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ORIGINAL RESEARCH ARTICLE

Occurrence of different insect species with emphasis on their abundance and diversity in different habitats of Faisalabad, Pakistan

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Abstract

The occurrence of diverse and copious communities of insects are considered the indicator of ecosystem sustainability in different habitats. This study was designed to investigate the diversity of various insect species among different habitats viz. Agro-farms, citrus orchards, and around the pond areas from January 2018 to December 2018. Sampling was done every month in the morning by using sweep nets, handpicking, and Forceps. The composition, relative abundance, and diversity indices of Diptera, Coleoptera, Lepidoptera, and Hymenoptera were computed. Maximum abundance was recorded for the Agro-farms (N = 1704) and minimum for citrus orchards (N = 1003). Diptera was documented to be the most abundant and diverse order (N = 1988), while Lepidoptera was the least diverse one ((N = 286). The diversity indices, Shannon index (3.832), Margalef richness (14.18), and Evenness (0.4662) from the citrus orchards were recorded high. Abiotic factors (Temperature, Humidity) showed a significant relationship with the occurrence of the fauna ($p < 0.05$). The temperature significantly and positively correlated, while the humidity negatively correlated to the diversity and abundance of fauna. However, we found a significant difference in species composition according to habitat ($P < 0.001$). All habitats were different from each other (Fisher post hoc test, $P < 0.05$). All the test was done at the level of significance ($\alpha = 0.05$). Future work needs to be done by expanding the duration of the study, area, scope, and by applying different sampling techniques.

Keywords Insects · Population · Habitats · Occurrence

Introduction

An ecosystem is a community consisting of both living and non-living components that are present in the environment. Biodiversity includes all sorts of natural elements, such as wild and cultivated animals and plants. Moreover, it also has many aspects of nature variabilities ranging from molecular to the individual level (Gaston and Spicer 1998). Insects are one of the largest group of animals which are enormously significant for the environment which plays a vital part for the conservation of the ecosystem, improve health of the ecosystem, and the critical component for food web in both terrestrial and aquatic ecosystems (Kevan 2002; Shuriin 2005). Biodiversity is the multidimensional property of natural systems that quantify different challenges due to the multitude of indices. Indices seek to define the general characteristics of ecosystems that enable us to compare taxa, multiple regions, and trophic levels. Therefore, these are of vital significance for the conservation and monitoring of the environment (Magurran 2004; Leinster and Cobbold 2012; Morris et al. 2014).

About 125,000 species of the order Diptera have been described, including flies, mosquitoes, and midges (Mayhew et al. 2007). It is an influential group that plays a valuable role for the human and ecological system e.g. pollinators of different crops (Symank et al. 2008), and many of them are flowering plant species (Larson et al. 2001). Coleoptera is generally bio-control representative in nature, and their communication with the prey is of great importance (Oelbermann et al. 2008). They consist of customarily more than 360,000 depicted species. However, biological control is an environment-friendly alternative to hazardous and toxic insecticides, which are frequently applied to protect the plants (Bellows 2001). They are of great importance in pest control (Brown et al. 2010). Lepidoptera includes

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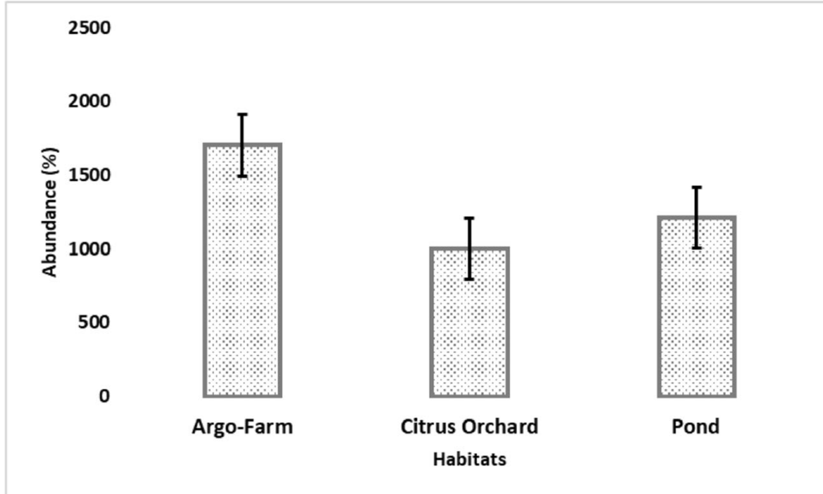
Fig. 1 Abundance of fauna from different habitats



157,424 described species, including butterflies and moths (Nieukerken et al. 2011). Butterflies are eminent taxonomically and ecologically, regarded as an excellent indicator of the ecosystem (Mihoci et al. 2011). Butterflies have cultural, financial, artistic values, and delicate to fractional deviation (Tiple 2011). They deliver significant model systems for scientific quarries and have a genuine impact on individuals as agricultural pests and predators (Wagner 2001; Roe et al. 2009). Hymenoptera consists of more than 115,000 defined species and covers nearly 10% of the species diversity (Sharkey 2007). Sawflies, ants, wasps, and bees are dominant groups in this order, and they affect agriculture by various roles such as pollinators, parasitoids, pests, and predators (Michener 2000; Wilson 2006).

Insect diversity is directly and indirectly affected by natural enemies (predator and parasites), population dynamics, plant diversity, density, family size, habitat structural complexity, and environmental factors (Fernandes et al. 1994; Schoonhoven et al. 1998). The landscape features are well known that influence the community and the population ecology of species. The isolation of habitat fragments (Collinge 2000), patch area (Kruess and Tscharntke 2000), patch quality (Kuussaari et al. 2000; Hanski and Singer 2001), the ratio of habitat edge to the interior (Radeloff et al. 2000), and diversity of patch and seasons (Varchola and Dunn 2001; Braman et al. 2000); all these factors contribute to determining the richness and abundance of insects in a particular habitat. Landscape structure and habitat fragmentation influence the occurrence of arthropod communities (Gibbs and Stanton 2001).

Agriculture is extending nowadays, which provides more food by increasing the productivity of farms (Haberl et al. 2004). It includes a significant part of GDP (Idrees et al. 2020). Orchards are complex ecosystems in which plants have adjacent associations with different living constituents. Consequently, the fundamental modification in the community of plant has an impact on the population of arthropod. Citrus is an essential group of fruit crops, with extremely

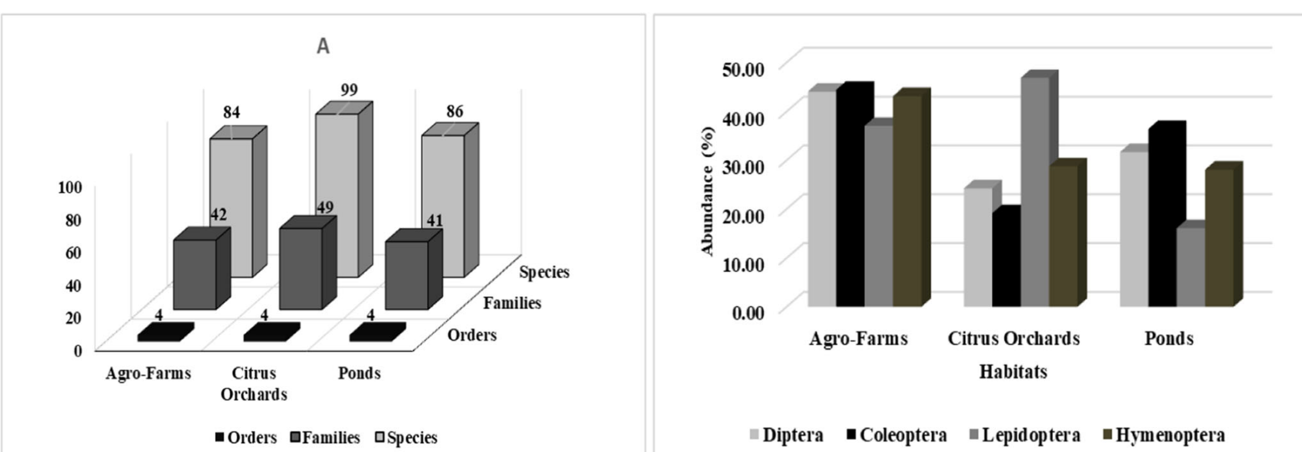


Fig. 2 (**A**) Taxa composition of insects among different habitats (**B**) Abundance of different insect's orders with regard to their habitat

Table 1 Diversity indices of various habitats

Diversity factors	Agro-Farms	Citrus orchards	Pond
Individuals	1704	1003	1214
Dominance (D)	0.04014	0.02997	0.04225
Simpson (1-D)	0.9599	0.97	0.9578
Shannon (H)	3.649	3.832	3.675
Evenness (e^H/S)	0.4578	0.4664	0.4589
Brillouin	3.578	3.716	3.579
Menhinick	2.035	3.126	2.468
Margalef	11.15	14.18	11.97
Equitability (J)	0.8236	0.834	0.8251
Fisher-alpha	18.54	27.26	21.14
Berger-Parker	0.1197	0.07178	0.117
Chao-1	90.88	122	88.1

nutritious fruits (Hussain et al. 2004) having vitamin C and minerals (Supraditareporn and Pinthong 2007). The area of cultivation and fruit production of sweet orange and Kinnow are very significant in Pakistan.

Nevertheless, on earth, the most productive ecosystems are Wetlands. They are considered "the kidneys of the landscape" and "biological supermarkets" (Barbier et al. 1997). Wetlands maintain the ecological processes that provide a healthy ecosystem by regulating climate (Brander and Schuyt 2010). This kind of studies conducted to increase the knowledge about the faunal composition in different habitats/landscapes and to describe the importance of biodiversity. The purpose of the current study was to address the diversity indices of insects, their abundance in a particular habitat, and the ecological effect on diversity and abundance in different habitats.

Materials and methods

Study area

The study was conducted at the University of Agriculture Faisalabad (Punjab), Pakistan. Faisalabad is located at height (604 ft) a.s.l having latitude 30° − 31.5 ° N and 73° − 74° E. It enclosed on East by Sheikhupura and Sahiwal, on West Jhung, North Chiniot, and South by Sahiwal and Toba Tek Singh (GOP 2015).

Sample collection and identification

The fauna was collected from the Agro-farms, citrus orchards, and around the pond areas (Eight Ponds) monthly from January 2018 to December 2018 (One-Year) for two hours. The insects (specimens) were obtained by succeeding methods: sweep net, direct handpicking, and Forceps.

In addition to these, the temperature and humidity of the study area were also noted as per objective. The collected specimens were preserved in jars containing 30:70% glycerin and alcohol solution. Besides these, collected samples were brought to the Biodiversity Laboratory, Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad. Then the glass vials were prepared with a 30:70% glycerin and alcohol solution. After separation, collected specimens were stored in glass vials for further identification. Identification was made with the taxonomic literature help (morphological based traits) (Borror and DeLong 2005; Triplehorn and Johnson 2005), stereomicroscope (to elaborate the distinctive characteristics), and magnifying glass lens.

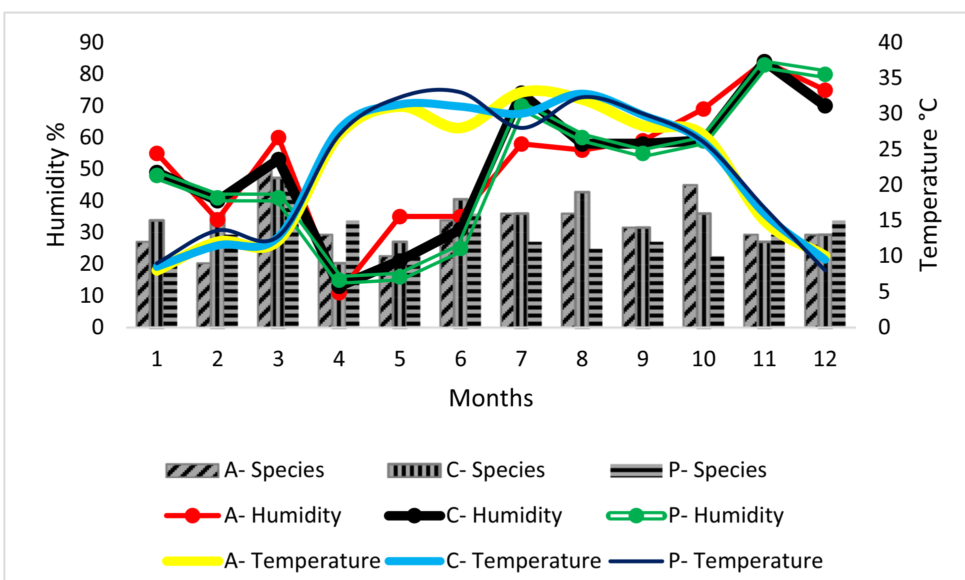


Fig. 3 Association of temperature and humidity with the species richness of insects (A = Agro-Farms; C = Citrus Orchards; P = Ponds)

Table 2 Correlation analysis of species with abiotic factors (Temperature, Humidity). *p < 0.05, **p < 0.01, n.s = no significant difference

Factors	Agro-Farms			Citrus orchards			Pond		
	Species Diversity	Temperature	Humidity	Species Diversity	Temperature	Humidity	Species Diversity	Temperature	Humidity
Species Diversity	1	0.424*	-0.329^{NS}	1	0.492*	-0.706**	1	0.481*	-0.607**
Temperature		1	-0.675**		1	-0.696**		1	-0.736**
Humidity			1			1			1

Statistical analysis

Subsequently, all the observed specimens (insects) were explicitly organized in the table by their morphological and taxonomic types e.g. order, family, genus, and species. For the determination of numerous features of diversity, Diversity (H), Evenness, Richness, and Dominance were calculated by given parameters/methods of Shannon (1948) and Magurran (1988). Pearson correlation was used to find the impact of abiotic factors (Temperature and Humidity) on the diversity and abundance of fauna.

For obtaining information about different diversity descriptors (number of rare species, singletons, doubletons, Shannon-weaver, and Simpson diversity indices) and richness estimators (Chao 2, Jacknifer 1 and Bootstrap), we used the Estimates v software. 9.1 (Colwell 2013). We built species accumulation curves for different habitats, plotting the cumulative number of insect species by the number of samples. We have used a Kruskall-Wallis test to assess whether the average number of insects recorded in the samples according to the habitats studied.

To evaluate a difference in the composition of insect assemblies according to habitat, we used Permutational Analysis of Variance (PERMANOVA). We used a non-metric multidimensional scaling (NMDS) to illustrate the relationship between the variables, using the Jaccard similarity index as the association measure. For this, we considered the presence or absence of each species in the sampling points. The statistical analyses were performed using the software PAST version 4.02 (Hammer et al. 2001) and R version 3.6.1 (R Core Team 2019), the package "vegan" (Oksanen et al. 2019), and Microsoft Office 365. All tests were analyzed at the level of significance $\alpha = 0.05$.

Results

Overall, 3921 individuals/specimens were recorded during the whole study period. Maximum relative abundance was recorded from Agro-farms (1704), followed by pond areas (1214) and citrus orchards (1003) (Fig. 1). In the pattern of diversity, four orders from each habitat, (42, 49, 41) families and (84, 99, 86) species were recorded from Agro-farms, citrus orchards, and pond areas, respectively (Fig. 2A). The maximum population of Coleoptera (44.41%) was recorded from Agro-farms, while Lepidoptera (46.85%) was recorded higher from citrus orchards. In pond areas, the Coleoptera order was recorded dominant (36.43%) (Fig. 2B).

Diversity (H′) was recorded maximum (3.832) from citrus orchards as compared to the ponds (3.675) and Agro-farms (3.649); whereas, Evenness was recorded dominant from citrus orchards (0.4664) and least from Agro-farms (0.4578). After that, dominance was verified maximum from the ponds (0.0422) and lowest from citrus orchards (0.0299). Whereas, Margalef richness (R) was recorded maximum in citrus orchards (14.18) as compared to the pond areas (11.97) and Agro-farms (11.15). Other analyzed diversity factors are shown in Table 1.

Both temperature and humidity had a strong influence on insect diversity. In summer months, the temperature was noted maximum, which affected the diversity and abundance of fauna while the average temperature season favored the richness of insects. Humidity also forced a positive influence on diversity; data showed that a decrease in the humidity level population of insects was decreased (Fig. 3). The temperature significantly and positively correlated ($p < 0.05$), while the

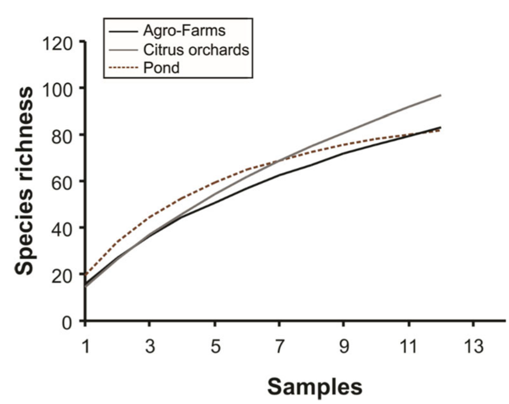


Fig. 4 Species accumulation curves for the different habitats studied

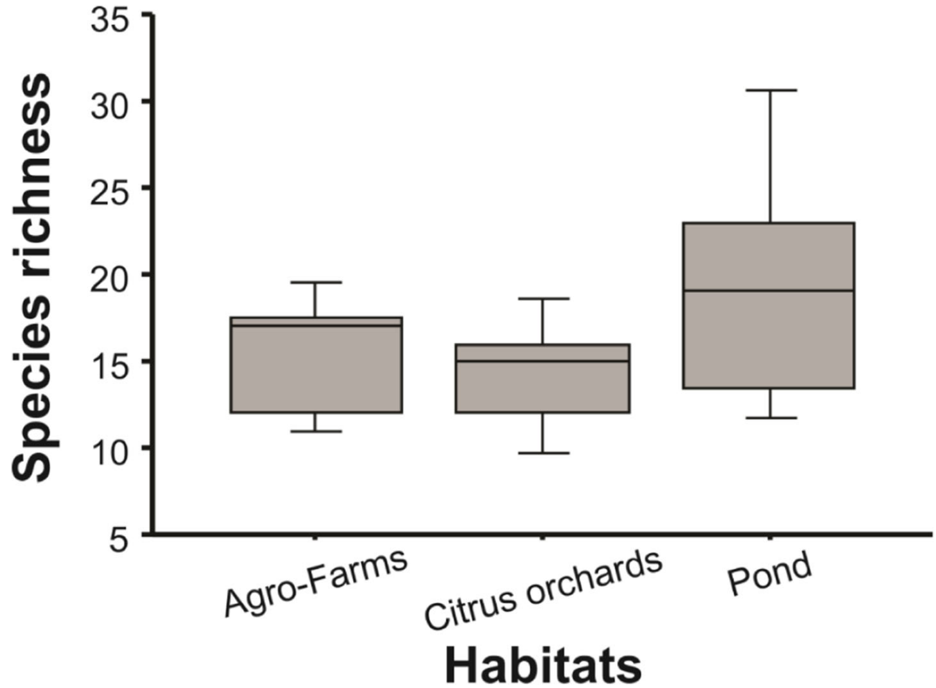


Fig. 5 Species richness according to different habitats studied

humidity correlated negatively with the diversity and abundance of the sampled insects ($p < 0.01$) from all the habitats (Table 2). For all habitats, the species accumulation curves did not reach a plateau and still in the growing phase. However, the curve referring to the ponds was the one that showed a significant tendency towards stability (Fig. 4). We found no difference in the average number of species according to the studied habitats ($H = 3.79$, $df = 2$, $P = 0.149$) (Fig. 5). However, we found a significant difference in species composition according to habitat ($F_{2.33} = 1.868$, $P < 0.001$). All habitats are different from each other (Fisher post hoc test, $P < 0.05$) (Fig. 6).

Discussion

Earth being supreme diverse, imperative habitat and species-rich community, has valuable diversity indices of flora and fauna (Khodashenas et al. 2012). Among them, macro-fauna has distinct diversity and local variations in different ecosystems, making the group much superior (Lavelle et al. 2006). The abundance and diversity of macro-fauna are also used as a tension-time index for soil profile (Palacios-Vargas et al. 2007). Biodiversity is considered very important in numerous ecosystem services, which depicts the current status of the area and can determine various factors (Xin et al. 2012;

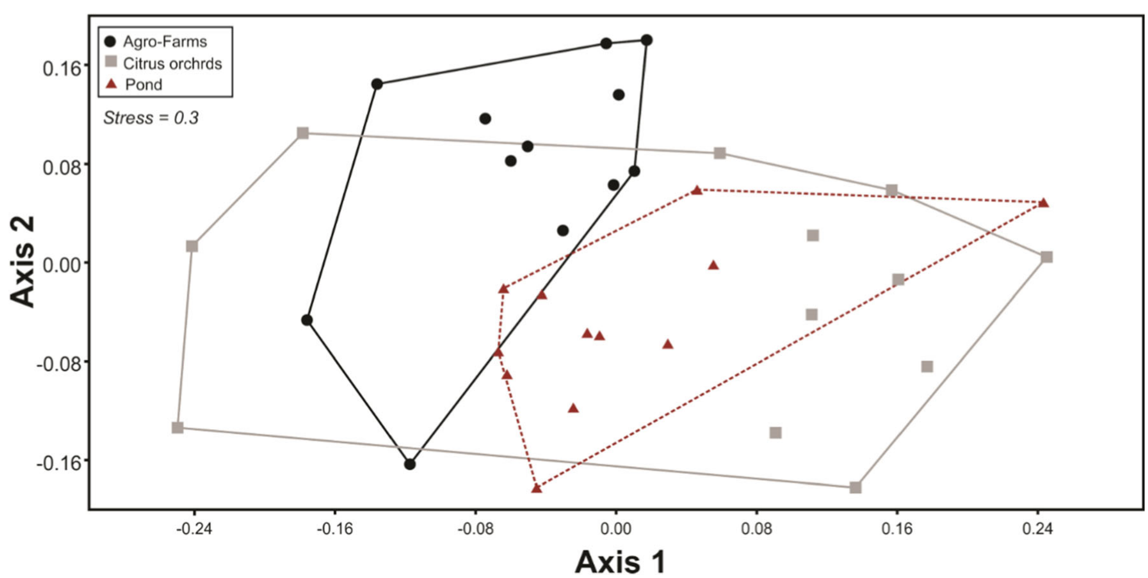


Fig. 6 Non-metric multidimensional scaling—NMDS of species composition according to different habitats studied

Moghimian and Kooch 2013). However, changes in land use, environment disintegration, supplement change, and stress may disturb the movement of energy and cycling of supplements (Wilsey and Potvin 2000). Determination of diversity, richness, Evenness, and abundance of fauna is required for ecological studies, habitat management, and conservation programs in any ecosystem (Nahmani et al. 2005).

Chiawo et al. (2017) studied the diversity of bees and floral resources in farmlands. A large abundance of bees was observed in Agro-farms, which described the plenty of floral resources in that habitat. The richness of floral resources is directly responsible for the richness of bee species. Wetlands are the main components of our climate, and these are in disturbance nowadays, ultimately affecting the associated fauna (Kevin 2008). The present study results described that temperature is the main factor in influencing insect diversity (Dunn et al. 2009; Diamond et al. 2012). Moreover, many scientists observed that climate change sturdily influenced the macro-faunal physiology through shifting the soil temperature and moisture (Booth et al. 2000; Brose et al. 2012; Lurgi et al. 2012). Hymenoptera exhibited prominent species dominance levels with variation in elevation (Sanders 2002; Burwell and Nakamura 2011), indicating that their distribution patterns were perhaps highly sensitive to overall temperature change (Deutsch et al. 2008; Del-Toro et al. 2015).

In the present study, Diptera was recorded maximum with a high richness of species. Order Diptera showed variations in their contact with humankind, habitat misuse, structure, and life habits. Economic losses occur due to flies, like fruit flies are responsible for damaging vegetables and fruits; due to this, it is considered as significant in agriculture (Thomas 2009). Abundance and species richness of different orders presented, unlike responses to structural connectivity of landscape and vegetation. Also, our findings were in line with studies indicating the positive response of syrphid species richness to flowers amount, vegetation, and grassland area (Kleijn and van Langevelde 2006; Meyer et al. 2009), which stress the importance of landscape composition for syrphid abundance (Alignier et al. 2014). Kathiresan and Bingham (2001) described that herbivorous insects could cause considerable damage to vegetations.

Agriculture has been the approach since a long time ago, and different studies have shown significant yield that upsurges in diverse cropping systems. Ecological studies proposed that more diverse plant communities are resilient to environmental perturbation and are resistant to a different environment (Alteiri and Nicholls 1999; Billeter et al. 2008). In the present work, diversity and abundance were recorded maximum from Agro-farms than all other habitats; the same inline context was found by the Rana et al. (2019); Naseem et al. (2020); Maqsood et al. (2020). Water bodies are tremendously helping in environmental sustainability as they support the faunal distribution in different ecosystems (Susila 2007; Balakrishnan et al. 2014; Majeed et al. 2019). The Coleoptera and Lepidoptera dominance in our study areas are indicated by the exceptionally higher abundance of some insects. They are considered the potential bioindicator of moist habitats as they prefer moist soil, litter, and rotting wood (Hall 2001; Sawada and Hirowatari 2002; Sorensson 2003).

Subsequently, from the complete data and discussion above, it is confirmed that our findings were similar to the literature those reported by previous researchers; however, at some point, deviations were observed due to differences in environmental conditions and skill power, documentation of data, and handling expertise.

Conclusions

Insects being a distinguished group on the earth, play a very crucial role in environmental management. In the present study, maximum abundance was found in the Agro-farms, and data also elaborated that Diptera was present in a significant number compared to other orders. Other orders which we found in less diversity and abundance suggested that environmental pressure and management techniques (primarily chemical) of food security affected them adversely. The ecological variables also subjected a substantial impact on the faunal diversity. Results might be beneficial in the management strategies of the biological control of fauna and conservation purposes. Future studies should be done with more and different sampling and planning approaches to elaborate insect fauna in particular habitats. Though it will also be endorsed for future research of biodiversity in different habitats to enhance the knowledge of this large group, that is still unknown.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

References

Alignier A, Raymond L, Deconchat M, Menozzi P, Monteil C, Sarthou JP, Vialatte A, Ouin A (2014) The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales. Biol Cont 77:76–82

Altieri MA, Nicholls CI (l999) Biodiversity, ecosystem function, and insect pest management in agricultural systems. In: Collins WW, Qualset CO (eds) Biodiversity in Agro-ecosystems, CRC Press, Boca Raton, pp 69–84

Balakrishnan S, Srinivasan M, Mohanraj J (2014) Diversity of some insect fauna in different coastal habitats of Tamil Nadu, southeast coast of India. J Asia Pac Biodivers 7:408–414

Barbier EB, Acreman MC, Knowler D (1997) Economic valuation of wetlands: A guide for policymakers and planners. Ramsar Secretariat, Gland

Bellows TS (2001) Restoring population balance through natural enemy introductions. Biol Cont 21:199–205

Billeter R, Liira J, Bailey D, Bugter R, Arens P, Augenstein I, Aviron S, Baudry J, Bukacek R, Burel F (2008) Indicators for biodiversity in agricultural landscapes: a pan-European study. J Appl Ecol 45:141–150

Booth LH, Heppelthwaite V, McGlinchy A (2000) The effect of environmental parameters on growth, cholinesterase activity, and glutathione S-transferase activity in the earthworm (*Apporectodea caliginosa*). Biomarkers 5:46–55.

Borror DJ, DeLong DM (2005) An introduction to the study of insects. Columbus, Ohio, p 812

Braman SK, Latimer JG, Oetting RD, McQueen RD, Eckberg TB, Prinster M (2000) Management strategy, shade, and landscape composition effects on urban landscape plant quality and arthropod abundance. J Econ Entomol 93:1464–1472

Brander L, Schuyt K (2010) The economic value of the world's wetlands. TEEB web.org. pp 1–3

Brose U, Dunne JA, Montoya JM, Petchey OL, Schneider FD, Jacob U (2012) Climate change in size-structured ecosystems. Philos Trans R Soc 367:2903–2912

Brown J, Scholtz CH, Janeau JL, Grellier S, Podwojewski P (2010) Dung beetles (Coleoptera: Scarabaeidae) can improve soil hydrological properties. Appl Soil Ecol 46:9–16

Burwell CJ, Nakamura A (2011) Distribution of ant species along an altitudinal transect in continuous rainforest in subtropical Queensland, Australia. Memoirs of the Queensland Museum 55: 391–412

Chiawo DO, Ogo CKPO, Kioko EN, Otiende VA, Gikungu MW (2017) Bee diversity and floral resources along a disturbance gradient in Kaya Muhaka forest and surrounding farmlands of coastal Kenya. J Pollination Ecol 20:51–59

Collinge SK (2000) Effects of grassland fragmentation on insect species loss, colonization and movement patterns. Ecology 81:2211–2226

Colwell RK (2013) Estimate S: statistical estimation of species richness and shared species from samples. Version 9. http://purl.oclc.org/estimates

Del-Toro I, Silva RR, Ellison AM, Andersen A (2015) Predicted impacts of climatic change on ant functional diversity and distributions in eastern North American forests. Divers Distrib 21:781–791

Deutsch CA, Tewksbury JJ, Huey RB, Sheldon KS, Cameron KG, Haak DC, Martin PR (2008) Impacts of climate warming on terrestrial ectotherms across latitude. Proc Nat Acad Sci U S A 105:6668–6672

Diamond S, Sorger DM, Hulcr J, Pelini SL, Del-Toros I, Hirsch C (2012) Who likes it hot? A global analysis of the climatic, ecological, and evolutionary determinants of warming tolerance in ants. Glob Change Biol 18:448–456

Dunn RR, Agosti D, Andersen AN, Arnan X, Bruhl CA, Cerda X (2009) Climatic drivers of hemispheric asymmetry in global patterns of ant species richness. Ecol Lett 12:324–333

Fernandes GW, Lara CFL, Price PW (1994) The geography of galling insects and the mechanisms that result in patterns. In: Price PW, Mattson WJ, Baranchikov Y (eds) The Ecology and Evolution of Gall-Forming Insects. Forest Service – US Department of Agriculture, St. Paul, pp 42–48

Gaston K, Spicer J (1998) Costanza and Folke. The biodiversity convention. Santuary 12:34–43

Gibbs JP, Stanton EJ (2001) Habitat fragmentation and arthropod community change: carrion beetles, phoretic mites, and flies. Ecol Appl 11:79–85

GOP (2015) Government of Pakistan. Archived from the original on 11 June 2013. Retrieved 18 June 2013

Haberl H, Wackernagel M, Krausmann F, Monfreda KH (2004) Ecological footprints and human appropriation of net primary production: a comparison. Ecol Econ 146:115–124

Hall WE (2001) Ptiliidae. In: Arnett RH, Thomas MC (eds) American Beetles, vol 1. CRC Press, Boca Raton, pp 233–246

Hammer O, Harper DAT, Ryan PD (2001) PAST: Paleontological Statistics software package for education and data analysis. Palaeontologia Electronica 4:1–9

Hanski I, Singer MC (2001) Extinction-colonization dynamics and host-plant choice in butterfly metapopulations. Am Nat 158:341–353

Hussain I, Asif M, Ahmed M, Khan M, Shakir I (2004) Effect of uni-packaging on the post-harvest behavior of citrus fruits in NWFP. Pak J Nutr 3:336–339

Idrees M, Gogi MD, Majeed W, Yaseen A, Mubashir M (2020) Impacts and evaluation of Hormoligosis of some insect growth regulators on Phenacoccus solenopsis (Hemiptera: Pseudococcidae). Int J Trop Insect Sci. https://doi.org/10.1007/s42690-020-00142-7

Kathiresan K, Bingham BL (2001) Biology of mangroves and mangrove ecosystems. Adv Marine Biol 40:81–251

Kevan PG (2002) Flowers, pollination, and the associated diversity of flies. Biodiversity 3:16–18

Kevin LE (2008) Wetlands and global climate change: the role of wetland restoration in a changing world. Wetlands Ecol Manag 17:71–84

Khodashenas A, Koocheki A, Rezvani P, Moghaddam, Lakzian A (2012) Evaluation of structural biodiversity in natural systems of arid and semiarid regions: 1-Soil characteristic and biodiversity. J Nat Environ 6:165–173

Kleijn D, Van Langevelde F (2006) Interacting effects of landscape context and habitat quality on flower visiting insects in agricultural landscapes. Basic Appl Ecol 7:201–214

Kruess A, Tscharntke T (2000) Species richness and parasitism in a fragmented landscape: experiments and field studies with insects on *Vicia sepium*. Oecologia 122:129–137

Kuussaari M, Hanski I, Singer M (2000) Local speciation and landscape-level influence on host use in an herbivorous insect. Ecology 81: 2177–2187

Larson BMH, Kevan PG, Inouye DW (2001) Flies and flowers: taxonomic diversity of anthophiles and pollinators. Can Entomol 133: 439–465

Lavelle P, Decaens T, Aubert M, Barot S, Blouin M, Bureau F, Margerie P, Mora P, Rossi JP (2006) Soil invertebrates and ecosystem services. Eur J Soil Biol 42:3–15

Leinster T, Cobbold CA (2012) Measuring diversity: the importance of species similarity. Ecology 93:477–489

Lurgi M, Lopez BC, Montoya JM (2012) Climate change impacts on body size distribution and food web structure in mountain ecosystems. Phil Trans R Soc Lond Ser B Biol Sci 367:3050–3057

Magurran AE (1988) Ecological diversity and its measurement. Princeton Uni Press, New Jersey, pp 7–45

Magurran AE (2004) Measuring biological diversity, 2nd edn. Blackwell Science Ltd, Oxford

Majeed W, Rana N, Qamar SUR, Nargis S, Raja IA, Kanwal S, Naseem R (2019) Diversity of foliage insects around different canal territories: A case study of Dingroo and Kamal Pur canal, Faisalabad, Pakistan. GSC Biol Pharm Sci 6:07–15

Maqsood S, Rana N, Majeed W, Nargis S (2020) Effect of dawn and dusk on the diversity and abundance of arthropods in a mixed agroecosystem. Pak J Agric Sci 57:975–980

Mayhew MG, Ashkanasy NM, Bramble T, Gardner J (2007) A study of the antecedents and consequences of psychological ownership in organizational settings. J Soc Psychol 147:477–500

Meyer B, Jauker F, Steffan-Dewenter I (2009) Contrasting resource-dependent responses of hoverfly richness and density to landscape structure. Basic Appl Ecol 10:178–186

Michener CD (2000) The bees of the world. John Hopkins University Press, Baltimore, p 913

Mihoci I, Hrsak V, Kucinic M, Stankovic MV, Delic A, Tvrtkovic N (2011) Butterfly diversity and biogeography on the Croatian karst mountain Biokovo: Vertical distribution and preference for altitude and aspect? Eurp J Entomol 108:623–633

Moghimian N, Kooch Y (2013) The effect some of physiographic factors and soil Physico-chemical features of hornbeam forest ecosystem on earthworm's biomass. J Wood For Sci Technol 20:1–21

Morris EK, Caruso T, Buscot F, Fischer M, Hancock C, Maier TS, Meiners T, Muller C, Obermaier E, Prati D, Socher SA (2014) Choosing and using diversity indices: insights for ecological applications from the German biodiversity exploratories. Ecol Evol 4: 3514–3524

Nahmani J, Capowiez Y, Lavelle P (2005) Effects of metal pollution on soil macro-invertebrate burrow systems. Biol Fert Soil 42:31–39

Naseem R, Rana N, Koch EBA, Majeed W, Nargis S (2020) Abundance and diversity of foliage insects among different olericulture crops. GSC Biol Pharm Sci 10:62–69

Nieukerken EJ, Kaila L, Kitching IJ, Kristensen NP, Lees DC (2011) Order Lepidoptera. In: Zhang Z-Q (ed). Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness: Zootaxa pp 212–221

Oelbermann K, Langel R, Scheu S (2008) Utilization of prey from the decomposer system by generalist predators of grassland. Oecologia 155:605–617

Oksanen J, Blanchet FG, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H (2019) Community ecology package. https://cran.r-project.org/

Palacios-Vargas JG, Cutz-pool IQ, Trada-Barcenas YDA (2007) En: Luna, I., J.J. Morrone y D. Espinosa (eds.). Biodiversidad de la Faja Volcanica Transmexicana. Las Prensas de Ciencias. Universidad Nacional Autonoma de Mexico, Mexico, pp 113–126

R Development Core Team (2019) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available: http://www.r-project.org

Radeloff VC, Mladenoff DJ, Boyce MS (2000) The changing relation of landscape patterns and jack pine budworm populations during an outbreak. Oikos 90:417–430

Rana N, Saleem M, Majeed W, Jalal F, Ehsan N, Nargis S (2019) Diversity of arthropods regarding habitat specialty in agro-ecosystem of Faisalabad, Pakistan. GSC Biol Pharm Sci 6:01–08

Roe AD, Weller SJ, Baixeras J, Brown J, Cummings MP (2009) Evolutionary framework for Lepidoptera model systems. In: Goldsmith MR, Marec F (eds) Molecular biology and genetics of the Lepidoptera. CRC Press/Taylor and Francis (Contemporary topics in entomology series), Boca Raton, pp 1–24

Sanders NJ (2002) Elevational gradients in ant species richness: Area, geometry, and Rapoport's rule. Ecography 25:25–32

Sawada Y, Hirowatari T (2002) A revision of the genus *Acrotrichis Motschulsky* (Coleoptera: Ptiliidae) in Japan. Entomol Sci 5:77–101

Schoonhoven LM, Jermy T, Loon JJA (1998) Insect–Plant Biology. Chapman and Hall, London

Shannon CE (1948) A mathematical theory of communication. Bell Syst Tech J 27:379–423

Sharrkey MJ (2007) Phylogeny and classification of Hymenoptera. Zootaxa 1668:521–548

Shuriin L (2005) Bio systematic of the Nymphomyiidae (Insecta: Diptera): life history, morphology and phylogenetic relationships. Smithson Cont Zool 550:41

Sorensson M (2003) New records of feather wing beetles (Coleoptera: Ptiliidae) in North America. Coleopt Bull 57:369–381

Supraditareporn M, Pinthong R (2007) Physical, Chemical and microbiological changes during storage of orange juices. Int J Agri Biol 9: 726–730

Susila S (2007) Biodiversity of coastal environmental insects from Parangipettai area. M.Sc. thesis, Centre of Advanced Study in Marine Biology. Annamalai University

Symank A, Kearns CA, Thomas P, Christian FT (2008) Pollinating flies (Diptera): A major contribution to plant diversity and agricultural production. Biodiversity 9:86–89

Thomas P (2009) The economic importance of Diptera. J Nat Hist Mus pp 65–77

Tiple AD (2011) Butterflies of Vidarbha region Maharashtra, India: A review with and implication for conservation. J Threatened Taxa 3: 1469–1477

Triplehorn CA, Johnson NF (2005) Borror and DeLong's introduction to the study of Insects, 7th edn. Brooks/Thomson Cole, Toledo

Varchola JM, Dunn JP (2001) Influence of hedgerow and grassy field borders on ground beetle (Coleoptera: Carabidae) activity in fields of corn. Agric Ecosyst Environ 83:153–163

Wagner DL (2001) Moths. In: Levin SA (ed) Encyclopedia of biodiversity. Academic, San Diego, pp 249–270

Wilsey BJ, Potvin C (2000) Biodiversity and ecosystem functioning: Importance of species evenness in an old field. Ecology 81:887–892

Wilson EO (2006) Genomics: How to make a social insect. Nature 443: 919–920

Xin WD, Yin XQ, Song B (2012) Contribution of soil fauna to litter decomposition in Songnen sandy lands in northeastern China. J Arid Environ 77:90–95