Faunistic analysis of insects of Deva Vatala National Park and agroecosystem of Gujrat Pakistan

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Abstract

Protected areas provide diverse resources with the least disturbance in a habitat that favours insect species belonging to different guilds to coexist and contribute to the ecosystem processes. Whereas agricultural landscapes are expected to affect the distribution patterns of insect fauna. To understand the species composition and abundance of the agricultural landscape, we explored insect fauna in Deva Vatala National Park (DVNP), Bhimber (Azad Kashmir), and associated croplands of Gujrat, Punjab, Pakistan. We explored the diversity of insect orders, families, and species. Fortnightly surveys were conducted during 2017-2019. We sampled insects by handpicking, using sweep nets, light traps, and pitfall traps. The specimens were identified by using taxonomic keys. We recorded a total of 239 insect species representing 10 orders and 69 families from both habitat types. Data showed significant differences in community composition at species, family, and order levels. Overall insect orders and families demonstrated significant differences ($p< 0.05$) in either abundance or richness or both between the two types of habitats. Coleoptera was the dominant insect order with 15 families and 71 species with a relative abundance of 14.20 %. Among families, Scarabaeidae (dung beetles), Carabidae (ground beetles), and Coccinellidae (ladybird beetles) showed greater species richness in DVNP. Similarly, we also noted 12 families and 54 species of Coleoptera with a relative abundance of 14.20 % in the croplands of Gujrat. The overall greater abundance of insect orders was observed in DVNP. The study concludes that both habitats share insect diversity though variations in species richness of different groups differ significantly. Protected areas adjacent to croplands have the potential to contribute immensely to biodiversity conservation and the provision of ecosystem services.

Keywords: Acrididae; agricultural landscapes; beetles; insect fauna; scarabaeidae.

1. Introduction

Insects constitute about three-fourths of the total organisms (Sankarganesh, 2017), and out of 5.57-9.8 million estimated animals, 4-8 million species are insects (Lokeshwari & Shantibala, 2010). Insects are one of the most diverse and successful groups of animals on this planet that make the major fauna of the terrestrial ecosystem (Samways & Samways, 2005; Collins & Thomas, 2012). Insect trophic interactions contribute to the stability of microhabitats as they regulate many ecological processes in terrestrial ecosystems (Abdala-Roberts *et al.*, 2019). They disperse seeds, pollinate plants, cycle nutrients, act as a food source for other animals, and maintain the fertility and structure of the soil (Foottit & Adler, 2018). The dynamics of insect population depend on the nutrient quality of plants and this association between plants and insects has attracted the interest of many ecologists (Arshad, 2020).

Insect fauna has an established role in all terrestrial landscapes including agroecosystems and protected areas. Many crops, ornamental plants, and tree plantations are dependent on insects for pollination in these landscapes (Cock *et al.*, 2012; Hodgson, 2012). Agricultural sustainability, environmental quality, and food security are threatened by declining trends in biodiversity loss (Udawatta *et al.*, 2019) mainly due to habitat modification, habitat fragmentation, and ultimately habitat loss (Rogan & Lacher Jr, 2018). Agricultural expansion, one of the most dominant and impactful anthropogenic disturbances, has caused global habitat loss and fragmentation (Haddad *et al.*, 2015; Pardini *et al.*, 2017). Agroecosystems are critical in determining the biodiversity in the adjacent natural landscapes (Muñoz-Sáez *et al.*, 2017). This threatens biological diversity and ultimately poses a menace to human populations (Wilkinson *et al.*, 2018). Protected areas in the form of National Parks have been found effective at limiting deforestation and protecting biodiversity within their boundaries (Naughton-Treves *et al.*, 2005; Dosso *et al.*, 2012; Suratman, 2018).

The present study was conducted to explore the insect fauna of Gujrat and Deva Vatala National Park (DVNP), Azad Jammu & Kashmir. This study aimed to provide the first assessment of the insect fauna in the protected area (DVNP) and the associated agricultural landscape of Gujrat. We documented the insect community composition within DVNP, providing a quantified basis for insect monitoring and conservation. This provided a template for similar studies in the region for assessing characteristic species including both beneficial and pest species in croplands and protected areas. This would contribute to understanding how best to manage these landscapes for the conservation of biodiversity and local communities. Thus, the study aims to provide an up-to-date checklist of insects and their general patterns of spatio-temporal distribution in Gujrat and DVNP. We envisage this would assist in planning for the conservation of insect fauna in these agricultural landscapes.

2. Materials and Methods

2.1 Study Area

The study was conducted in Deva Vatala National Park (DVNP), Bhimber (AJ&K), and Gujrat, Punjab, Pakistan (Fig. 1). DVNP is situated to the west of the line of control between Pakistan and India at 32°51-32°55N, 74°16-74°24E, representing sub-tropical semi-evergreen forests (Grimmett *et al.*, 2008) and cultivated areas dominated by wheat crops (Anwar *et al.*, 2015; Umar *et al.*, 2021) over an undulating terrain of the Deva and Vatala ranges (GOAJ&K, 1985). DVNP was declared as a National Park in 2007, which covers an area of 2,993 ha in the Western Himalayan foothills at an elevation of 267 to 536m above sea level.

Deva Vatala National Park is located in Azad Jammu and Kashmir, area is flat and hilly with different types of trees species i.e., *Dalbergia sissoo*, *Zanthoxylum armatum*, *Launea coromendaliana*, *Butea monosperma*, *Acacia nilotica*, *Calotropis procera*, *Cassia occidentalis*, and *Mangifera indica* (Subhani *et al.*, 2010). The common names of these trees are *Dalbergia sissoo*, *Zanthoxy lumarmatum*, *Launea coromendaliana*, *Butea monosperma*, *Acacia nilotica*, *Calotropis procera*, *Cassia occidentalis,* and *Mangifera indica* (Umar *et al.*, 2021).

Whereas Gujrat is an industrial city in Punjab, Pakistan, located between the Chenab and Jhelum Rivers (32°34'26" N, 74°4'44" E). By population, it is the 20th largest city, covering an area of 65 km^2, representing a large-scale variation in topography. This region falls in the temperate zone with temperatures ranging from 2°C-45°C.

This area is mainly comprised of three habitat types: agroforestry, urban cropland area, and rural croplands. Main crops include *Triticum aestivum*, *Oryza sativa*, *Pennisetum glaucum*, *Zea mays*, and *Saccharum officinarum* are major field crops grown in Gujrat. Important trees include *Acacia nilotica*, *Azadirachta indica*, *Bauhinia purpurea*, *Bombax ceiba*, *Dalbergia sissoo*, *Ficus benghalensis*, *Melia azedarach*, and *Pongamia glabra* (Parvaiz, 2014; Umar *et al.*, 2021).

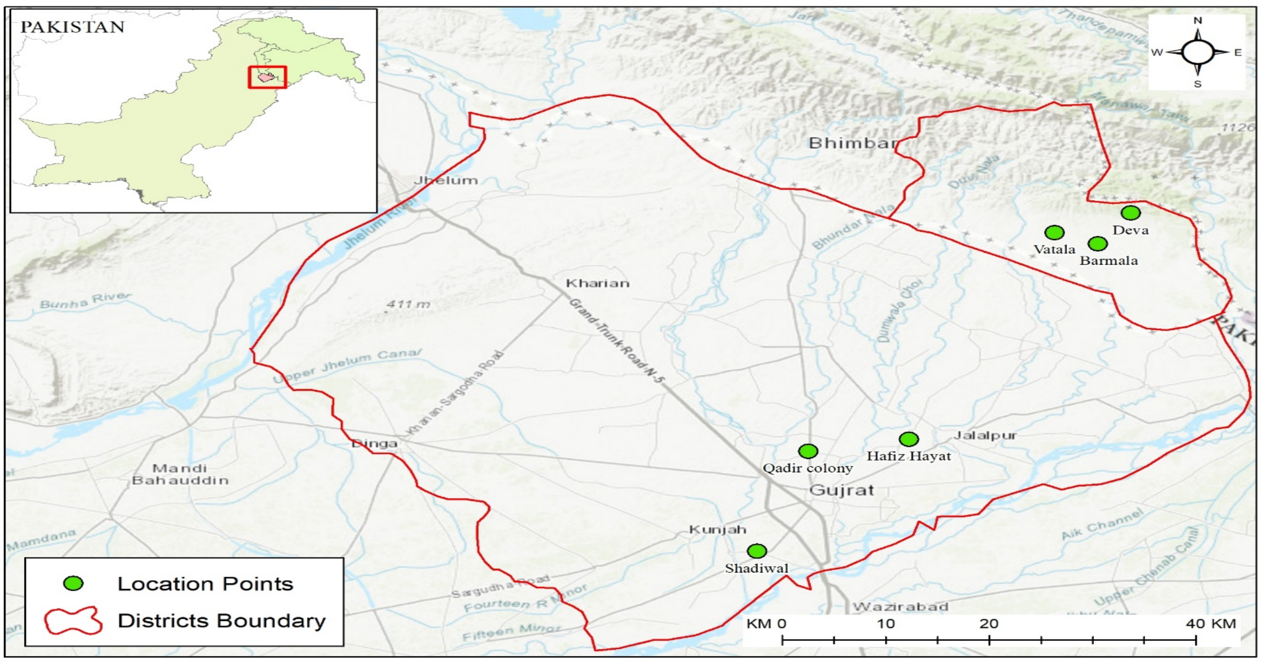

Fig. 1. Study area showing major sampling sites

2.2 Sampling sites

Barmala (32°52'58.7" N, 74°20'18.97" E) is situated at an elevation of 350-411m asl and the topography represents hilly forests. This area has seasonal streams and is dominated by tree species like *Butea monosperma*, *D. sissoo*, *D. viscosa*, *Lannea coromandelica*, *S. spontaneum*, *V. nilotica, Salvia* spp., *Senna occidentalis*, and *Zanthoxylum armatum* (Goursi *et al.*, 2012). While comparatively undisturbed, livestock grazing, cutting wood for fuel, and grass collection and burning are the factors that have an impact in this part of the study area.

2.3 Sampling procedure

At Gujrat, we categorized sampling sites into agroforestry, urban cropland area, and rural croplands in each of the selected study sites i.e., Hafiz Hayat, Qadir colony, and Shadiwal. Whereas at DVNP, we sampled all three locations (Deva, Vatala, and Barmala) at twenty-four points i.e., eight points at each habitat type (agroforestry, urban cropland area, and rural croplands). We collected data from each of these points (separated by ~1 km) of selected locations twice a month for two consecutive years (Table 1).

Table 1. Description of sampling sites

Study area	Study sites	Coordinates / height from sea level	Topography, vegetation, and land cover characteristics
Gujrat	Hafiz Hayat	32°38′29.55″ N, 74°9′55.58″ E/ 244 m asl	The study area consists of plains with a mix of canal irrigated, rainfed, and tube well-irrigated lands. the visual estimations of land cover which were mainly based on non-agricultural vegetation or the percentage of the crop subdivided into three habitat types each represented about 40 % land cover (Muñoz-Sáez *et al.*, 2017) with a specific type of vegetation cover i.e. agroforestry (trees interspersed with cropped with cereals and fodder crops), urban cropland area (houses, sheds, cropped fragments, roads, and greenhouses), and rural croplands (cereals, pulses, and vegetables, plowed soil or soil with stubble of previous crops and weeds (Umar *et al.*, 2021).
	Qadir colony	32° 37' 50" N, 74°4' 55" E/ 239 m asl	
	Shadiwal	32° 22' 20" N, 73° 10' 50" E/ 252 m asl	
DVNP	Barmala	32°52'58.7" N, 74°20'18.97" E/ 350-411m asl	This study site is dominated by tree species like *Butea monosperma*, *D. sissoo*, *D. viscosa*, *Lannea coromandelica*, *S. spontaneum*, *V. nilotica, Salvia* spp., *Senna occidentalis*, and *Zanthoxylum armatum* and has seasonal streams and, across vegetation layers, are dominated (Goursi *et al.*, 2012). While comparatively undisturbed, livestock grazing, cutting wood for fuel, and grass collection and burning all impact upon the area (Umar *et al.*, 2021).
	Vatala	32°52'38.7" N, 74°17'44.7" E/ 350-396m asl	Vatala shares a similar plant community composition to the other sites but is particularly dense with *D. sissoo*, *M. indica*, and *D. viscosa.* Human disturbance is the highest in this area, due to a higher population density, summer visitors, and the army, with most areas impacted by stone quarrying and livestock grazing. This has left only a few undistributed areas, mainly comprising open and cultivated areas (Umar *et al.*, 2021).
	Deva	32°54'8.6" N, 74°21'29.7" E/ 306-381m asl	The forests of Deva include species characteristic of Barmala along with *Aesculus indica*, *Ziziphus mauritiana, M. indica* and *Senegalia modesta* (Subhani *et al.*, 2010). Shrubs include *Calotropis procera*, *D. viscosa*, *S. spontaneum*, and *Trichodesma indicum* (Goursi *et al.*, 2012). This area of the DVNP has plains and seasonal streams. Human population density is lower than in Vatala but is impacted by the daily movement of livestock to the forest areas, and vehicles transporting quarried stones. Situated closest to the line of control, the army's presence may also disturb this area of the park (Umar *et al.*, 2021).

2.4 Insect collection methods

We selected a variety of insect collection methods described and used in different studies conducted for reporting insect fauna from different landscapes. We employed both active sampling and passive sampling for the insect collection. Active sampling included handpicking, sweep netting, foliage beating, searching the ground, and peeling tree bark for insect collection. Passive sampling approaches included pitfall traps, light traps, and yellow pans were also employed (Schauff, 2001; Upton & Mantle, 2010).

2.4.1 Pitfall traps

We placed a total of ten traps in a grid arrangement at each point separated by a 15m distance. At each location, one line transect was established with pitfall traps being allocated within the transect line by systematic random sampling technique (Leather, 2008; Ojija *et al.*, 2016). The traps were placed in the soil while their rims were at the level with the soil surface. Pitfall traps consisted of transparent plastic containers with a top diameter of 8 cm and a height of 10 cm with uncovered openings containing an aqueous solution of 10% formalin (Larsen & Forsyth, 2005; Ojija *et al.*, 2016). The traps were kept in the fields for 48 hours (Inayat *et al.*, 2010).

2.4.2 Sweeping nets

Muslin nets with a diameter of 32cm were used to sweep through the vegetation forming a figure of eight. A sweep net was used to sweep all types of insect fauna present above the canopy (Borror & White, 1970; Arya & Joshi, 2011; Kannagi *et al.*, 2013; Rajkumari *et al.*, 2014). Sweep sampling was done from herb and shrub layers of the vegetation to trap flying insects (Bhosale *et al.*, 2012; Akhtar *et al.*, 2014; Ojija *et al.*, 2016). The sampling was carried out for three hours along a line transects while walking from 10.00 am to 1.00 pm fortnightly (Inayat *et al.*, 2010; Thorp & Rogers, 2010; Belamkar & Jadesh, 2014; Capinera, 2020; Gibb & Oseto, 2020). We performed 50 sweeps at each sampling point within the location while moving in the sampling sites (Ghani & Maalik, 2020).

2.4.3 Beating sheets

We used Beating sheets for the collection of arboreal insects by selecting ten bushes, trees, and other plants randomly (Ojija *et al.*, 2016).

2.4.4 Hand collection

Manual collection of insects was accomplished by actively searching on the ground, in leaf litters and grasses, under logs, tree barks, and other substrates during the daytime for 3hrs twice a month (Oman & Cushman, 1946; Thakare & Zade, 2012; Marsh *et al.*, 2013; Ojija *et al.*, 2016).

2.4.5 Light traps

Nocturnal flying insects were collected by installing bucket-type light traps with 24-watt incandescent electric bulbs hanged were adjusted according to the height of trees at selected 1.5 m above the ground. The bottom of the bucket was filled with the ethyl acetate-based killing agent

(Mathew & Rahmathulla, 1995; McGavin, 1997; Tyagi *et al.*, 2011; Bhosale *et al.*, 2012; Gaikwad *et al.*, 2012; Singh, 2013; Ashfaq *et al.*, 2014; Nair *et al.*, 2014; Borah *et al.*, 2015; Abbas *et al.*, 2019).

2.4.6 Pan traps

The pans used to collect insects were each painted in one of the following colours, blue, white, and yellow with UV-reflecting color. The pans had a diameter of 8.5cm with a volume of 0.5 L and were filled with propylene glycol (40% concentration), to conserve the pollinators and to decrease the surface tension. One set of pan-trap consists of three pans, one in each colour placed at the same height (Berglund, 2016). Data collected from traps after 15 days constituting a single sample (Paiva *et al.*, 2020).

2.5 Identification and preservation

Principal morphological characteristics (including thoracic pattern, wing venation, abdominal appendages and features, legs, genitalia, antennae, color patterns, etc.) of each taxon (order level, family, genera, and species) were used to identify the specimens (Mouhoubi *et al.*, 2019). The insects were preserved in 70% alcohol and the specimens were separated into different orders and families and identified as morphospecies (Paiva *et al.*, 2020).

2.6 Data analysis

Diversity analysis was made using Shannon-Wiener and Simpson diversity indices and density, relative abundance, and species richness were calculated (Magurran, 1988, 2004). We tested for differences between insect communities by using a one-way Analysis of Similarities (ANOSIM). We calculated the abundance of each species abundance and the richness that were compared between two habitats using Wilcoxon's matched pairs (signed rank) test using Statistix software at a significance of 0.05. We used a paired analysis, where our samples were paired by month between two sites. We did not consider the samples for the analysis when the corresponding pair was not observed at any of the sites in order not to unbalance the analysis for insect species (Paiva *et al.*, 2020). We also performed the similarity of percentages analysis (SIMPER) to identify the species contributing most to differences in communities across space and time. Differences in the abundance of key species (those that contributed >5% to dissimilarities between insect communities) were tested non-parametrically since species abundances were not normally distributed.

Species richness measures biodiversity in its simplest form by providing number of species in a given area, however, it depends greatly on sampling size and effort. Margalef's diversity index (value varies with the variation in the number of species) and Menhinick's diversity (varies with the sampling effort) indices address species richness. Richness-Evenness indices include Shannon-Wiener diversity index (ranges from1.5 to 4.5), Brillouin index, fisher's alpha (always > 0.9 and never > 1.0), Pielou index (0 to 1; where zero represent no evenness and 1 represent complete evenness), and Simpson's index (ranges from 0 to 1; with 0 representing infinite diversity and 1 representing no diversity). Species abundance, dominance, richness, and evenness were measured by using different indices i.e. Simpson's index $\left(\mathbf{D} = \sum_{i=1}^{s} \frac{ni(ni-1)}{N(N-1)}\right)$, Shannon-Wiener ($\mathbf{H'} = -\sum_{i=1}^{s} \frac{ni}{N} \times \ln\frac{ni}{N}$), Berger–Parker$\left(\frac{1}{D} = \frac{1}{\frac{N\,max}{N}}\right)$, Margalef index for species richness$\left(\mathbf{DMg} = \frac{s-1}{\ln N}\right)$, Menhinick's diversity index, fisher's alpha (S = $N(1-X)/X$), and Pielou index ($\mathbf{J'} = \frac{H'}{\ln(S)}$) (Fisher *et al.*, 1943; Shannon & Weaver, 1949; Simpon, 1949; Berger & Parker, 1970; Whittaker, 1977; Gaines, 1999; Magurran, 2004).

3. Results

3.1 Overall taxonomic composition

We collected 11829 individuals from both DVNP and Gujrat belonging to 10 orders. We recorded, 6279 individuals representing 68 families and 213 morphospecies were recorded from DVNP whereas 5550 individuals belonging to 66 families and 222 morphospecies from Gujrat croplands (Table 1). We also observed relatively greater relative abundance of individuals at DVNP (53.08 %) as compared to Gujrat (46.92 %). Coleoptera (14.20 % DVNP; 9.77 % Gujrat) was the most abundant order followed by Orthoptera (7.57 % DVNP; 10.31 % Gujrat). Coleoptera, Orthoptera, Lepidoptera, Diptera and Hemiptera collectively contributed 80.55 % of the sampled individuals (Table 2).

Table 2. Relative abundance of insects in different orders collected from Gujrat and Deva Vatala National Park during 2017-2019. Data presented includes relative abundance (%) of insect orders (at a given location all month-wise samples were pooled, and relative abundance was calculated by using total number of individuals from both sites)

	DVNP			**Gujrat**		
Insect orders	Families (No.)	Species (No.)	Relative abundance (%)	Families (No.)	Species (No.)	Relative abundance (%)
Coleoptera	15	71	14.20	12	54	9.77
Lepidoptera	11	29	7.77	11	35	7.29
Hemiptera	10	15	5.70	11	18	4.40
Orthoptera	07	39	7.57	07	50	10.31
Diptera	07	19	7.14	07	23	6.40
Hymenoptera	07	17	3.53	07	19	3.59
Odonata	05	13	3.31	05	13	2.65
Neuroptera	03	03	1.25	03	03	0.73
Isoptera	02	05	1.78	02	05	1.28
Mantodea	01	02	0.83	01	02	0.49
Total	68	213	53.08	66	222	46.91

3.2 Wilcoxon's matched pairs (signed rank) test for insect orders

We also calculated diversity and richness of insect orders and species for both sites using Wilcoxon's matched pairs (signed rank) test which indicated significant differences for both diversity and abundance in the abundance and richness of species, families, and orders in either abundance or richness or both between the two types of habitats (Table 2). Several families of Coleoptera, which contained mainly scarabaeid, carabid, coccinellid beetles showed greater richness in DVNP. However, we also detected that several insect orders showed greater richness in the croplands of Gujrat. But we observed the pattern of the greater abundance (number of individuals in each order) of insect orders in DVNP. The abundance, richness and diversity within each order showed that Hymenoptera, Mantodea, Neuroptera, and Odonata had a similar abundance, and richness in both types of habitats (Table 2). Coleoptera had significantly greater abundance and Shannon's Diversity (H′) in croplands. However, richness was significantly greater in DVNP. Diptera were significantly more abundant in DVNP with no significant difference in richness and Shannon's H′ index was similar in both types of habitats. Orthoptera showed non-significant differences in the abundance, richness, and Shannon's Diversity (H′) almost similar at two types of habitats (Table 3).

Table 3. Abundance, richness, and Shannon's H′ diversity of the insects collected in the protected area (DVNP) and Gujrat.

Order	Abundance				Richness				Shannon's Diversity (H′)	
	No. of individuals		V-statistic	p value	No. of species		V-statistic	p value		
	DVNP	Gujrat			DVNP	Gujrat			DVNP	Gujrat
Coleoptera	1118	1139	928.50	0.110	71	54	2006.0	0.0003*	3.931	3.948
Diptera	844	628	162	<0.002*	19	23	176.00	0.4660	2.914	2.907
Hemiptera	674	453	117	0.0002*	15	18	141.50	0.0023*	2.694	2.702
Hymenoptera	418	387	84	0.2845	17	19	78.50	0.6384	2.791	2.778
Isoptera	211	152	15	0.0312*	05	05	15.00	0.2187	1.603	1.607
Lepidoptera	919	728	339.5	0.0003*	29	35	358.50	0.1661	3.339	3.358
Mantodea	98	58	-	-	02	02	03.00	0.7893	0.688	0.644
Neuroptera	148	86	6	0.125	03	03	07.00	0.3125	1.087	1.084
Odonata	392	313	65	0.1001	13	13	66.00	0.8160	2.519	2.549
Orthoptera	895	966	318.5	0.3218	39	50	263.0	0.0114*	3.590	3.625
Overall	5717	4910	17445	0.001*	213	222	17203	0.0014*	5.190	5.237

1. Comparison of abundance and richness is based on the non-parametric Wilcoxon matched-pairs test (exact *p* values).
2. *indicates significant differences in abundance and richness between two sites
3. ⁻Analysis was not performed due to the low number of individuals or species.

3.3 The difference in species at Gujrat and DVNP

We also detected seventeen species unique to DVNP and twenty-six species recorded only in croplands of Gujrat. At DVNP, 8 species of Acrididae and 4 species of Tephritidae were not detected. Similarly, twelve species of Scarabaeidae, 4 species of Chrysomelidae, and 3 species of Meloidae were not recorded at Gujrat (Table 4).

Table 4. Species unique at one location (not recorded both types of habitats)

Order	Family	Species	DVNP	Gujrat
Coleoptera	Buprestidae	*Sternocera sp.*	✓	X
	Carabidae	*Acinopus laevigatus*	✓	X
	Cerambycidae	*Acanthophorus serraticornis*	✓	X
	Chrysomelidae	*Chrysolina hyperici*	✓	X
		Pyrophorus sp.	✓	X
	Coccinellidae	*Adalia bipunctata*	✓	X
	Elateridae	*Aeolus mellillus*	✓	X
	Lucanidae	*Lucanus sp.*	✓	X
	Meloidae	*Zonitoschema gibdoana*	✓	X
	Oedemeridae	*Ananca sp.*	✓	X
	Scarabaeidae	*Onthophagus falsus*	✓	X
		Onthophagus dama	✓	X
		Metacatharcius inermis	✓	X
		Drepanocerus kirby	✓	X
		Coprisrepertus sp.	✓	X
		Tiniocellus modestus	✓	X
	Tenebrionidae	*Stenochinus sp.*	✓	X
Diptera	Tephritidae	*Bactrocera nigrofemoralis*	x	✓
		Bactrocera scutellaris	x	✓
		Bactrocera tau	x	✓
		Bactrocera zonata	x	✓
Hemiptera	Aphididae	*Macrosiphum euphorbiae*	x	✓
		Macrosiphum rosae	x	✓
	Lygaeidae	*Spilostethus sp.*	x	✓
Hymenoptera	Vespidae	*Delta dimidiatipenne*	x	✓

		Poekilocerus pictus	x	✓
Lepidoptera	Nymphalidae	*Danaus genuttia*	x	✓
		Ergolis merione	x	✓
		Junonia almanac	x	✓
		Vanessa cardui	x	✓
	Pieridae	*Catopsilia florella*	x	✓
		Catopsilia pyranthe	x	✓
Orthoptera	Acrididae	*Acrida ungarica*	x	✓
		Chortophaga viridifasciata	x	✓
		Dittopternis venusta	x	✓
		Hieroglyphus banian	x	✓
		Mermiria bivittata	x	✓
		Oxya japonica	x	✓
		Shistocera alutacea	x	✓
		Trilophidia annulata	x	✓
	Pyrgomorphidae	*Atractomorpha crenulata*	x	✓
	Tettigoniidae	*Ducetia japonica*	x	✓
		Neoconocephalus triops	x	✓

3.4 Species contributing to dissimilarities among site communities

Similarity Percentage Analysis (SIMPER) indicating the average percent dissimilarity in the insect community composition between DVNP and Gujrat. Presented here are the top ten species contributing to the community dissimilarity at each site and the percent contribution of each species to community dissimilarity in pair-wise comparisons. The biological dissimilarity was assessed based on insect taxonomy showed that *Aedes albopictus, Eristalis arbustorum, Eristalis tenax, Halyomorpha halys, Mantis religiosa* and *Chrysoperla carnea* were the main contributing species in the community dissimilarity (Table 5). The compositional dissimilarity between DVNP and Gujrat, based on counts at each site, indicated *Aedes albopictus* (0.34)*,* followed by *Eristalis arbustorum* (0.33), *Eristalis tenax* (0.33), and *Halyomorpha halys* (0.33). The results showed that the compositional dissimilarity is lesser between the two sites as the Bray–Curtis dissimilarity ranges between 0 and 1, where 0 means the two sites have the same composition and 1 means the two sites do not share any species). The composition of insect communities was significantly different between locations (ANOSIM; R = 0.890, P = 0.001). Insect families showed average dissimilarity of 50.73 % between DVNP and Gujrat (ANOSIM; *R* = 0.078, P= 0.127). The top five species, represented by 10 species across all locations (districts), contributed 90.03% to 98.32% of community composition dissimilarities, while three species contributed to dissimilarities between all three sites' insect communities. Whereas five species contributed to dissimilarities in insect communities between at least two locations (Table 5).

Similarly, Scarabaeidae and Acrididae were two top equally contributing families in the dissimilarity between sites. We also detected that top contributing families in dissimilarities (about 28 %) in the composition belonged to Coleoptera, Orthoptera, Diptera and Hemiptera (Table 6).

Table 5. Main Species contributing to dissimilarities among site communities. Only the top ten contributing species are listed. The analysis is based on pre-treated square-root transformed abundance (Clarke & Warwick, 2001) of the samples pooled for each species at a given site.

Species	Mean abundance	Mean abundance	Mean dissimilarity	Contribution (%)	Cumulative (%)
	DVNP	**Gujrat**			
Aedes albopictus	1.64	1.85	0.3431	0.6142	0.614
Eristalis arbustorum	1.80	1.52	0.3333	0.5967	1.211
Eristalis tenax	1.86	1.22	0.3311	0.5928	1.804
Halyomorpha halys	1.80	1.30	0.3277	0.5867	2.390
Mantis religiosa	1.69	1.41	0.3159	0.5656	2.956
Chrysoperla carnea	1.67	1.3	0.3151	0.5642	3.520
Episyrphus viridaureus	1.77	1.32	0.3131	0.5605	4.081
Phenococcus solenopsis	1.64	1.26	0.3101	0.5552	4.636
Bactrocera correcta	1.74	1.23	0.3101	0.5551	5.191
Musca domestica	1.67	1.47	0.3049	0.5459	5.737

Table 6. Main families contributing to dissimilarities among site communities. Only the top ten contributing families are listed. The analysis is based on pre-treated square-root transformed abundance (Clarke and Warwick, 2001) of the samples pooled for each family at a given site.

*Family	Order	Mean abundance	Mean abundance	Mean dissimilarity	Contribution (%)	Cumulative (%)
		DVNP	**Gujrat**			
Scarabaeidae	Coleoptera	6.76	5.7	2.377	4.686	4.686
Acrididae	Orthoptera	4.78	6.49	2.316	4.566	9.252
Erebidae	Lepidoptera	3.80	3.42	1.372	2.704	11.96
Syrphidae	Diptera	3.73	3.08	1.316	2.594	14.55
Tephritidae	Diptera	2.98	3.5	1.241	2.447	17.00
Pieridae	Lepidoptera	3.00	3.09	1.141	2.249	19.25
Nymphalidae	Lepidoptera	2.51	3.14	1.121	2.21	21.46
Pentatomidae	Hemiptera	3.14	2.56	1.114	2.195	23.65
Gryllidae	Orthoptera	3.03	2.99	1.101	2.17	25.82
Chrysomelidae	Coleoptera	3.09	2.70	1.093	2.155	27.98

3.5 Diversity indices calculated for families and species

For families, the values Simpson diversity index for DVNP (1-D: 0.963) and croplands (1-D: 0.954) showed similarity in the species dominance. Similarly, Shannon- Wiener index for species diversity and evenness for DVNP (H= 3.74; e^= 0.640) and Croplands (H= 3.610; e^= 0.588) indicated that DVNP showed greater diversity than Gujrat croplands (Table 6). For the species, the values Simpson diversity index for DVNP (1-D: 0.994) and Gujrat (1-D: 0.995) showed similarity in the species dominance. Similarly, Shannon- Wiener index for species diversity and evenness for Gujrat (H= 5.36; e^= 0.9632) and DVNP (H= 5.277; e^= 0.919) indicated that Gujrat showed greater species diversity than DVNP. Similar trends of index values were observed in Brillouin, Menhinick, Berger-Parker and Fisher-alpha where the maximum value was calculated for Gujrat. However, Margalef index showed maximum value for DVNP (Table 7).

Table 7. Diversity indices calculated for different families and species for both habitat types

	Families		Species	
	DVNP	Gujrat	DVNP	Gujrat
Taxa_S	66	63	213	222
Individuals	6279	5550	6279	5550
Dominance_D	0.0375	0.0459	0.0059	0.0049
Simpson_1-D	0.9625	0.9541	0.9945	0.9952
Shannon_H	3.7450	3.6130	5.277	5.365
Evenness_e^H/S	0.6409	0.5883	0.9192	0.9632
Brillouin	3.7140	3.5800	5.191	5.266
Menhinick	0.8329	0.8457	2.688	2.980
Margalef	7.4330	7.1910	24.24	25.63
Equitability_J	0.8938	0.8720	0.9843	0.9931
Fisher_alpha	10.2900	9.9610	42.60	46.30
Berger-Parker	0.1317	0.1395	0.01051	0.01171
Chao-1	66	63	213	222

We plotted the Whittaker rank abundance plot for families and species of DVNP and Gujrat. The results indicated that families were more evenly distributed at DVNP than Gujrat (Fig. 2).

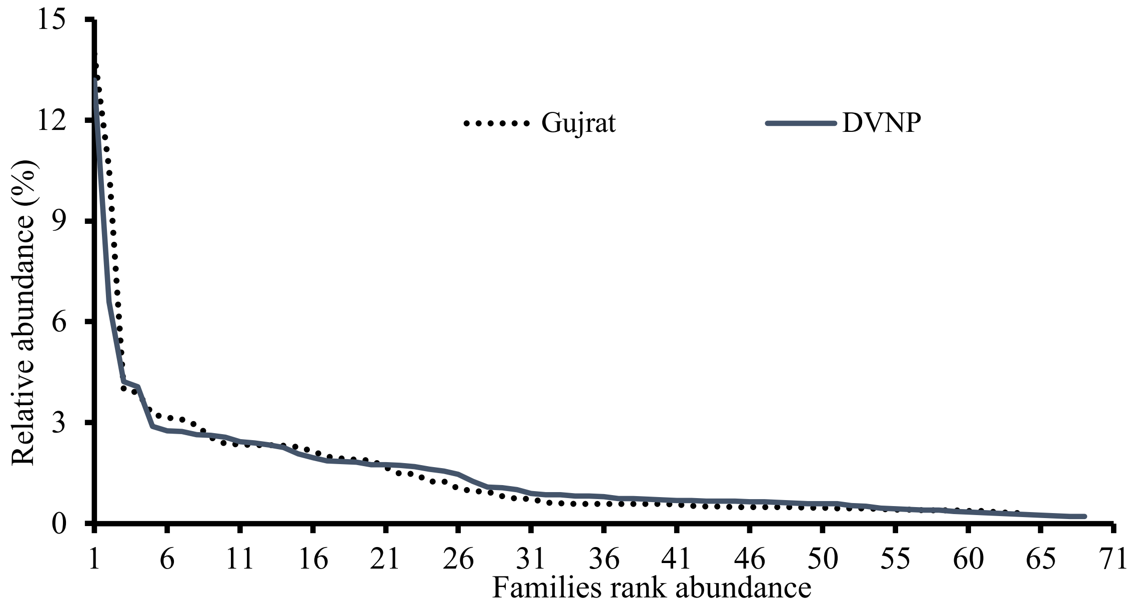

Fig. 2. Whittaker plot (rank abundance) of families was plotted for both sites using relative abundance (%) of specimens in each family

Similarly, we plotted rank abundance curve for the species which showed variation in the assemblages in two habitats. About 66 species showed greater relative abundance at DVNP and then a declining trend in the relative abundance was observed (Fig. 3).

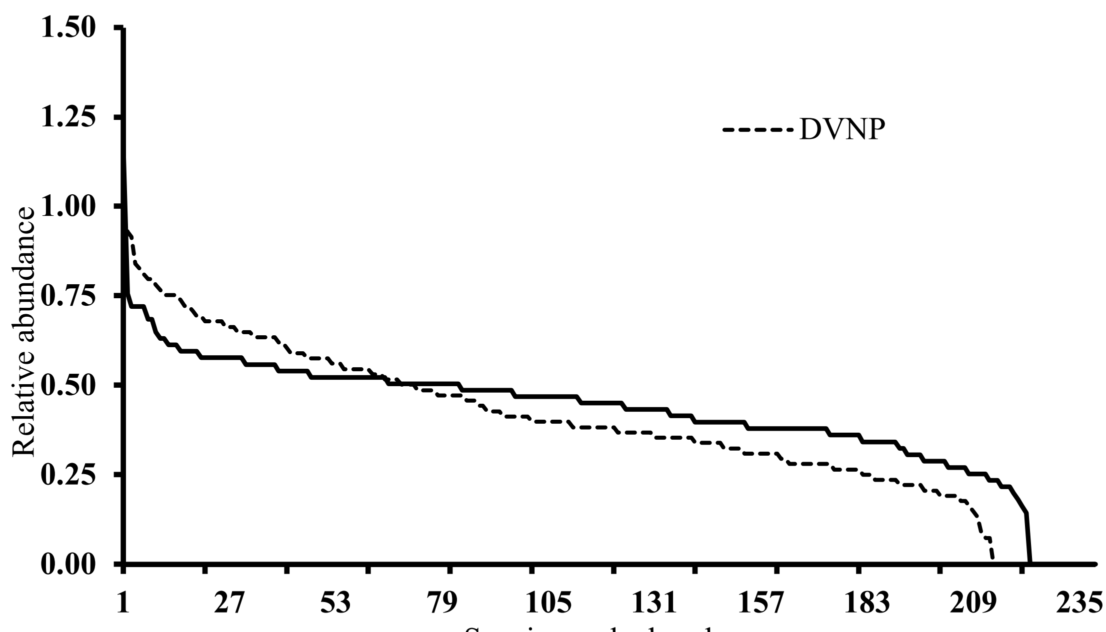

Fig. 3. Whittaker plot (rank abundance) of species was plotted for both sites using relative abundance (%) of specimens for each location

Individual rarefaction curves for species were also plotted which showed similar accumulation in both habitat types until 700 individuals, and the continued accumulating morphospecies with stabilizing trend (Fig. 4).

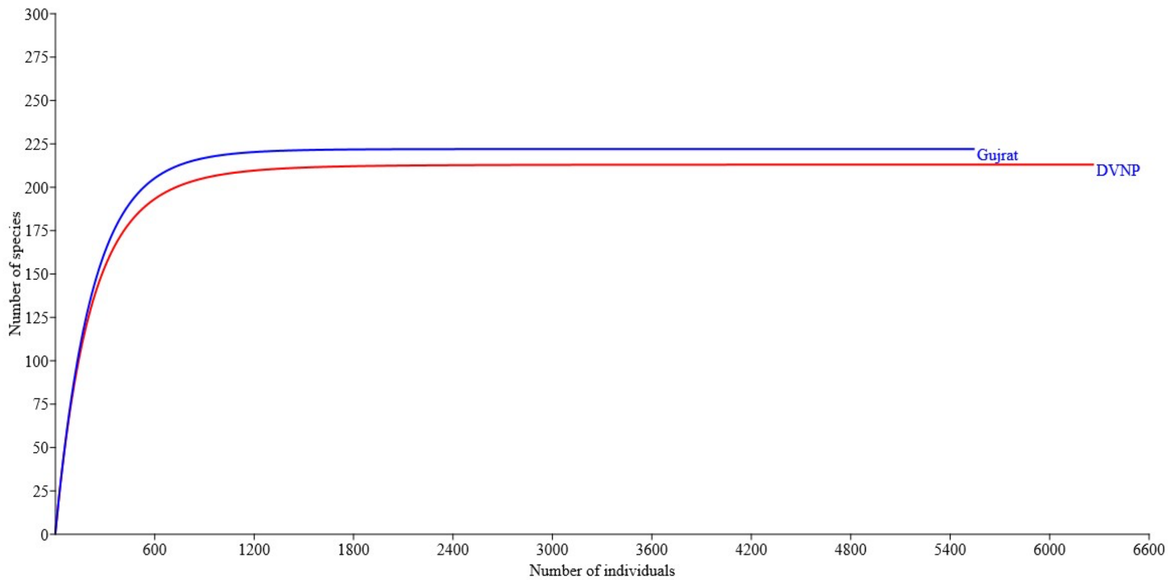

Fig. 4. Rarefaction curves from the DVNP and croplands of species collected

4. Discussion

We explored the patterns of insect communities in protected area and agroecosystem at order, family, and species level. We recorded changes in the abundance and species richness of insect orders, as well as changes in the community composition of insect families under two different habitat types i.e., protected area and agroecosystem. Our results present an overall comparison of insect diversity in protected area adjacent to croplands which highlighted the significance of both type of habitats.

We detected that both habitats support greater diversity at species and family levels. For instance, we recorded insect species belonging to 68 families in DVNP and 66 families in Gujrat. Similarly, greater number of species 222 were noted in Gujrat whereas 213 in DVNP. However, we also observed certain insect groups were more dominant in one type of habitat as compared to other. For example, the species richness and abundance of Coleoptera was greater at DVNP. However, the number of species belonging to other insect orders was nearly similar at both habitat types i.e., Hymenoptera, Odonata, Neuroptera, Isoptera and Mantodea. Earlier studies reported that species diversity under different landscapes vary significantly. Greater number of species were reported from croplands of Faisalabad (Inayat *et al.*, 2010). In the brinjal-based agroecosystem, 27 species of insects were reported (Chang *et al.*, 2019). These patterns of species composition could be attributed to the variations in the abiotic conditions in different environments of the habitats. For instance, this happens when the shift of more generalist species in the simpler environment towards more

specialists in the more complex environment without a disturbance in their richness or abundance occurs (Kruess & Tscharntke, 2002; Nemec & Bragg, 2008; Paiva *et al.*, 2020).
We found Coleoptera, Orthoptera and Lepidoptera among top three insect orders contributing 62.61 % of the species at Gujrat whereas 65.25 % at DVNP. An earlier study reported that the most abundant species belonged to Lepidoptera, Coleoptera, and Orthoptera (Wahyuni *et al.*, 2011). Though in our study, Orthoptera showed relatively greater species richness and abundance in Gujrat as compared to DVNP. Acrididae was the most diverse family represented by six subfamilies followed by Pyrgomorphidae and Tetrigidae (Kwon & Byun, 1996; Waghmare *et al.*, 2013; Hussain *et al.*, 2017; Zergoun *et al.*, 2019). We identified that in both study areas; however, some insect groups have almost similar community patterns, suggesting that habitat type is not the most important factor determining the species composition. Such community patterns where several factors contribute in the composition of communities were reported earlier (Di Giulio *et al.*, 2001). The dominance exhibited by Coleoptera, Lepidoptera and Orthoptera in both habitats indicated the greater abundance of some insect species. This may be attributed to the availability of preferred habitats to the species i.e., moist soil, litter and rotting wood (Wilson, 1990; Ross *et al.*, 2002; Sawada & Hirowatari, 2002; Sörensson, 2003; Bhusnar, 2015; Rana *et al.*, 2019).
Coleoptera exhibited species dominance in both study areas indicating that the distribution patterns in different landscapes may be due to composition of communities, and their ecological role in the ecosystems (Rykken *et al.*, 1997; Méndez-Rojas *et al.*, 2021). Coleoptera accounts for 40% of entire insects represented by 400,000 species that are known to exist in the world (Crowson, 2013; Bouchard *et al.*, 2017; Hong *et al.*, 2017). Scarabaeid species showed different patterns of assemblages in DVNP and Gujrat which may be attributed to variations in vegetation, animal type, and habitat stability. Scarabaeid beetles have been reported as an important visitor of shrubs and tree species with some role as pollinators (Rodger *et al.*, 2004; Nasir *et al.*, 2016; Ghazanfar *et al.*, 2017; Hussain *et al.*, 2020). However, the larger landscape fragments comprise of higher species abundance of Scarabaeid beetles and distinct species (Magagula, 2006; Whipple, 2011; Labidi *et al.*, 2012; Campos & Hernández, 2013; Salomão & Iannuzzi, 2015). In our study, DVNP and Gujrat offer a gradient of variations from mountainous landscapes (dominated by woody trees and shrubs) to agricultural plains (dominated by cropping monocultures). This would have facilitated the distribution of species along the altitudinal gradient with a uniform trend allowing some species to have increased abundance or vice versa. It has been synthesized that conservation of agricultural landscapes through compensation schemes to lower agriculture intensification may help to protect taxonomic groups especially Orthoptera (Kwon & Byun, 1996; Marini *et al.*, 2008). Moderate temperature ranges in both agricultural landscapes of Pakistan contribute to the distribution, diversity, and abundance of syrphid flies (Saleem *et al.*, 2001; Sajjad *et al.*, 2010; Khan & Hanif, 2016). Ecological studies, habitat management, and conservation require the estimation of community composition patterns at local, regional and global levels (Nahmani *et al.*, 2005; Ramzan *et al.*, 2021). Species diversity has been under perils due to anthropogenic changes in the landscapes which results in habitat modifications (Turner, 1989; Gibbs & Stanton, 2001; Wagner & Edwards, 2001). To understand species distributional patterns in different landscapes, insect fauna has been studied at local and regional levels (Cho *et al.*, 2008; Ahn & Park, 2012; Lim *et al.*, 2013; Rafi *et al.*, 2017). Exploring higher taxonomic categories (orders and families) allows understanding of

large changes in the biodiversity associated with different landscapes (Paiva *et al.*, 2020). Species richness and abundance vary with the suitability of habitat and mobility of the species which suggests that the density of orthopterans may be a more sensitive measure for habitat quality.

5. Conclusion

Insect diversity in the protected area and agroecosystems has demonstrated the importance of both type of habitats. Agricultural landscapes of Gujrat despite the use of farm inputs like fertilizers, herbicides, and insecticides in different crops at different stages may change the population dynamics of insect species but species thrive to exist. Whereas in protected area (DVNP), on the other hand offered uniform microenvironment to the insect fauna which helped them to maintain their population dynamics and diversity consistent throughout the study duration. We conclude variations in the species diversity at both habitat types though certain insect orders were dominant in both study areas i.e., Coleoptera, Lepidoptera, Hemiptera and Hymenoptera. We documented thirty-seven species unique in DVNP which indicates protected area has favourable conditions for these species.

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Conflict of interest

The authors declare no conflict of interest for this study.

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