open for general public. The gardens are lush green throughout the year. These gardens have several flowering plants. The flower shows during winter time are major attractions for locals and tourists. Hundreds of flower species are on display during these shows.

The garden has also large number of tree species including *Ficus benghalensis* which is found all over Vadodara (and the city is named after this tree).

The studies were carried out in the following gardens:

i. Sayaji Baug and Lal Baug (CG)

Frequent human activity observed. Both the gardens have a small stream of river Vishvamitri passing and a small pond respectively along with vegetation covering them. Below big trees very less litter found. Monkeys on the trees are usual sight.

ii. Common flora of the gardens

Major large trees in the gardens are, *Ficus bengalensis, Azadirachta indica, Terminalia catappa, Feronia limonia, Aegle marmelos, Butea monosperma, Casuarina tamarindus, Polyalthia longifolia, Saraca indica, Dalbergia latifolia India, Mangifera indica, Syzygium cumin.* Herb like *Commelina nudiflora, Tephrosia purpurea, Hibiscus lobatus, Abutican indicum.* Climbers like *Bougainvillea*, Shrub like *Ixora coccinea*, Grasses of *Tephrosia strigosa, Andropogon annulatus* (common grass) Floral plants of *Vinca rosea, Rosa chinensis,Lantana camara.* Weeds like *Ceaselia axillary, Cyprus exhaltus, Sesbania bipilosa, Cyanodon dactylon, Calotropis* etc.

b) Fragmented habitat

University campus and Laxmivilas Palace compound (FH).

In both the sites frequent anthropogenic activity was found.

i. Laxmivilas palace compound

Which surrounds Laxmivilas Palace of King Gaekwad. It coveres 707 acres. It has lush green vegetation during monsoon and post monsoon period, but no permanent water body is located inside it only small and big puddles are formed due to rains in the playground area. Everywhere abundance of litter found. Vegetation here consists of *Tridax procumbens, Commelina nudiflora, Sida acuta, agave, casuarinas, Tamarindus indicus, Cassia species, Azadirecta indica, Abutilon indicum, Cymbopogon martini, Urena lobata, Brassica nigra Koch., Aegle mermelos Linn., feronia Lemonia Linn.,Zizyphus jujube. Butea monosperma Lamk. Pongamia pinnata Linn. Cassia siamea Lamark, Acacia nilotica, Pithecelobium dulce Roxb, Hyphaena indica, Cuscuta species, etc.*

ii. M.S. university campus

Which includes university botanical garden, cricket ground, and lower bridge.Vegetation mostly consists of *Acacia nilotica, Pithecellobium dulce, Pongamia pinnata, Ficus benghalensis, Prosopis spicegera, Aegle marmelos, Ailanthus exelsa, Phoenix sylvestris, Ficus glomerata, Xanthium strumarium, Argimone mexicana, Calotropis gigantean, C.procera Lantana camara, Abutilon indicum, Zizyphus mauritiana, Cassia tora, C.occidentalis, Limonia acidissima, Sida acuta, Convolvulus microphyllus, Boerhavia diffusa, Cyperus mechelianus, Nicotiana plumbaginifolia*. University botanical garden has following plantations available throughout the year. *Michelia champaca, Annona uncinata, Annona sqamosa, A.reticulata, Reseda odorata, Portulaca oleracea, Canna species, Viola odorata, Tamarix gallica, Hibiscus syriacus*. Pond in the garden has *Nymphea stellata, Trapa species, Utricularia stellaris, Hydrilla verticillata, Typha augustata, Vallisnaria spiralis.*

c) Residential areas

New and old city area (RA). Both sites had building under construction, roads and pavements, Residential houses and some vegetation in private compounds. They are mostly inhabited by human and other domestic animals. No permanent open water body located except closed water tanks. Very little litter found in private gardens. Stray cattles and dogs are usual sight. New city area vegetation includes *Mangifera indica, Polyalthia longifolia, Livistona chinensis, Murrya koengii, Azadirechta indica, Moringa oleifera,Pithecellobium dulce, Terminalia catappa, Cocos nucifera, Achras zapota, Ficus glomerata, Cordia sebestena, Alstonia scolaris, Tecoma stans, Rosa chinensis, Lawsonia inermis, Ixora coccinea, I.arborea, Vinca rosea Nerium oleander, Calotropis procera, Ocimum sanctum, Euphorbia neriifolia, Aloe vera, Andropogon annulatus, A. martinii, Thevetia peruviana, Quisqualis indica, Pyrostegia, Caeselpinia crista, Achyranthes aspera var porphyristachya, Bryophyllum calycinum, Datura fastuosa, Bignonia stans, Nyctanthes arbortristis, Chrysanthemum sp., Clerodendrum splendens, Mirabilis jalapa, Jasminum sambac, etc.*

Old city area has *Polyalthia longifolia, Ficus religiosa, Azadirachta indica, Rosa chinensis, Ixora coccinea, I.arborea. Euphorbia neriifolia Linn, Ocimum sanctum, Vinca rosea, Zizyphus jujube, Pothos, Nerium oleander, Jasminum sambac*.

B. Collection-method

Insects were collected throughout the year. Each study area was visited twice every month on two consecutive days. Pitfall trapping, which is the most reliable method for collecting insects for distribution and abundance studies [16]. Pitfall traps

were employed at all study sites. At each site 8 pitfall traps were established. Each pitfall t rap consists of a 250 ml polycarbonate sampling container with 48 mm opening diameter. The opening was covered with a funnel, the stem of the funnel opened into a smaller container filled with 50 ml of 20% ethylene glycol. Pitfall traps were sunk into the soil so that the container opening was level with the ground surface. They were collected after 24 hours. The solution in the internal container was replaced and the pitfall left there for another round of sampling. Ground beetles were collected through this method. To account for the beetle species not recorded in pitfall trap sampling, sweep net and hand collection are resorted to. In Sweep net method a butterfly net is swept across bushes once right to left and then left to right. This was repeated after every half an hour. Sweep net method was carried out specifically on garden hedges and the shrubs in the periphery of the agricultural fields. Ladybird beetles and Chrysomelid beetles were collected through this method. Hand collection was done by picking with a hand or forceps into a Cyanide bottle. This method involved searching and collecting beetles in different microhabitats. The search was carried in grass, shrubs, flowers, leaf litter, bare ground, base of roots of trees, under stones, in field margins, tree trunks, cow dung etc. Buprestid, Cyrambicid and Scarabid beetles were collected by this method.

Photography in the urban and agro-ecosystems was done using Nikon digital camera Cool pix, L4, 10x optical zoom identification.

Insects collected were identified using keys available in Richard and Davies (1997) [17], Borror *et al*. (1992) [18], Leffroy (1909) [19] and Ananthkrishnan and David (2004) [20] and standard manuals. The identified material was confirmed from Entomology Division of Indian Agriculture Research Institute (IARI), PUSA, New Delhi.

Host Plants were identified and confirmed with Catalogue of Sabnis (1967) [21] and Dave (2002) [22].

1. Data analysis

The raw data of all the sampled sites from the field diaries of seven consecutive years were transferred on to an electronic format in spreadsheet layout (Microsoft excels). The data was finally analyzed to calculate important value indices from all the sampling sites. The diversity indices were calculated by Species diversity and richness software, PISCES Conservation Ltd. File Version 2.65 [23].

i. Shannon-Weiner index (H)

The richness of species within habitats was calculated using Shannon-Weiner index (H) of alpha diversity index (H= -∑ Pi loge P). Where Pi is the proportion of individual in ith species. The higher value of H, greater is the uncertainty. This implies higher diversity and evenness of the community as biological community value of H does not exceed 5. It ranges from 4 (most diverse) to 0 (least diverse).

ii. Equitability or Evenness (J) refers to the pattern of distribution of the individuals between the species in a specific habitat. In our study this was done for all the four habitats. If H is the observed Shannon-Wiener index, the maximum value this could take is log(S), where S is the total number of species in the habitat.

Therefore, the index is: J = H/log(S).

This index is high if a community has many species and their abundances are evenly distributed; index is low if the species are few and their abundances are unevenly distributed.

iii. Berger–Parker index

It is simple measure of the numerical importance of the dominant species. The Berger-Parker Index accounts for both richness and relative abundance, presents the proportional importance of the most dominant species, and is simple and easy to calculate:

Let d = Nmax/N,

Where, Nmax is the number of individuals in the most abundant species and N is the total number of individuals in the sample.

The Berger-Parker index is then simply 1/d. so that increase in the index value follows an increase in species diversity or a decrease in dominance. It ranges from 0 (most diverse) to 1(least diverse).

iv. Species evenness was found using plot for rank order-log abundance.

v. Diversity of species was found using Renyi diversity ordering graph. This method uses lattice graphics, and displays the diversity values against each scale in separate panel for each site together with minimum, maximum and median values in the complete data [24]. According to the theory of diversity ordering, one community can be regarded as more diverse than other only if its Renyi diversities are all higher [25].

vi. Whitaker's and wilson shmida index

For measuring extent of change in species, from one habitat to another Whitaker's, and Wilson's index were calculated:

Whittaker index $\beta w = S/\alpha - 1$

Wilson Shmida index $\beta T = g(H) + l(H)/2\alpha$

Its value ranges from 0 (least diverse) to 1(most diverse). If the value obtained for diversity is in close proximity to one, the greater is richness of the species in community.

Results

Species richness and abundance

A total of 3719 individuals were collected from all sites during the entire study period. 94 species, 77 genera from 25 families were identified. (Table 1).

Table 1: Total no. of families, genera and species

Sub order	Families	No. of genera	No. of species
Adephaga	Carabidae	6	12
	Cicindellidae	1	1
	Dytiscidae	1	1
	Paussidae	1	1
Polyphaga	Hydrophilidae	2	2
	Staphylinidae	1	1
	Scarabaedae	7	10
	Dynastidae	1	1
	Melolonthidae	2	3
	Buprestidae	2	4
	Bruchidae	1	1
	Cyrambicidae	10	10
	Chrysomelidae	6	7
	Cassididae	5	6
	Haliplidae	1	1
	Curculionidae	5	5
	Elateridae	1	1
	Cantharidae	1	1
	Silvanidae	1	1
	Bostrychidae	2	2
	Anobiidae	1	1
	Coccinellidae	8	9
	Tenebrionidae	6	8
	Meloidae	3	3
	Dermestidae	2	2

Out of the 25 families, Carabidae, had maximum representation in both the habitats followed by families Scarabidae, Cyrambicidae and Coccinellidae. Families Haliplidae, Elateridae, Cantharidae, Silvanidae, Bostrychidae, Anobidae, Dermestidae, Staphylinidae, were having minimum number of species (Fig.1).

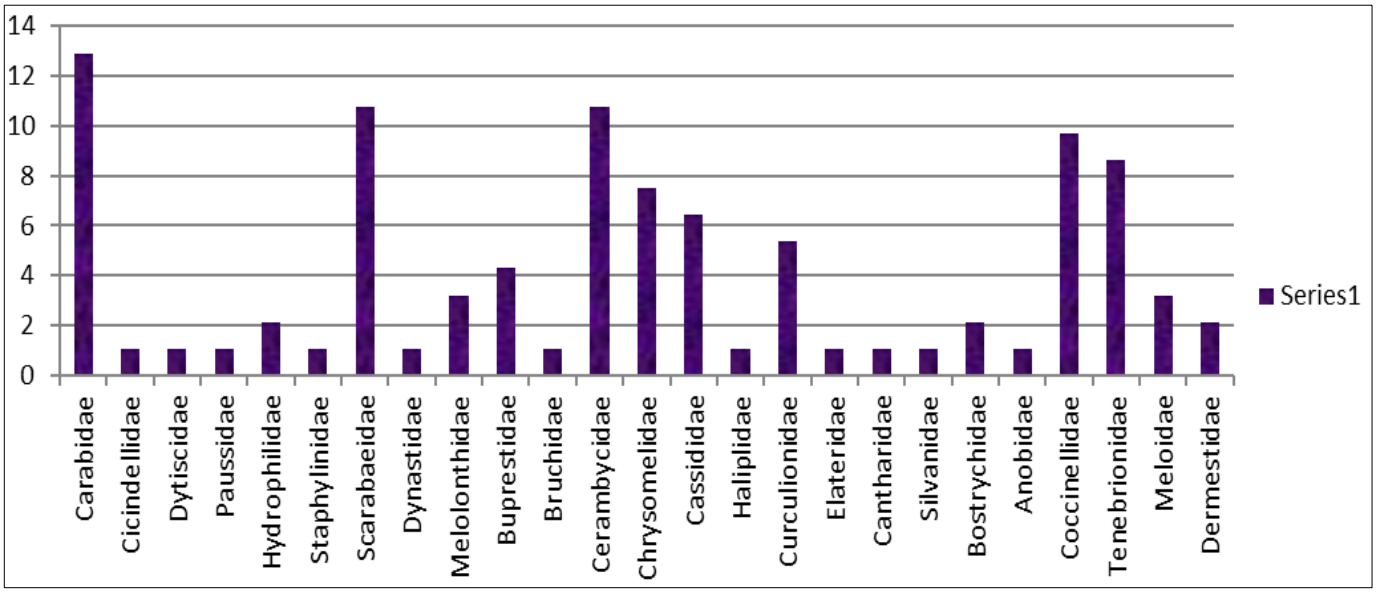

Fig 1: Percentage composition of families of Coleoptera in Vadodara

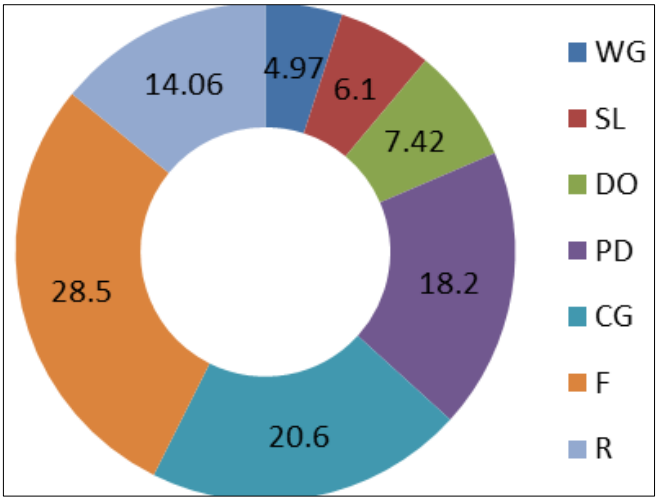

Fig 2: Percentage population of coleopteran species in various study sites

In all the agricultural fields *Paederus fuscipes* was maximum (Table 2) due to presence of its food of hoppers and decaying leaves.

Table 2: Species abundance in studied sites

No.	*Species*	WG	SL	DO	PD	CG	F	R	Total
1	*Scarites bengalensis Dejean, 1826*	1	3	2	3	5	12	4	30
2	*Scarites subterraneus Fabricius, 1785*	1	4	1	4	4	13	3	30
3	*Anthia sexguttata fabricius,1775*	1	4	2	5	9	14	4	39
4	*Calosoma orientalis (*Pic.11*)*	0	0	0	2	4	5	0	11
5	*Calosoma pretiosus Linnaeus,1758*	0	1	0	1	5	3	0	10
6	*Chlaenius pictus*	0	0	0	1	3	2	0	6
7	*Chlaenius rayotus DeJean,1826*	1	0	1	1	5	3	1	12
8	*Chlaenius nitidicolis*	0	0	3	2	6	4	2	17
9	*Chlaenius nepalensis Duftschmid, 1812*	2	1	1	1	3	5	0	13
10	*Chlaenius duvaucelli Bates, 1874*	3	1	2	1	2	5	0	14
11	*Pheropsophus lineifrons de Chaudoir*	3	4	4	2	5	3	0	21
12	*Casnonia bimaculata*	1	2	4	3	6	5	3	24
13	*Myriochila melancholica Fabricius, 1798*	0	0	0	1	2	3	0	6
14	*Cybister punctatus*	0	0	1	0	8	2	0	11
15	*Paussus nauceras*	1	0	0	6	5	10	1	23
16	*Hydrous indicus*	1	0	0	3	3	4	0	11
17	*Sternolophus rufipes Fabricius, 1792*	0	1	0	0	9	15	0	25
18	*Paederus fuscipes Curtis, 1826*	20	21	30	38	29	42	12	192
19	*Heliocopris bucephalus Fabricius, 1775*	0	2	6	6	8	10	2	34
20	*Catharsius molossus Linnaeus, 1758*	3	2	1	2	9	30	2	49
21	*Catharsius pithecus Fabricius, 1775*	4	3	1	6	10	21	9	54
22	*Oxycetonia versicolor Fabricius, 1775*	2	1	1	5	4	6	6	25
23	*Onthophagus gazella Fabricius, 1787*	2	0	1	8	12	16	11	50
24	*Protaetia aurichalcea Fabricius, 1775*	2	1	1	1	2	3	0	10
25	*Onthophagus bonasus Fabricius, 1775*	3	1	1	11	9	12	11	48
26	*Gymnopleurus cyaneus Fabricius, 1798*	3	4	5	10	15	38	6	81
27	*Gymnopleurus miliaris Fabricius,1775*	5	5	6	19	16	24	13	88
28	*Canthon viridia*	0	1	2	1	2	4	0	10
29	*Oryctes rhinoceros Linnaeus 1958*	0	2	1	1	2	3	0	9
30	*Holotrichia insularis Brenske*	1	2	1	16	10	12	6	48
31	*Holotrichia tuberculipennis*	3	4	1	12	9	6	3	38
32	*Autoserica insanabilis*	2	1	1	10	12	16	4	46
33	*Sternocera chrysidioides Castelnau & Gory,1837*	1	0	0	1	0	2	0	4
34	*Sternocera nitidicolis Castelnau & Gory,1836*	0	0	1	2	0	3	0	6
35	*Sternocera rugosipennis Castelnau & Gory,1837*	0	0	1	3	0	5	0	9
36	*Psiloptera cupreosplendens Saunders*	2	1	1	6	10	15	0	35

37	*Callosobruchus maculatus Fabricius, 1775*	3	2	4	9	0	0	0	18
38	*Batocera rufomaculata DeGeer,1775*	2	1	1	3	1	5	2	15
39	*Xystrocera globosa Fabricius, 1775*	2	1	1	1	2	3	0	10
40	*Apomecyna saltator Fabricius, 1781*	1	0	2	2	1	3	0	9
41	*Plocaederus ferrugineus Linnaeus,1792*	2	1	0	1	2	5	0	11
42	*Coptops aedificator Fabricius, 1792*	2	1	1	2	3	5	0	14
43	*Hypoeshrus indicus Gahan, 1906*	2	1	1	3	2	6	0	15
44	*Acanthophorus rugicelis*	0	0	0	2	3	4	0	9
45	*Prionus heroicus Semenov,1907*	0	1	1	2	0	1	0	5
46	*Macrotoma crenata Voit 1778*	2	1	1	3	0	4	0	11
47	*Gelonaetha hirta. Fairmaire, 1850*	2	1	3	2	0	5	0	13
48	*Chrysolampra indica* (Pic 5)	6	12	14	15	12	19	10	88
49	*Lema fortunei Baly, 1859* (Pic. 6)	6	14	16	12	10	15	9	82
50	*Aulacophora foveicollis*	2	15	19	15	13	20	8	92
51	*Aulacofora species*	3	20	14	13	15	16	10	91
52	*Sagra empyrea Lacordaire, 1845*	0	0	1	0	10	8	0	19
53	*Oides bipunctata Fabricius, 1781*	0	0	0	5	4	6	0	15
54	*Altica coerulea*	1	0	1	3	6	8	1	20
55	*Aspidomorpha species*	0	1	1	3	6	8	2	21
56	*Aspidomorpha diformis* (Pic.15)	1	1	1	10	15	13	5	46
57	*Cassida piperata Hope, 1842*	10	19	20	13	15	18	9	104
58	*Glyphoeossis trilineata*	1	0	1	12	14	15	8	51
59	*Conchyloctania nigrovittata*	0	0	0	10	12	11	2	35
60	*Sindia clathrata Fabricius, 1798*	1	0	1	10	9	12	1	34
61	*Haliplus augustifrons Reg*	0	0	0	0	2	3	0	5
62	*Pycnodactylus hypocrita Chevrolat, 1873*	0	0	0	3	6	8	1	18
63	*Sitophilus oryzae Linnaeus 1763 n*	3	1	4	12	0	0	44	64
64	*Xanthochelus superciliosus Gyllenhal, 1834*	2	2	1	10	0	15	9	39
65	*Apion aeneum Fabricius, 1775*	0	0	1	9	2	12	1	25
66	*Cyrlozernia dispar* (Pic.7)	2	4	5	2	3	4	0	20
67	*Agrypnus fuscipes Fabricius, 1775*	0	5	2	2	0	3	0	12
68	*Sybaris testaceus*	2	0	1	2	3	4	0	12
69	*Oryzaephilus surinamensis Linnaeus, 1758*	6	7	9	16	0	0	30	68
70	*Synoxylon anale Lesne, 1897*	1	0	0	5	6	9	0	21
71	*Rhyzopertha dominica Fabr,1792*	0	0	10	12	0	0	0	22
72	*Lasioderma testacea Duft*	10	8	7	12	15	19	2	73
73	*Coccinella septumpunctata Linnaeus 1758*	10	2	4	20	38	42	15	131
74	*Chilomenes/Menochiles sexmaculata Fab.1781*(Pic.10)	6	8	7	16	31	28	10	106
75	*Chilocorus subindicus Booth* (Pic.9)	2	1	1	8	12	15	0	39
76	*Thea/illeis indica Timberlake*	2	1	0	10	16	12	5	46
77	*Epilachna vigintioctopunctata Fabricius,1775*(Pic.1)	1	0	0	6	5	9	1	22
78	*Coccinella transversalis Fabricius, 1781*	1	4	2	26	32	41	17	123
79	*Harmonia octomaculata Fabricius, 1781*	3	4	10	25	35	46	12	135
80	*Brumoides suturalis Fab,1798*	2	4	7	25	38	41	10	127
81	*Anegleis cardoni Weise*	5	4	6	24	26	26	9	100
82	*Tribolium castaneum Herbst, 1797*	0	0	0	0	0	0	60	60
83	*Tribolium confuseum Jacquelin Du Val,1863*	0	0	0	0	0	0	42	42
84	*Platynotus excavatus Fabricius, 1775*	2	0	1	5	3	9	1	21
85	*Pseudoblaps mellyi*	0	0	0	4	5	9	2	20
86	*Blaps orientalis Sol*	0	0	1	0	0	6	0	7
87	*Gonocephalum dorsogranosum Fairmaire, 1896*	0	1	4	10	12	15	3	45
88	*Gonocephalum planatum*	0	1	0	12	15	13	6	47
89	*Rhytinota impolita Fairmaire, 1896*	0	0	0	10	12	14	3	39
90	*Cyaneolytta coerulea*	2	1	1	15	13	18	4	54
91	*Psaldolytta menoni*	1	4	4	12	15	16	5	57
92	*Mylabris pustulata Thunberg, 1791*	4	1	1	22	24	38	13	103
93	*Trogoderma granarium Everts, 1898*	1	0	0	0	0	0	39	40
94	*Attageus piceus Olivier, 1790*	0	0	0	0	0	0	9	9

As population of aphids were found in abundance, its predators *Brumoides suturalis* and *Coccinella septumpunctata* were maximum in community gardens, small hoppers and aphids were found in abundance from fragmented habitats of palace compound and University campus, population of their predator *Harmonia octamaculata* was maximum there, being stored grain pest *Tribolium casteneum* were maximum in residential areas so they are on the highest rank on the plot. Their abundance is more thus they are dominant species. (Fig 3).

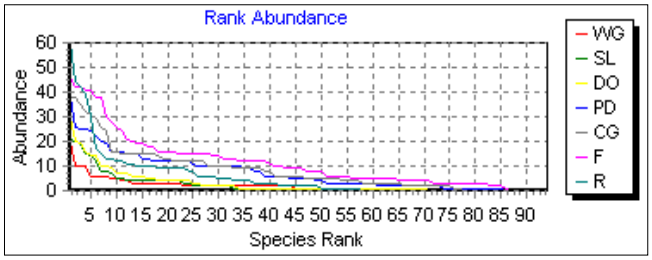

Fig 3: Rank abundance of species in all the sites

Species diversity indices and evenness

Shannon Weiner index H for Fragmented habitat (F) is more (4.1) than rural area (>4.1) (Table 4) that means species richness is more in the area having higher Shannon Weiner index. Number of individuals found in urban area is more than rural area (Table 3) the reason is usage of pesticides in the agricultural fields which might have cause decrement of some species in that area.

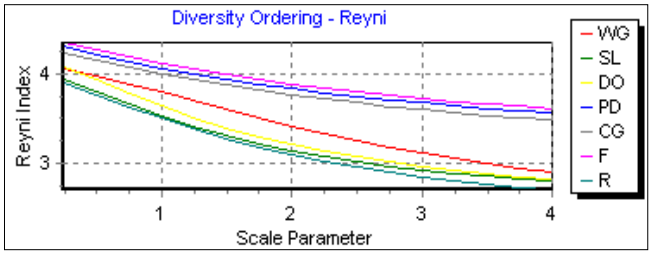

Fig 4: Diversity ordering of all the sites

As it is seen in Fig. 4 the shallower shape which is found on top of the curve reflects high diversity thus Fragmented habitat is most diverse followed by Padra and community gardens respectively. Steeper shape curves indicating least diversity is found in the bottom of the graph thus residential sites and fields of Savli are least diverse.

Fragmented habitat and Padra has a greater number of species which are evenly distributed, species richness is more and species evenness is also high which is depicted by shallow graph of rank abundance (Fig 3).

Savli and residential area have total 59 and 57 species present respectively. Paederus and Tribolium are in abundance in Savli and Residential sites respectively. Both the sites have low species evenness indicated by steep graph of rank abundance (Fig.3) Species richness is also less.

Table 3: Number of individuals and total percentage in urban and rural habitats

Habitat	Individuals	Percent population
Urban	2351	63.2
Rural	1368	36.7

Table 4: Species diversity and evenness in all the study sites

Sample	Species number	Shannon weiner H	Equitability index J	Berger parker dominance
WG	63	3.8	0.83	0.1
SL	59	3.53	0.77	0.09
DO	70	3.64	0.8	0.1
PD	85	4.07	0.89	0.05
CG	77	4.01	0.88	0.04
F	86	4.13	0.91	0.04
R	57	3.5	0.77	0.11

Structure of communities along the habitat gradients

Rate of change of species in fields of Savli and Residential areas is maximum (0.3) thus species of these sites differ greatly while species of Padra fields and fragmented habitat are more or less similar so tornover rate is minimum (0.05) (Table 5). Only few species were not found either in rural or in urban habitat so rate of change is less. Due to the habitats considered were not very far from each other, they are in the same district – Vadodara there was not much variation in Beta diversity.

Table 5: Beta diversity index between all study sites

Sample	Whitakers, Wilson-schmida index	Sample	Whitakers, Wilson-schmida index
SL-R	0.327	WG- S	0.196
DO-R	0.291	SL-PD	0.194
WG-R	0.266	WG-DO	0.172
PD-R	0.253	WG-P	0.162
SL-CG	0.25	SL-DO	0.162
SL-F	0.227	DO-F	0.153
WG-C	0.214	DO-PD	0.135
DO-CG	0.21	PD-CG	0.098
WG-F	0.208	PD-F	0.052

Trophic groups and feeding habit

The evaluation of the trophic groups of the coleopteran families identified in all habitats was made according to Marinoni *et al* (2001) [26]. The known alimentary habits of Coleoptera are classified in five trophic groups - herbivores, algivores, fungívores, detrivores and carnivores [26]. Further we divided these groups into subgroups based on type of food.

➢ **Herbivore**

1. Phytophagous: Feeding on Plant parts
2. Granivorous: Feeding on Grains/seeds
3. Xylophagous: Feeding on wood of living plant/tree
4. Nectarivore: Feeding on Nectar
5. Pollenophagous: Feeding on Pollens of plants

➢ **Algivore**

1. Myxophagous: Feeding on green Algae

➢ **Detrivore**

1. Saprophagous: Feeding on dead organic matter
2. Saproxylophagous: Feeding on dead wood
3. Coprophagous: Feeding on Feces/animal dung
4. Chitinophagous/Keratophagous: feeding on Feather, Hair, Wool

➢ **Carnivore**

1. Entomophagous: Feeding on other insects

2. Aphidophagous: Feeding on Aphids
3. Predaceous: Feeding on other animals

➢ **Fungivore**

1. Feeding on fungus

Out of 94 species identified, 42 species are Herbivorous,24 are Carnivorous, 15 are Detrivorous, 1 is Algivore and 12 species, grubs and adult having different food. (Table 6). In all four agricultural fields, *Paederus*, which is a detrivore, was abundant. In Fragmented habitats, carnivorous *Harmonia octamaculata* (46) and in Community gardens, *Coccinella* (38*)* were in abundance. In Residential sites Phytophagous, pest of stored grains, *Tribolium* (60) was dominating the other species. Only one fungivore species, *Haliplus augustifrons* was found in community gardens and fragmented habitat.

Table 6: Feeding habit and trophic structure of coleopteran species in Vadodara

No.	*Species*	Trophic group	Trophic Subgroup
1	*Scarites bengalensis Dejean, 1826*	Carnivorous	Entomophagous
2	*Scarites subterraneus Fabricius, 1785*	Carnivorous	Entomophagous
3	*Anthia sexguttata fabricius,1775*	Carnivorous	Entomophagous
4	*Calosoma orientalis*	Carnivorous	Entomophagous
5	*Calosoma pretiosus Linnaeus,1758*	Carnivorous	Entomophagous
6	*Chlaenius pictus*	Carnivorous	Entomophagous
7	*Chlaenius rayotus DeJean,1826*	Carnivorous	Entomophagous
8	*Chlaenius nitidicolis*	Carnivorous	Entomophagous
9	*Chlaenius nepalensis Duftschmid, 1812*	Carnivorous	Entomophagous
10	*Chlaenius duvaucelli Bates, 1874*	Carnivorous	Entomophagous
11	*Pheropsophus lineifrons de Chaudoir*	Carnivorous	Entomophagous
12	*Casnonia bimaculata*	Carnivorous	Entomophagous
13	*Myriochila melancholica Fabricius, 1798*	Carnivorous	Entomophagous
14	*Cybister punctatus*	Carnivorous	Predaceous
15	*Paussus nauceras*	Carnivorous	Entomophagous
16	*Hydrous indicus*	Carnivorous-Detrivorous	Predaceous-Saprophagous
17	*Sternolophus rufipes Fabricius, 1792*	Carnivorous	Entomophagous
18	*Paederus fuscipes Curtis, 1826*	Detrivorous -Carnivorous	Saprophagous -Entomophagous
19	*Heliocopris bucephalus Fabricius, 1775*	Detrivorous	Coprophagous
20	*Catharsius molossus Linnaeus, 1758*	Detrivorous	Coprophagous
21	*Catharsius pithecus Fabricius, 1775*	Detrivorous	Coprophagous
22	*Onthophagus gazella Fabricius, 1787*	Detrivorous	Coprophagous
23	*Onthophagus bonasus Fabricius, 1775*	Detrivorous	Coprophagous
24	*Gymnopleurus cyaneus Fabricius, 1798*	Detrivorous	Coprophagous
25	*Gymnopleurus miliaris Fabricius,1775*	Detrivorous	Coprophagous
26	*Canthon viridia*	Detrivorous	Coprophagous
27	*Oxycetonia versicolor Fabricius, 1775*	Herbivorous	Pollenophagous
28	*Protaetia aurichalcea Fabricius, 1775*	Herbivorous	Pollenophagous
29	*Oryctes rhinoceros Linnaeus 1958*	Detrivorous	Saprophagous
30	*Holotrichia insularis Brenske*	Herbivorous	Phytophagous
31	*Holotrichia tuberculipennis*	Herbivorous	Phytophagous
32	*Autoserica insanabilis*	Herbivorous	Phytophagous
33	*Sternocera chrysidioides Castelnau & Gory,1837*	Herbivorous-Detrivorous	Xylophagous-Saproxylophagous
34	*Sternocera nitidicolis Castelnau & Gory, 1836*	Herbivorous- Detrivorous	Xylophagous-Saproxylophagous
35	*Sternocera rugosipennis Castelnau & Gory,1837*	Herbivorous- Detrivorous	Xylophagous-Saproxylophagous
36	*Psiloptera cupreosplendens Saunders*	Herbivorous- Detrivorous	Xylophagous-Saproxylophagous
37	*Callosobruchus maculatus Fabricius, 1775*	Herbivorous	Granivorous
38	*Batocera rufomaculata DeGeer,1775*	Herbivorous	Xylophagous-Phytophagous
39	*Xystrocera globosa Fabricius, 1775*	Herbivorous	Xylophagous-Phytophagous
40	*Apomecyna saltator Fabricius, 1781*	Herbivorous	Xylophagous-Phytophagous
41	*Plocaederus ferrugineus Linnaeus,1792*	Herbivorous	Xylophagous-Phytophagous
42	*Coptops aedificator Fabricius, 1792*	Herbivorous	Xylophagous-Phytophagous
43	*Hypoeshrus indicus Gahan, 1906*	Herbivorous	Xylophagous-Phytophagous
44	*Acanthophorus rugicelis*	Herbivorous	Saproxylophagous-Phytophagous
45	*Prionus heroicus Semenov,1907*	Herbivorous	Xylophagous-Phytophagous
46	*Macrotoma crenata Voit 1778*	Herbivorous	Xylophagous-Phytophagous
47	*Gelonaetha hirta. Fairmaire, 1850*	Herbivorous	Xylophagous-Phytophagous
48	*Chrysolampra indica*	Herbivorous	Phytophagous
49	*Lema fortunei Baly, 1859*	Herbivorous	Phytophagous
50	*Aulacophora foveicollis*	Herbivorous	Phytophagous
51	*Aulacofora species*	Herbivorous	Phytophagous
52	*Sagra empyrea Lacordaire, 1845*	Herbivorous	Phytophagous

53	*Oides bipunctata Fabricius, 1781*	Herbivorous	Phytophagous
54	*Altica coerulea*	Herbivorous	Phytophagous
55	*Aspidomorpha species*	Herbivorous	Phytophagous
56	*Aspidomorpha diformis*	Herbivorous	Phytophagous
57	*Cassida piperata Hope, 1842*	Herbivorous	Phytophagous
58	*Glyphoeossis trilineata*	Herbivorous	Phytophagous
59	*Conchyloctania nigrovittata*	Herbivorous	Phytophagous
60	*Sindia clathrata Fabricius, 1798*	Herbivorous	Phytophagous
61	*Haliplus augustifrons Reg*	algivorous	Myxophagous
62	*Pycnodactylus hypocrita Chevrolat, 1873*	Herbivorous	Phytophagous
63	*Sitophilus oryzae Linnaeus 1763 n*	Herbivorous	Granivorous
64	*Xanthochelus superciliosus Gyllenhal, 1834*	Herbivorous	Phytophagous
65	*Apion aeneum Fabricius, 1775*	Herbivorous	Phytophagous
66	*Cyrlozernia dispar*	Herbivorous	Phytophagous
67	*Agrypnus fuscipes Fabricius, 1775*	Carnivorous-Herbivorous	Entomophagous- Phytophagous
68	*Sybaris testaceus*	Herbivorous	Entomophagous-Nectarivorous
69	*Oryzaephilus surinamensis Linnaeus, 1758*	Herbivorous	Granivorous
70	*Synoxylon anale Lesne, 1897*	Herbivorous	Xylophagous
71	*Rhyzopertha dominica Fabr,1792*	Herbivorous	Granivorous
72	*Lasioderma testacea Duft*	Herbivorous	Phytophagous
73	*Coccinella septumpunctata Linnaeus 1758*	Carnivorous-Herbivorous	Aphidophagous-
74	*Coccinella transversalis Fabricius, 1781*	Carnivorous	Aphidophagous
75	*Chilomenes/Menochiles sexmaculata Fab.1781*	Carnivorous	Aphidophagous
76	*Chilocorus subindicus Booth*	Carnivorous	Entomophagous
77	*Thea/illeis indica Timberlake*	Carnivorous	Aphidophagous
78	*Epilachna vigintioctopunctata Fabricius, 1775*	Carnivorous	Aphidophagous
79	*Harmonia octomaculata Fabricius, 1781*	Carnivorous	Aphidophagous
80	*Brumoides suturalis Fab,1798*	Carnivorous	Aphidophagous
81	*Anegleis cardoni Weise*	Carnivorous	Aphidophagous
82	*Tribolium castaneum Herbst, 1797*	Herbivorous	Granivorous
83	*Tribolium confuseumJacquelin Du Val,1863*	Herbivorous	Granivorous
84	*Platynotus excavatus Fabricius, 1775*	Detrivorous	Saprophagous
85	*Pseudoblaps mellyi*	Detrivorous	Saprophagous
86	*Blaps orientalis Sol*	Detrivorous	Saprophagous
87	*Gonocephalum dorsogranosum Fairmaire,1896*	Detrivorous	Saprophagous
88	*Gonocephalum planatum*	Detrivorous	Saprophagous
89	*Rhytinota impolita Fairmaire, 1896*	Detrivorous	Saprophagous
90	*Cyaneolytta coerulea*	Carnivorous-Herbivorous	Entomophagous-Phytophagous
91	*Psaldolytta menoni*	Carnivorous-Herbivorous	Entomophagous-Phytophagous
92	*Mylabris pustulata Thunberg, 1791*	Carnivorous-Herbivorous	Entomophagous-Phytophagous
93	*Trogoderma granarium Everts, 1898*	Herbivorous	Granivorous
94	*Attageus piceus Olivier, 1790*	Detritus-Herbivorous	Chitinovorous-Nectarivorous

Pic.1 *Epilachna vigintioctopunctata*

Pic.2 *Coccinella transversalis*

Pic.3 *Psiloptera cupriosplendense*

Pic.4 *Catharsius molossus*

Pic.5 *Chrysolampra indica*

Pic.6 *Lema fortunei*

Pic.7 *Cyrlozernia dispar*

Pic.8 *Oxytonia versicolour*

Fig 5

Discussion

Panzer and Schwartz (1998) [27] observed that the plant species richness explained more than 49% of the variance of the insect species richness among the studied areas. So, the reason for greater species richness and abundance of coleopterans in fragmented habitats which consists of variety of vegetation is explained in study conducted by Panzer and Schwartz. The richness and diversity of fragmented habitat sites of university campus and Lakshmivilas palace compound is related to its complex structure which includes many plant species, vertical stratification, more litter content and varied landscapes. The lack of vegetation in the residential sites of urban areas may have contributed to the richness and abundance of the beetle species due to low availability of food resources [28].

Among the identified coleopteran families, Carabidae presented the highest number of morph- Species especially *Chlaenius* species. All the identified species of this family are predaceous in nature. They were found mostly in community

gardens and fragmented habitats where soil organic matter and vegetation was diverse. Study of Samir *et al* (2017) [29] also suggested that habitat heterogeneity is the predictor of beetle assemblages.

Amongst all the habitat types, *Paederus fuscipes* had highest abundance and *Chlaenius* Species had highest richness.

The composition of beetles in each environment differs due to the needs, trophic level and behaviour of each group [30]. The lesser number of coleopterans was observed in rural sites as compared to urban sites. The reason for this was the use of Organophosphorous pesticides used in all the agriculture fields. If biological control was used by farmers, then the abundance of insects would have increased. On the other hand, the urban sites of community garden, fragmented habitats and residential sites were having diversity of vegetation and diverse landscapes, which harbored a greater number of beetles. *Paederus fuscipes* which is detrivorous – carnivorous was found in all the habitats. In agricultural fields, they were found in edges of the fields and in the soil litter under the big trees. In urban sites, they were found in soil litter of community gardens, botanical garden and some highly vegetated areas of university campus and palace compound. Detrivores require environments with relatively dense vegetation and soils with thick layers of leaf litter [31] Herbivores like *Chrysolampra indica* (Pic. 5), *Lema fortune (*Pic. 6), *Aulacophora species and Cassida piperata* were found in all the sites on edges of agricultural fields where *Salvadora, Abutilon indicum* and *Michelia champaca* were found. In gardens they were inhabiting on *Ipomea sp* and *Cryophyllus sp*. In other sites also on these plantations they were found. Coprophagous dung roller species of *Heliocopris Bucephalus, Catharsius molossus*, (Pic. 4) *C. pithecus, Onthophagus gazella, O. bonasus, Gymnopleurus cyaneus, G. miliaris, and Canthon viridian* were found in areas nearby agricultural fields and in residential site roads where cattle usually wander freely. In community gardens and fragmented habitats, they were found on bird droppings and feces of other animals. Xylophagous Bupristidae and Cyrambicidae beetle species were found in all sites where trees of Sal, Mango, *Ficus, Dalbergia and Albizzia* were present. Fungivorous *Haliplus augustifrons* were found in Stream of Vishwamitri River flowing through university campus. Aquatic vegetation of *Typha augustata* and *Hydrilla vercitillata* harbouring algae on the ventral side of their leaves. *Haliplus* feeds on these algae. Granivorous beetles were found mostly in residential sites as stored grains and food products were mainly obtained in these sites. Species like *Calosubruchus maculatus, Rhizopertha dominica, Oryzyphilus surinamensis, Tribolium casteneum, T.confusius, Lasioderma testaceum* were found in stored cereals, pulses, spices and dry fruits stored in houses of residential sites. Due to their granivourous feeding habit they are considered as pest of stored grains. Aphidophagous species of lady bird beetles were found in all sites. As these species are predaceous on aphids. They are in abundance where floral plants and cultivated food grain vegetation is available in plenty. Due to its polyphagous feeding, most abundant species found was *Coccinella septumpunctata*. This family of Coccinellidae being predaceous, is considered biocontrol agent for pests like aphids and thrips. Saprophagous species of *Platynotus excavates, Pseudoblaps mellyi, Blaps orientalis, Gonocephalum dorsogranosum, Gonocephalum planatum, Rhytinota impolita* were found in all sites from the ground under litter. The only Chitinovorous species of *Attageus piceus* was found in the woollen fabrics stored in houses of residential sites. Some of the phytophagous species are considered pest. *Mylabris pustulata* feeds on fruits of leguminosea family, *Henosepilachna vigintioctopunctata* feeds on fruits and foliage of Solanacea and cucurbitace, *Holotrichia insularis* feeds on foliage of Paddy and Sugarcane, *Oryctes rhinoceros* feeds on roots of coconut palm and sugarcane.

Most collected species belong to families exclusively carnivorous as observed by Marinoni *et al* (2001) [26]. It is true in our study also. Most abundant family was Coccinellidae and the greatest number of species were found in Scarabidae. There was almost no difference in coleoptera diversity found in Padra fields and Community gardens. Beetles' diversity varied in Saavli fields and Residential sites. The variation of the species diversity is influenced also by factors such as phylogenetic diversity [32] and endemism [33].

The species abundance distributions of rural and city sites were similar and followed log-series distributions. However, the abundance distributions of the city communities were less steep than the respective rural ones (Fig. 3). Nevertheless, the evenness values of city and rural sites did not significantly differ.

The highest beetle's species richness and diversity in fragmented habitats of University Campus and Palace Compound could be as a result of higher plant diversity. Diverse landscape provides higher heterogeneity and thereby support different communities [34]. The agricultural fields of Padra are second highest in terms of species richness. This could be due to diverse food sources provided by different vegetables and crops. Similarity between species of Padra and fragmented habitats as well as community gardens reflects the difference in floristic composition of the ecosystem. Furthermore, the difference between species of Residential area and Agricultural fields is probably due to homogenous and less vegetation resulting to less varied food resources available. Thus, our results indicate that fragmented habitats of Lakshmivilas palace compound and M.S. University campus harbor higher diversity and different species composition of Coleoptera than agricultural fields of rural area. These areas are habitats of coleopterans with abundance of resources in form of diverse vegetation. So, such habitats should be conserved and no more infrastructure should be developed by destroying these habitats.

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