

Assessment of orthopteran diversity across different habitats of semiarid eastern plain, Rajasthan, India

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Abstract

Understanding how habitat variation shapes insect diversity is essential for ecological monitoring and sustainable land management. This study assessed the species diversity, abundance, and distribution patterns of orthopteran insects across four distinct habitat types: agricultural fields, urban gardens, soil regions, and open hilly areas in the semi-arid eastern plains of Rajasthan, India. A total of 10,915 individuals belonging to 30 species, 25 genera, and 15 subfamilies were recorded using standardized collection methods. Agricultural habitat exhibited the highest abundance ($n = 5,004$) and species richness, while soil habitat recorded the lowest ($n = 1,790$). The family Acrididae was the most dominant (49.20%), followed by Gryllidae (29.50%) and Pyrgomorphidae (18.11%). Diversity indices varied significantly across habitats: the Shannon index ranged from 1.912 to 2.732, Simpson's index from 0.8068 to 0.9196, and Margalef richness from 1.626 to 3.515. Bray-Curtis clustering and NMDS ordination revealed distinct community structures among habitats, with pest guilds dominating overall species composition (67.31%). Statistical analysis (ANOVA, Tukey HSD) confirmed significant habitat-driven differences in species abundance and guild composition ($p < 0.05$). The findings underscore the role of microhabitat heterogeneity in structuring orthopteran communities and reinforce their value as ecological indicators for semiarid landscapes.

Keywords: Agricultural fields, Community structures, Ecological indicators, Habitat variation, Insect diversity, Orthopteran, Pest guilds, Species richness

Introduction

Orthoptera, an insect order encompassing grasshoppers, locusts, katydids, and crickets, exhibits global distribution (Newport & Newport, 2020; Sperber *et al.*, 2020) [33, 46]. They are the dominant group of herbivorous insects throughout the world and serve as bioindicators due to their high sensitivity to habitat disturbance and environmental change (Köhler *et al.*, 1990; Poniatowski & Fartmann, 2014) [37]. Their abundance and distribution are influenced by multiple biotic and abiotic factors such as vegetation structure, moisture, temperature, and land-use intensity (Humbert *et al.*, 2021; Wang *et al.*, 2024) [17, 54].

Orthoptera exhibit hemimetabolous development and possess adaptive traits like diapause timing and wing polymorphism, enabling them to survive fluctuating climates typical of semiarid environments (Zhao *et al.*, 2023) [56]. These insects show remarkable adaptability across a range of habitats, from arid plains to grassy meadows, meadows responding sensitively to biotic and abiotic variables including vegetation composition, soil moisture, temperature, and land-use patterns (Guido & Gianelle, 2001; Humbert *et al.*, 2021) [15, 17]. Their abundance and distribution patterns are shaped by interactions between habitat structure, food availability, predation pressure, and disturbance gradients, with some species thriving in homogeneous open grasslands and others in complex, mosaic habitats (Poniatowski & Fartmann, 2014; Wang *et al.*, 2024) [37, 54].

Species are generally distinguished by their fidelity to a specific habitat type and high sensitivity to ecosystem

variation (Procheset *al.*, 2009; Bazelet and Samways, 2011; Laws and Joern, 2017) [5, 25]. Microhabitat heterogeneity, particularly in vegetation type, soil composition, and moisture availability, strongly affects orthoptera community structure, breeding success, and dispersal patterns (Lehmann *et al.*, 2014; Ramola *et al.*, 2024) [27, 40]. These characteristics make them ideal taxa for assessing the ecological impact of habitat fragmentation and anthropogenic pressure. Microhabitat is known to affect the distribution patterns of organisms; there have been very few studies on the effect of environmental heterogeneity caused by human-induced disturbance on the small-scale distribution of consumers (Laws and Joern, 2017; Ramola *et al.*, 2024) [25, 40]. The vegetation creates microclimates that provide physical and nutritional conditions conducive to the survival and reproduction of the orthopteran insects. The survival of orthopterans is closely linked to the climatic conditions of habitats or ecological niches. Temperature and humidity are the most important climatic factors (Guendouz-Benrima *et al.*, 2011; Moussi *et al.*, 2011) [14, 32], because they directly or indirectly create an environment favourable to the development of orthopteran populations.

Agroecosystems are among the most regulated landscapes, offering shelter and food sources and providing many ecosystem services, including pollinators, decomposers, and natural predators, making them key habitats for studying orthopteran diversity (Storkey & Westbury, 2007; Makowski *et al.*, 2007; Tanaya *et al.*, 2024) [29, 47, 51]. On the other hand, Open hilly regions support a diverse array of indigenous and frequently specialized flora and fauna and

have a significant impact on diversity, either directly because they represent a certain type of habitat or indirectly through their influence on microclimatic conditions and drainage (Sukumar, 1989; Basnet *et al.*, 2016) [4, 49]. In contrast, the soil habitats foster biodiversity by providing shelter, nutrients, and breeding grounds for various organisms and enhance it by offering shelter, breeding grounds, and nutrient sources for insects and other organisms. With grasses, shrubs, and herbaceous plants, soil inhabitant decomposers, which enhance ecosystem functions such as nutrient cycling, decomposition, and soil aeration and maintain biodiversity and ecosystem stability (Bennett, 2010; MacIvor and Lundholm, 2011; Covy *et al.*, 2019; Rohyani, 2021) [6, 11, 28, 42]. The gardens habitats significantly contribute to insect diversity by offering heterogeneous microhabitats with abundant vegetation and organic matter. With ornamental plants, herbs, and grasses, urban gardens enhance pollination, nutrient cycling, and predator-prey interactions, thus playing a vital role in urban biodiversity conservation (Jaganmohan *et al.*, 2013; Park and Jeong, 2020) [20, 35].

Spatial and temporal environmental heterogeneity are thought to significantly influence both the dynamics and structure of ecological communities (Huston, 1979) [19]. Rajasthan, a state in northwestern India, presents a mosaic of ecological zones ranging from dry plains to open hilly terrain. This state is characterized by limited and irregular rainfall, high temperatures and evaporation, and hot, dry winds that fluctuate due to the Aravalli hills. As a result, the vegetation is sparse and represented by perennial, seasonal, and adaptive plants (Prajapat *et al.*, 2022) [38]. The semiarid eastern plain (Agroclimatic Zone IIIA), encompassing Jaipur, Ajmer, Dausa, and Tonk districts, is particularly diverse due to its complex topography and fluctuating microclimates (Hussain, 2017; Ahmad *et al.*, 2017) [1, 18]. Although vegetation in this semiarid region creates vital microclimates for insect survival, a significant knowledge gap exists regarding orthopteran biodiversity in Rajasthan. To address this lack of region-specific data, this study investigates the diversity, small-scale distribution, and habitat preferences of orthopteran species across four contrasting ecosystems; agro-farms, soil, urban gardens, and rocky hilly outcrops in the semiarid eastern plain. Specifically, the objectives were to:

1. Updating the list of orthopteran species present in the semiarid region.
2. Identifying the assemblages of orthopteran species across different habitats.
3. Examine how habitat heterogeneity influences orthopteran abundance.

Materials and methods

Study Area: The study was conducted across the semi-arid eastern plains of Rajasthan, India, which fall under Agroclimatic Zone IIIA. This region comprises four districts-Jaipur, Ajmer, Dausa, and Tonk characterized by sparse vegetation, hot dry winds, and erratic rainfall. Despite these harsh environmental conditions, the area supports a variety of habitats, including cultivated agricultural fields, urban gardens, soil-dominated patches, and rocky outcrops. These habitats were selected based on their ecological heterogeneity and potential to support diverse orthoptera communities.

Sampling Design and Site Selection: The field surveys were conducted from March 2021 to February 2023 [42, 56], covering all three major climatic seasons. Each of the four districts was designated as a primary study site (Site I–IV) (tab. 1), and each site was further divided into four representative habitat-based sampling stations (**fig. 1**). The habitats included:

- **Agricultural fields:** characterized by monoculture and cultivated crops.
- **Urban gardens:** dominated by dense ornamental and flowering vegetation.
- **Soil regions:** semi-exposed bare land with herbaceous cover.
- **Open hilly terrain:** rocky outcrops and sparsely vegetated elevated zones.

Each station spanned 50–100 m² with 5–10 replicates per habitat to ensure representative sampling. Orthopteran insects were collected using a combination of standardized entomological methods, tailored to suit different microhabitats and insect behaviours. The visual surveys were used to detect and collect mobile grasshoppers and crickets in all habitats; the line transect method (50 m) was applied particularly in agriculture and soil zones for herbivorous species, and quadrat sampling (10 m²) was employed for less mobile or burrowing species in soil and garden habitats (Moses *et al.*, 2019; Leksono *et al.*, 2022). Different collection methods including, handpicking, sweep and aerial netting, beating and light traps, pitfall traps were applicable for different orthopteran insects' behavioural activities and niches. Each habitat was surveyed twice a month during daylight hours, while nocturnal surveys were conducted using light traps at night for Ensiferan groups.

Specimen preservation and identification: All specimens were killed using ethyl acetate, pinned, and preserved in entomological boxes. Taxonomic identification was carried out using dichotomous keys (Zahid *et al.*, 2020) [55] and the literature of previous studies (Shishodia and Gupta, 2009; Chandra and Gupta, 2013 [8, 9]; Swaminathan and Swaminathan, 2019) [50] and online databases such as GBIF and Orthoptera Species File. Key morphological characters were examined under a CILIKA stereo zoom microscope and verified with expert consultation where necessary (Triplehorn & Johnson, 2005; Cigliano *et al.*, 2024) [10, 53].

Statistical analysis: The determination of numerous features of alpha diversity, such as Shannon-Weiner (H'), Simpson's Diversity Index (D), Margalef Richness (R), and Evenness (J) were computed using PAST v 4.01 software (Hammer *et al.*, 2001). The collected orthopteran insects were categorized into ecological guilds (pests, decomposers, leaf-eaters) for community analysis and also species-abundance distributions (SADs) were categorised. To assess differences in species composition across habitats One-way ANOVA was applied with a post-hoc Tukey HSD test for comparing mean abundance across groups. The K-dominance curve and Non-Metric Multidimensional Scaling (NMDS) based on Gower dissimilarities were used to visualize inter-habitat variation in community structure. The Chorda Diagram (Origin software) represents orthopteran species abundance, and Bray-Curtis's index examines the degree of similarity and dissimilarity of orthopteran

compositions across the habitats. All tests were analysed at the level of significance $\alpha = 0.05$ and 0.01 .

Results: A total of 10,915 orthopteran individuals were collected across four ecosystems representing 30 species, 25 genera, and 15 subfamilies from the suborders Caelifera (24 species, $n = 7,409$) and Ensifera (6 species, $n = 3,507$) (tab. 2). The agricultural habitat exhibited the highest abundance ($n = 5,004$) and species richness (29 species). Moderate abundance was observed in the urban garden ($n = 2,209$) and open hilly region ($n = 1,912$), while the soil region recorded low abundance ($n = 1,790$). One-way ANOVA confirmed a significant difference in orthopteran abundance across habitats (DF = 3; $F = 3.465$; $p = 0.0147$). Tukey HSD post hoc test revealed that the agricultural ecosystem was significantly different from both the open hilly and soil regions ($p < 0.05$), but not from the urban garden ($p > 0.05$) (fig. 2). The family Acrididae was the most species-rich and dominant, contributing 18 species and 5,370 individuals (49.20%). Acrididae showed high representation in agricultural habitat (27.10%) but was less prevalent in the soil (6.41%) and open hilly regions (6.39%). Gryllidae (2 species, $n = 3,219$; 29.50%) was prevalent in urban gardens and agriculture, while Pyrgomorphidae (5 species, $n = 1,977$; 18.11%) showed a balanced distribution. Tettigonidae (3 species, 93 individuals; 0.86%) and Tetrigidae (1 species, 61 individuals; 0.56%) were confined to more specialized or microhabitats. ANOVA showed significant differences among families (DF = 5; $F = 5.454$; $p = 0.00315$), with Acrididae differing significantly from Tettigonidae ($p < 0.01$), Tetrigidae ($p < 0.01$), and Gryllotalpidae ($p < 0.05$) (fig. 3a).

The community classification of orthopteran species into pests, decomposers, and leaf eaters was based on their feeding behavior, ecological roles, and habitat associations. Pests primarily feed on crops, while decomposers break down organic matter. Leaf eaters feed on foliage without direct economic damage. This ecological guild-based approach allows for a functional analysis of species diversity and abundance patterns across habitats. The guild analysis observed that orthopteran pests were the most abundant ($n = 7347$, 67.31%) and had the highest number of species (23), while decomposers ($n = 3414$, 31.28%) and leaf-eater species ($n = 154$, 1.41%) were less diverse, with 3 species each. The ANOVA results indicate a significant difference among the groups (DF = 2; $F = 8.0714$, $p = 0.0018$). The post-hoc Tukey test observed a significant difference between leaf-eater species and pest and decomposer species (** $p < 0.01$) (fig. 3b). The most abundant individuals in all the systems were *Acheta domesticus* ($n = 1683$, 15.42%), followed by *Gryllus bimaculatus* ($n = 1536$, 14.07%), *Spathosternum prasiniferum* ($n = 1325$, 12.14%), and *Hieroglyphus* spp. ($n = 1104$, 10.11%). The species composition further demonstrated that few species had the least abundance, including *Tetrix* sp. and *Phaneroptera* sp. ($n = 61$, 0.56% each, respectively), followed by *Euconocephalus incertus* ($n = 21$, 0.19%) and *Isopsera pedunculata* ($n = 11$, 0.10%) (tab. 3).

The Species Abundance Distribution of orthopterans was evaluated using the Important Value Index (IVI). Notably, *Hieroglyphus* spp. achieved the highest IVI (57.85) as a serious crop pest, yet was classified as Least Common (LC) because its numerical dominance is strictly localized to

agricultural habitats. Conversely, species like *Acheta domesticus*, *Gryllus bimaculatus*, and *S. prasiniferum* exhibited high IVIs across multiple habitats, classifying them as Very Common (VC) or Common (C). *A. domesticus*, *G. africana*, and *P. bispinosa* were the most prevalent, occurring across all surveyed sites. Meanwhile, species with the lowest IVIs (e.g., *Isopsera pedunculata*) were deemed LC or Uncommon due to limited detectability. Ultimately, the high IVI pests in agriculture dictates targeted management, proving that assessing ecological status requires evaluating both abundance and geographical habitat specialization (tab. 2, 3; fig. 4).

The nonmetric multidimensional scaling (NMDS) analysis revealed distinct species compositions across habitats, with a low stress ($s = 0.0811$), indicating a reliable fit. As a result of that, agriculture and open hilly regions showed distinct species clustering, while urban gardens and soil habitats exhibited some overlapping clusters, revealing the presence of the same orthopteran species in both habitats (fig. 5). The K-dominance curve plotted for orthopteran species across four habitats provided insights into the patterns of species dominance and evenness. The agricultural habitat exhibited a gentler slope, indicating that species were more uniformly abundant, with a more stable and diverse community structure. In contrast, urban gardens and soil regions showed higher dominance and lower evenness, potentially due to habitat fragmentation or anthropogenic disturbance favouring a few adaptable species. The open hilly region displayed an intermediate level of dominance (fig. 6).

The Bray-Curtis similarity analysis using group average linkage revealed distinct clustering patterns in species such as *G. bimaculatus*, *A. domesticus*, *P. pictus*, *P. bispinosa*, and *A. crenulata* exhibited strong similarities in abundance, forming a close cluster as shown in the dendrogram. In contrast, species like *H. banyan*, *A. simulatrix*, *E. incertus*, *I. pedunculata*, and *Phaneroptera* sp. displayed higher dissimilarity in abundance, indicating distinct habitat preferences. The cluster analysis also highlighted similarity among *T. annulata*, *S. prasiniferum*, and *T. eximia*, suggesting shared ecological adaptability across multiple habitat types (fig. 7).

The biodiversity indices revealed that agricultural habitats consistently support the highest orthopteran diversity across multiple metrics. The Shannon-Weiner Index ranged from 1.912 to 2.732, peaking in agriculture to reflect a highly balanced community, while soil habitats recorded the lowest evenness (1.912), indicating dominance by a few species. Similarly, the Simpson Index (0.8068–0.9169) reached highs in agriculture (0.9169) and soil (0.9157), demonstrating low single-species dominance, though temporal variations yielded the lowest value (0.8068) within agriculture during a different sampling period. Finally, the Margalef Index (1.626–3.515) confirmed peak species richness in agriculture (3.515). In contrast, urban gardens recorded the lowest Margalef richness (1.626), likely driven by human disturbance and habitat fragmentation (tab. 4).

Discussion

The observed small-scale patterns of different habitats used by orthopterans suggest that habitat affects the presence and relative abundance of orthopteran species. The present study demonstrates clear variations in orthopteran species diversity, abundance, and distribution across four distinct

habitats in the semiarid eastern plain of Rajasthan. The study supports the hypothesis that habitat heterogeneity and environmental conditions significantly influence orthopteran community structure, consistent with previous findings in semiarid and tropical ecosystems; the same inline context was found by Rana *et al.*, 2020; Maqsood *et al.*, 2020; and Suganya *et al.*, 2020 [30, 48]. Agricultural habitats and urban gardens supported the highest orthopteran richness and abundance due to diverse vegetation and favourable microclimates, aligning with findings that structurally diverse agroecosystems harbour rich insect communities (Storkey, 2006; Tanaya *et al.*, 2024) [51]. Conversely, harsh environmental exposure and limited vegetation reduced biodiversity in soil and open hilly regions. Furthermore, NMDS and Bray-Curtis analyses revealed tight ecological grouping among species in agricultural and urban habitats, indicating overlapping resource use. In contrast, species like *A. simulatrix*, *Tetrix* spp., and *Phaneroptera* spp. displayed distinct habitat specialization within hilly or shaded environments. Ultimately, these spatial segregations emphasize the critical role of microhabitat heterogeneity in shaping orthopteran communities (Lehmann *et al.*, 2014; Ramola *et al.*, 2024) [27, 40].

The Acrididae dominance in study areas was indicated by the exceptionally higher abundance and considered the potential bioindicators of agro-ecoregions as they prefer crops, grasses, and vegetables (Mariño-Pérez, 2022; Pudasaini and Dhital, 2022) [31, 39]. Alongside the highly adaptable Pyrgomorphidae persist in various habitats, including gardens, bare soil, sandy soil, along with roadsides, and in many field crops (Soomro & Sultana, 2023). These polyphagous families dominated agricultural sites, supporting previous records of abundant diurnal Caelifera in such habitats (Paulraj *et al.*, 2009; Chandra *et al.*, 2009; Dhakad *et al.*, 2014; Thakkar *et al.*, 2015) [8, 13, 36, 52]. The members of Tetrigidae and Tettigoniidae families were found in urban gardens and open hilly regions, while the families Gryllidae and Gryllotalpidae's members were soil-dwelling and decomposers in nature (Chandra *et al.*, 2009) [8]. They were likely to occur in lowlands rather than rocky outcrops, where vegetation was lacking and leaf litter covered forest ground, trunks of large trees, dead logs,

brambles, and canopy foliage (Jain and Balakrishnan, 2011; Crous *et al.*, 2014; Lecoq and Zhang, 2019) [12, 22, 26].

Pest species dominated the orthopteran community across all habitats, with the highest concentration in agricultural systems. This dominance reflects both the resource availability and potential vulnerability of agroecosystems to insect herbivory. The relatively low abundance of decomposer and leaf-eating guilds may be due to reduced detritus availability and limited leaf canopy in more exposed or intensively used sites. The significant variation in guild abundance among habitats underscores the need to consider functional groups in ecological monitoring. The grasses and paddy fields in Madhya Pradesh supported a high diversity of orthopterans, particularly species like *Gryllotalpa africana* and *Modicogryllus confirmatus* in soil habitats (Chandra *et al.*, 2009) [8], while the grasshopper species *Hieroglyphus banian* was reported as a pest in the rice ecosystem of Maharashtra (Jahao and Khurad, 2011) [21], in Uttar Pradesh (Akhtar *et al.*, 2012; Singh and Singh, 2014; Akhtar *et al.*, 2014) [2, 3, 44].

The variations in orthopteran diversity across Rajasthan driven by crop types and microclimatic gradients. Geographic variations strongly influence pyrgomorphid distribution in maize-wheat systems (Jat *et al.*, 2010) [23], whereas species like *Hieroglyphus nigrorepletus* and *Spathosternum prasiniferum* predominantly dominate maize fields (Pareek *et al.*, 2017) [34]. Habitat moisture further dictates assemblage structure; for example, sugarcane ecosystems support moisture-loving *Oxya* and *Aiolopus* species, while dry-adapted *Atractomorpha* thrive in drier conditions (Dhakad *et al.*, 2014) [13]. Similarly, extreme arid environments like Bikaner host distinct, drought-tolerant assemblages dominated by *Ochridia*, *Gryllus*, and *Chrotogonus* (Bhati & Srivastava, 2016) [7]. Ultimately, these habitat-specific compositional shifts reinforce the role of orthopteran insects as highly sensitive bioindicators of environmental change and overall habitat quality.

Table file: Assessment of orthopteran diversity across different habitats of semiarid eastern plain, Rajasthan, India

Table 1: Regional biodiversity assessment of orthopteran insects with sampling sites, along with habitats and their vegetation, survey and collections methods in semiarid eastern plain, Rajasthan.

Sites	Sampling stations	GPS coordinates	Habitats	Vegetation
Site I (Jaipur)	Bassi	26°50'39"N 76°02'56"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Sanganer	26°49'14"N 75°45'57"E	Urban garden	Dense vegetation
	Viratnagar	27°26'11"N 76°10'48"E	Open hilly	Rocky outcrops
	Chomu	27°10'37"N 75°43'04"E	Agriculture, Soil region	Cultivated area Spare vegetation
Site II (Ajmer)	Kishangarh	26°35'17"N 74°51'14"E	Urban garden	Dense vegetation
	Beawar	26°05'59"N 74°15'39"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Sarwar	26°03'42"N 75°00'54"E	Urban garden, Soil region	Dense vegetation Spare vegetation
	Nasirabad	26°17'58"N 74°43'49"E	Open hilly, Soil region	Rocky outcrops Spare vegetation
Site III (Dausa)	Lalsot	26°34'20"N 76°19'03"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Dausa	26°54'30"N 76°20'20"E	Urban garden	Dense vegetation
	Bandikui	27°03'32"N 76°34'32"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Mahwa	27°02'48"N 76°55'24"E	Open hilly, Agriculture	Rocky outcrops Cultivated area
Site IV (Tonk)	Todaraisingh	26°01'31"N 75°28'50"E	Open hilly, Soil region	Rocky outcrops Spare vegetation
	Uniara	25°55'03"N 76°01'28"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Niwai	26°21'33"N 75°55'20"E	Agriculture, Soil region	Cultivated area Spare vegetation
	Malpura	26°18'03"N 75°21'35"E	Urban garden	Dense vegetation

Table 2: Taxonomic composition, distribution and occurrence of orthopterans recorded in different habitats of the study area (2021 –23).

Suborder	Family	Sub family	Species	Site I (Jaipur)	Site II (Ajmer)	Site III (Dausa)	Site IV (Tonk)	Site I (Jaipur)	Site II (Ajmer)	Site III (Dausa)	Site IV (Tonk)	Site I (Jaipur)	Site II (Ajmer)	Site III (Dausa)	Site IV (Tonk)	Site I (Jaipur)	Site II (Ajmer)	Site III (Dausa)	Site IV (Tonk)	Status
				Agriculture	Urban garden	Soil region	Open hilly region	Agriculture	Urban garden	Soil region	Open hilly region	Agriculture	Urban garden	Soil region	Open hilly region	Agriculture	Urban garden	Soil region	Open hilly region	
Caelifera	Acrididae	Hemiacridinae	<i>Hieroglyphus</i> spp.***	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	LC
		Spathosterninae	<i>Spathosternum prasiniferum</i> **	+	+	+	-	-	-	+	+	-	+	+	+	+	+	+	+	VC
		Gomphocerinae	<i>Aulacobothrus</i> sp. *	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-	LC
		Catantopinae	<i>Xenocatantops karnyi</i> *	-	-	-	-	+	+	+	+	-	+	-	-	+	+	-	-	UC
			<i>Diabolocatantops pinguis</i> **	+	-	-	+	+	+	+	+	+	+	-	-	+	+	-	-	C
		Oedipodinae	<i>Gastrimargus africanus</i>	+	-	+	-	+	+	+	-	+	+	-	-	+	+	+	+	C
			<i>Oedaleus abruptus</i> *	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-	LC
			<i>Acrotylus longipes</i> *	-	-	-	+	-	+	-	+	-	-	-	-	+	-	-	-	LC
			<i>Acrotylus humbertianus</i> *	-	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	VC
			<i>Aiolopus simulatrix</i> **	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	LC
			<i>Trilophidia annulata</i> *	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	VC
		Acridinae	<i>Acrida exaltata</i> **	+	-	-	-	+	+	+	+	+	+	-	-	+	+	-	-	C
			<i>Acrida turrata</i>	+	-	-	+	-	+	+	+	+	+	-	-	+	+	-	-	C
		Truxalinae	<i>Truxalis indica</i>	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	LC
			<i>Truxalis eximia</i>	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	C
		Coptacrinae	<i>Eucoptacra praemorsa</i>	-	-	-	-	-	-	-	-	+	-	+	+	+	+	+	+	LC
			<i>Epistaurus sinetyi</i>	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+	+	LC
	Eyprepocnemidinae		<i>Heteracris notabilis</i>	-	-	+	-	-	-	+	-	+	+	-	+	+	+	+	-	UC
	Pyrgomorphidae	Pyrgomorphinae	<i>Chrotogonus trachypterus</i> *	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	UC
			<i>Chrotogonus oxypterus</i>	-	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+	VC
			<i>Pyrgomorpha bispinosa</i> **	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	VC
			<i>Atractomorpha crenulata</i> *	+	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	VC
			<i>Poekilocerus pictus</i> **	+	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+	C
	Tetrigidae	Tetriginae	<i>Tetrix</i> sp.	-	-	-	-	+	+	+	+	-	-	-	-	-	-	+	-	LC
Ensifera	Gryllidae	Gryllinae	<i>Gryllus bimaculatus</i>	-	-	-	+	-	+	+	+	+	+	+	+	+	+	+	+	C
			<i>Acheta domesticus</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	VC
	Gryllotalpidae	Gryllotalpinae	<i>Gryllotalpa africana</i>	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	VC
	Tettigoniidae	Phaneropterinae	<i>Phaneroptera</i> sp.	-	-	-	-	-	+	-	+	-	-	-	+	+	+	+	-	LC
			<i>Isopsera pedunculata</i>	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	LC
		Conocephalinae	<i>Euconocephalus incertus</i>	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	LC

VC- Very Common; UC- Uncommon; C- Common; LC- Least Common

* -Least severe pest; ** - Moderate pest; *** - Serious pest

Table 3: Species Abundance Distribution (SAD) of orthopterans collected from four habitats of the semiarid eastern plain of Rajasthan.

Orthopteran species	Agriculture		Urban Garden		Soil Region		Open Hilly Region		Overall abundance
	RA $\pm$ SE	IVI	RA $\pm$ SE	IVI	RA $\pm$ SE	IVI	RA $\pm$ SE	IVI	
<i>A. domesticus</i>	5.87 $\pm$ 0.94	26.78	3.33 $\pm$ 0.51	17.18	2.91 $\pm$ 0.43	15.88	3.29 $\pm$ 0.5	17.71	1683
<i>A. exaltata</i>	2.14 $\pm$ 0.23	12.65	0.45 $\pm$ 0.21	6.18	0.04 $\pm$ 0.04	4.77	0.48 $\pm$ 0.29	6.74	340
<i>A. turrita</i>	1.62 $\pm$ 0.25	11.07	0.72 $\pm$ 0.24	7.16	0.13 $\pm$ 0.13	5.16	0.61 $\pm$ 0.38	7.3	350
<i>A. longipes</i>	1.004 $\pm$ 0.49	6.38	0.02 $\pm$ 0.02	4.61	0.62 $\pm$ 0.43	7.79	0.06 $\pm$ 0.04	4.53	187
<i>A. humbertianus</i>	0.71 $\pm$ 0.31	7.31	0.3 $\pm$ 0.14	3.57	0.87 $\pm$ 0.49	6.66	0.24 $\pm$ 0.05	3.77	237
<i>A. simulatrix</i>	0.09 $\pm$ 0.05	2.75	-	2.3	-	2.3	-	2.3	9
<i>A. crenulata</i>	1.8 $\pm$ 0.29	11.28	1.06 $\pm$ 0.27	8.57	0.74 $\pm$ 0.09	7.41	1.01 $\pm$ 0.26	8.5	494
<i>Aulacobothrus sp.</i>	0.6 $\pm$ 0.23	6.02	0.02 $\pm$ 0.02	3.53	0.017 $\pm$ 0.01	3.53	-	3.45	68
<i>C. oxypterus</i>	0.59 $\pm$ 0.16	6.92	0.42 $\pm$ 0.13	6.21	0.43 $\pm$ 0.16	6.39	0.41 $\pm$ 0.14	6.28	211
<i>C. trachypterus</i>	0.63 $\pm$ 0.37	6.22	0.25 $\pm$ 0.15	3.91	0.24 $\pm$ 0.15	3.81	0.13 $\pm$ 0.08	3.1	156
<i>D. pinquis</i>	0.95 $\pm$ 0.09	8.29	0.48 $\pm$ 0.17	6.28	0.03 $\pm$ 0.03	4.74	0.18 $\pm$ 0.16	5.44	181
<i>E. sinetyi</i>	0.22 $\pm$ 0.13	3.41	0.19 $\pm$ 0.11	3.25	0.07 $\pm$ 0.05	2.6	0.05 $\pm$ 0.04	2.5	51
<i>E. incertus</i>	0.03 $\pm$ 0.03	1.39	0.02 $\pm$ 0.02	1.31	0.02 $\pm$ 0.02	1.31	0.13 $\pm$ 0.12	2.28	21
<i>E. praemorsa</i>	0.83 $\pm$ 0.49	6.32	0.4 $\pm$ 0.29	4.16	0.08 $\pm$ 0.05	2.7	0.26 $\pm$ 0.17	3.51	149
<i>G. africanus</i>	1.18 $\pm$ 0.13	9.24	0.52 $\pm$ 0.17	6.46	0.42 $\pm$ 0.2	6.39	0.23 $\pm$ 0.14	5.41	259
<i>G. africana</i>	0.85 $\pm$ 0.15	8.01	0.28 $\pm$ 0.13	5.58	0.41 $\pm$ 0.11	6.32	0.19 $\pm$ 0.02	5.34	195
<i>G. bimaculatus</i>	5.41 $\pm$ 0.51	25.16	3.14 $\pm$ 0.44	16.48	2.84 $\pm$ 0.3	15.67	2.77 $\pm$ 0.51	15.07	1536
<i>H. notabilis</i>	0.03 $\pm$ 0.01	2.45	0.05 $\pm$ 0.03	2.55	0.23 $\pm$ 0.12	3.71	0.03 $\pm$ 0.04	2.5	40
<i>Hieroglyphus spp.</i>	9.51 $\pm$ 5.5	57.85	-	2.3	-	2.3	-	2.3	1104
<i>I. pedunculata</i>	-	-	-	-	-	-	0.1 $\pm$ 0.07	0.22	11
<i>O. abruptus</i>	0.96 $\pm$ 0.58	6.83	0.43 $\pm$ 0.27	4.31	0.04 $\pm$ 0.04	2.5	0.21 $\pm$ 0.2	3.36	155
<i>Phaneroptera sp.</i>	0.02 $\pm$ 0.02	2.4	0.06 $\pm$ 0.04	2.65	0.03 $\pm$ 0.03	2.45	0.42 $\pm$ 0.19	4.76	61
<i>P. pictus</i>	1.39 $\pm$ 0.61	9.28	1.24 $\pm$ 0.41	9.08	0.99 $\pm$ 0.44	7.63	1.16 $\pm$ 0.42	8.84	523
<i>P. bispinosa</i>	2.16 $\pm$ 0.42	12.47	1.23 $\pm$ 0.27	9.13	1.01 $\pm$ 0.23	8.25	1.29 $\pm$ 0.23	9.38	593
<i>S. prasiniferum</i>	4.67 $\pm$ 0.52	22.35	3.42 $\pm$ 0.36	17.46	1.9 $\pm$ 0.39	12.19	2.07 $\pm$ 0.56	12.96	1325
<i>Tetrix sp.</i>	0.2 $\pm$ 0.12	3.56	0.01 $\pm$ 0.01	2.35	0.26 $\pm$ 0.12	3.86	0.03 $\pm$ 0.03	2.5	61
<i>T. annulata</i>	1.69 $\pm$ 0.24	11.1	1.33 $\pm$ 0.25	9.52	1.16 $\pm$ 0.08	8.99	1.43 $\pm$ 0.23	9.91	601
<i>T. eximia</i>	0.33 $\pm$ 0.08	5.83	0.51 $\pm$ 0.11	6.57	0.11 $\pm$ 0.04	5.02	0.09 $\pm$ 0.04	4.98	114
<i>T. indica</i>	0.22 $\pm$ 0.14	3.66	0.31 $\pm$ 0.23	4.31	0.22 $\pm$ 0.16	3.76	0.15 $\pm$ 0.09	3.25	115
<i>X. karnyi</i>	0.13 $\pm$ 0.1	3.05	0.55 $\pm$ 0.24	5.27	0.05 $\pm$ 0.05	2.6	0.04 $\pm$ 0.04	2.55	85

RA: Relative abundance; SE: Standard error; IVI: Important value index

Table 4: Heatmap of diversity attributes of orthopteran species in different habitats of semiarid eastern plain of Rajasthan during study period (2021-2023).

Agriculture	Urban garden	Soil region	Open hilly region
Simpson Index			
0.8068	0.8747	0.8953	0.8938
0.8932	0.8869	0.9157	0.8824
0.8427	0.9071	0.8101	0.8723
0.9169	0.9108	0.8828	0.885
Shannon-Weiner Index			
2.215	2.209	2.49	2.523
2.591	2.497	2.715	2.435
2.404	2.636	1.912	2.304
2.732	2.669	2.386	2.341
Margalef Index			
2.328	1.626	2.443	2.786
2.842	3.244	3.4	3.111
2.883	2.912	1.935	2.438
3.515	3.276	2.952	2.401

Figure file: Assessment of orthopteran diversity across different habitats of semiarid eastern plain, Rajasthan, India





Fig 1: Habitats (Open hilly region, Agriculture region, Soil region and Urban garden) of the study area

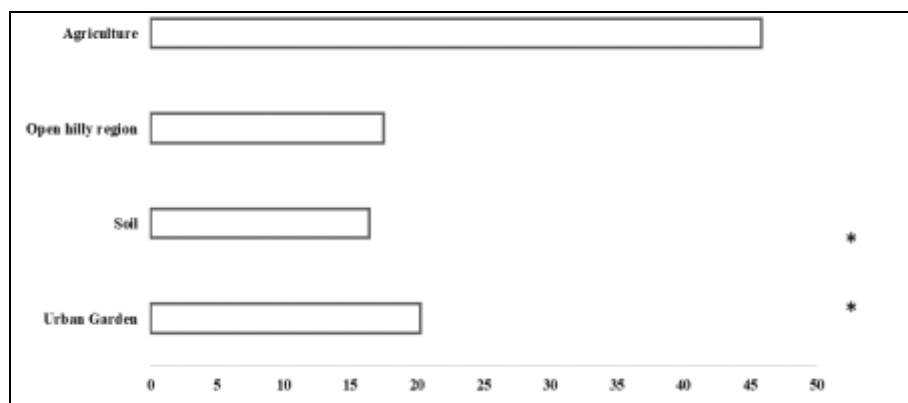


Fig 2: Relative abundances of all studied orthopteran insects in four habitat types. one-way ANOVA: * $P_{2,27} < 0.05$. (* - significant)

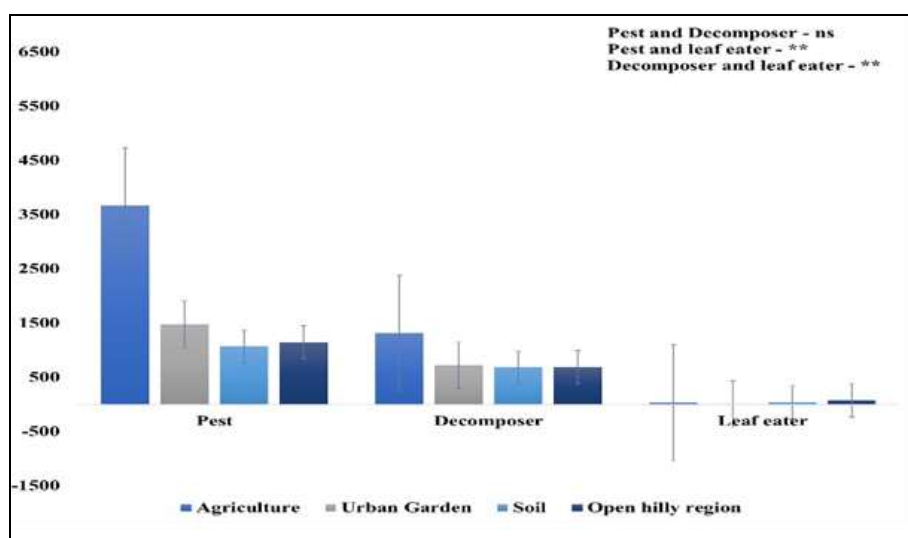
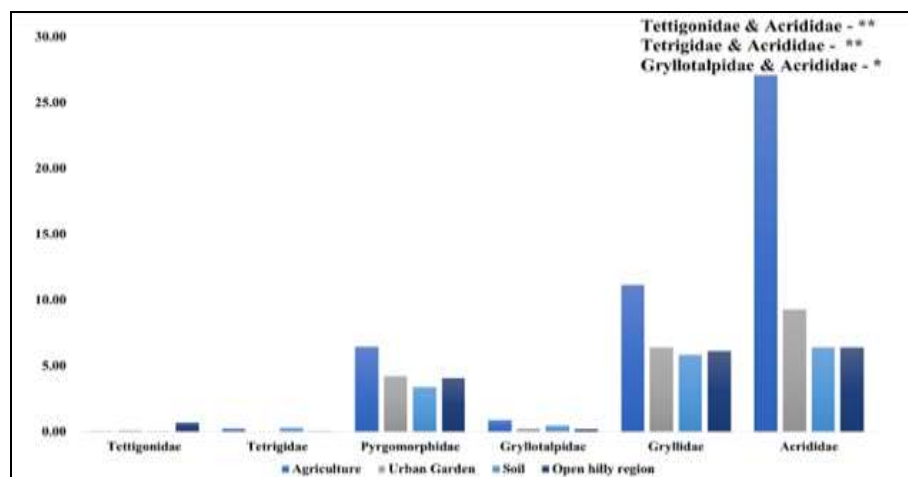


Fig 3: Relative abundances of a) orthopteran families assessed; and b) orthopteran species assigned to different guilds in four habitat types. one-way ANOVA: * $P_{2,27} < 0.05$; ** $P_{2,27} < 0.01$.

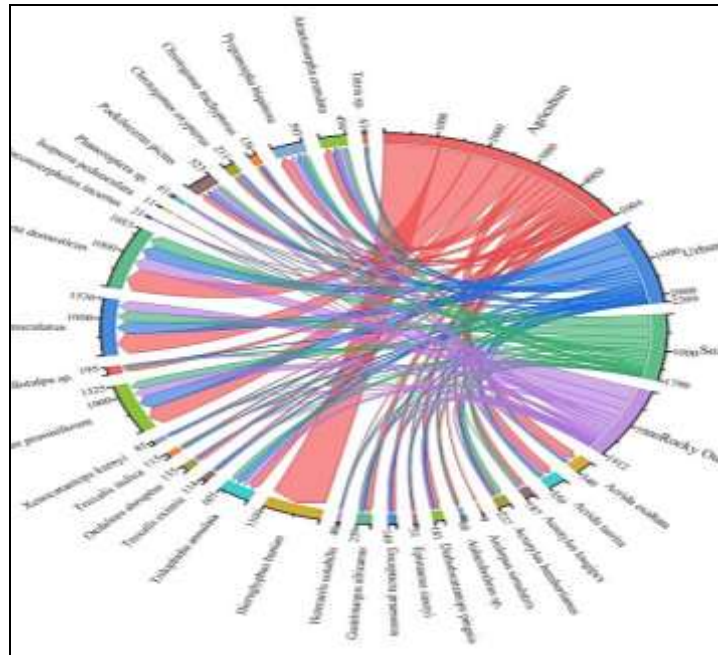


Fig 4: Chord diagram of orthopteran species abundance across different habitats of semiarid eastern plain, Rajasthan during study period (2021-2023).

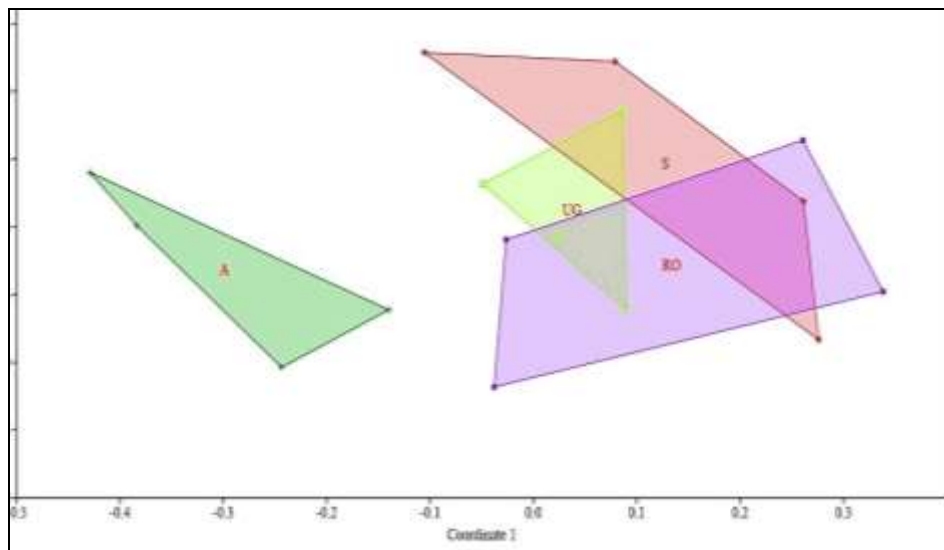


Fig 5: The first two axes of non-metric multidimensional scaling (Gower dissimilarities) separated orthopteran species of the four habitats: green: agriculture (A); neon: urban garden (UG); brown: soil (S); blue: open hilly (RO).

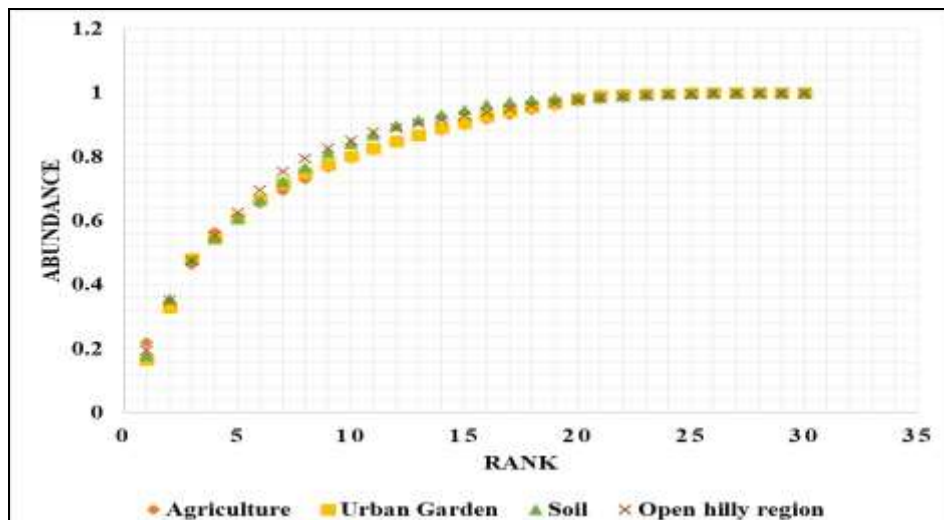


Fig 6: K – dominance curve of orthopteran composition across all habitats of semiarid eastern plain of Rajasthan.

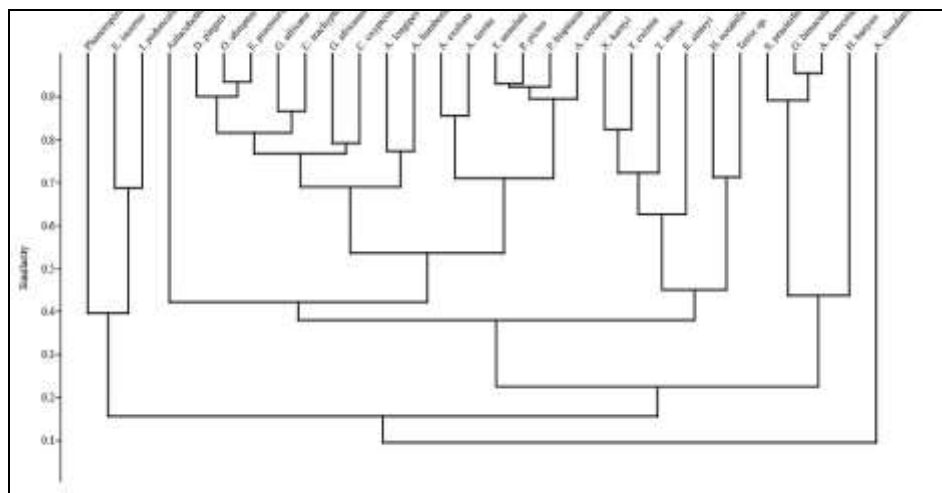


Fig 7: Bray-Curtis cluster analysis for the orthopteran species community composition (taxonomic similarity) in the semiarid eastern plain of Rajasthan between March 2021 and February 2023.

Conclusion

The assessment of orthopteran insect diversity, distribution and abundance, in selected ecosystems naturally favour diurnal and open-area Caelifera families, particularly Acrididae, which are more prominent in these habitats due to their adaptation to semiarid conditions and vegetation structure. In contrast, habitats conducive to nocturnal orthopterans, such as dense vegetation and moist microhabitats, were limited in the selected study sites.

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