Insect Fauna with Special Emphasis on their Abundance and Diversity in different Habitats of Kashmir Valley

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ABSTRACT

An assessment of aerial entomofauna is of utmost significance which offers inputs as part of the understanding for conservation and management of biodiversity. This study provides insights into aerial entomofauna dynamics in different habitats of Kashmir Himalaya. A random sampling design over line transects of 100 m were used for entomofauna collection. Overall, 188 species were collected from 10 different habitats/ecosystems, belonging to 13 orders and 63 families. Among the species collected from the various ecosystems, the order Lepidoptera was the most diverse in number (60 species), followed by Hymenoptera (28 species), Coleoptera (25 species), Diptera (24 species), Odonata (18 species), Orthoptera (12 species), Hemiptera (10 species), Homoptera (3 species), Trichoptera (3 species), Neuroptera (2 species), Heteroptera (1 species), Phasmatodea (1 species), and Mantodea (1 species). The highest number of individuals was recorded in habitats like protected forest areas (127 in Dachigam), followed by aquatic ecosystems (126 in Nigeen and 73 in Dal Lake), and the lowest in high altitude forests (12 in Dhara). Cluster analysis revealed the formation of two main clusters with Gulmarg being a riparian/transitional ecosystem type forming a separate cluster I, while the other 9 habitats forming the II cluster. Shannon-Wiener's diversity indices showed highest diversity of 3.83 at Gulmarg and low diversity of 2.2 at Dhara. The ordination of the abundance data using non-metric multidimensional scaling (NMDS) at stress value 0.11 in 2D space resulted in a clear separation between the locations of the sampled habitats.

Keywords: *Aerial entomofauna, Cluster analysis, Distribution, Diversity indices, Ecosystems, Kashmir Himalaya*

INTRODUCTION

Entomofauna are recognized as vital components of the natural ecosystems that sustain important environmental processes and services (Cardinale *et al.,* 2012; Cristo *et al.,* 2019). They regulate natural ecosystems and support diverse ecological services and functions of huge importance (Quijas *et al.,* 2019). Furthermore, they are characterized by a variety of a quite large number of classes displaying a broad range of environmental attributes. Entomofauna are predominantly sensitive to changes in environmental variables including the diversity of plants displaying specificity many times, the complexity of habitats, the structure of landscapes, moisture, topographic gradients, and climate anomalies (Dyck, 2010). They are important indicators of the quality of environments, considering their high degree of host-plant specificity and vulnerability to degradation of natural habitats (EEA, 2017). Given their presence in a broad range of habitats, the loss of one species may directly alter the delivery of key ecosystem services such as pollination and natural pest control

(Fox, 2006; Fox *et al.,* 2011). From the last few decades, ecologists and conservationists all over the world have been concerned about the worldwide decline of entomofauna (Newbold *et al.,* 2016; Simmons *et al.,* 2019).

Globally, the decline of entomofauna at an unprecedented rate, has challenged the viability of species, ecosystems, and their ecological services and functions (Barnosky *et al.,* 2011; IPBES, 2019). The decline of entomofauna not only implies the less abundance but also a more restricted geographical distribution of species that represents the first line towards the extinction of species. Anthropogenic activities like loss of natural habitats through intensification of agricultural activities, deforestation of natural habitats, urbanization, and industrialization seem to be the main drivers for the loss of species (Chapin *et al.,* 2000; Sánchez-Bayo and Wyckhuys, 2019). The warming temperatures as a result of climate change are believed to be one of the foremost drivers of entomofauna decline as the species thrive well only in narrow thermal thresholds and are particularly vulnerable to temperature upsurges (Breed *et al.,* 2012; Gilburn *et al.,* 2015). Besides, nowadays the use of chemical pesticides in agriculture and horticulture are thought of as the major causes for the decline of species at all levels of taxa (Weston *et al.,* 2014). As entomofauna species are particularly susceptible to various drivers, therefore continuous monitoring and assessment of biodiversity at habitat levels are vital and largely documented as basis to effectively report the current state of entomofauna biodiversity (Schmeller *et al.,* 2015).

Kashmir Himalaya in the Indian Himalayan region has varied geography, breathtaking natural landscapes, and a variety of habitats that sustain a large formation of biodiversity (Dar and Khuroo, 2020). However, the growing impacts of changing climate and large-scale land transformations across the Kashmir Himalaya (Dar *et al.,* 2020a, b; Dar *et al.,* 2021a, b, c), have put sturdy pressures on biodiversity, changing composition of communities and distribution pattern of species (Chapin *et al.,* 2000). Nevertheless, Kashmir Himalaya are known to support a great diversity of entomofauna species and thus their role as shelters for insect conservation needs to be reinforced. Therefore, it becomes imperative to have a knowledge of the aerial entomofauna, its distribution and dynamics in Kashmir Himalayan region. As compared to the larger animals and higher plants, the knowledge of aerial entomofauna in Kashmir Himalaya, however, is dispersed in a plethora of unpublished literature which is mostly inaccessible, incomplete, and at times obsolete. This necessitated the urge for having up-to-date documentation of aerial entomofauna in different habitats of the Kashmir Himalaya. Therefore, this study was designed along different habitats vis-a-vis altitudinal gradients to understand the diversity and community patterns of aerial entomofauna. We were primarily interested in testing two hypotheses. First the species richness and diversity are positively related with the richness of plant species in the sampled habitats. Second the diversity and abundance of entomofauna is higher at lower altitudes due to favorable environmental conditions compared to higher altitudes.

MATERIAL AND METHODS

Study area

The Valley of Kashmir is situated in the sub-tropical north temperate region of Asia in North-Western Himalayas. It lies between 33°20′ and 34°54' N latitudes and 73°55′ and 75°35′ E longitudes, covering an area of 101387 Sq. km (Fig. 1). Topographically, it is a deep elliptical bowl-shaped valley bounded by lofty mountains of the Pir-Panjal range in the south and southwest and the Great Himalayan Range in the north and east, with 64% of the total area being mountainous (Dar et al. 2021d). On account of its position, it is zoo-geographically cut off from Jammu in the south and Ladakh in the north, the two important provinces of Jammu & Kashmir State. The major characteristics of the Kashmir Himalayas are glaciers, snow peaks, deep valleys, and high mountain passes. There is a rich diversity of habitats such as lakes, swamps and marshes, springs, rivers, cultivated fields, orchards, roadside, wastelands, vegetable fields, subalpine and alpine meadows, moderate and steep mountain slopes, and permanent glaciers, etc. One of the chief features contributing to the global fame of Kashmir is the rich biodiversity that adorns its captivating landscapes. Being phytogeographically located at the intersection of Holarctic and Paleotropical Floristic Realms and falling within the North-Western Himalaya. It represents a unique bio-region owing primarily to its varied topography and habitat heterogeneity along with a wide elevational range.

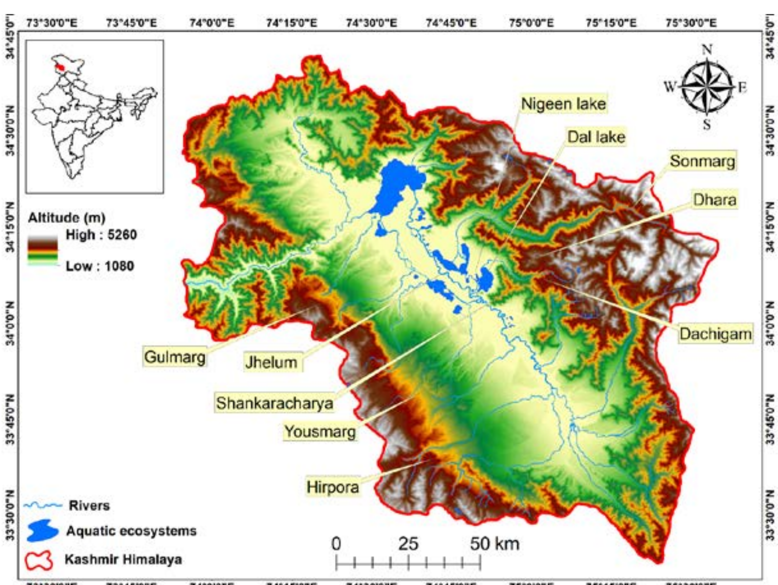

Fig. 1. Study area map showing the different habitats sampled for collection of insect fauna

Entomofauna surveys

Sampling and Collection

The present article incorporates detailed field observations of insect fauna in Kashmir Valley at different altitudes ranging from 1080 to 5260 m. A stratified random sampling design was chosen for the collection of entomofauna. A total of 10 habitats were selected for the insect collection. The samplings were performed after every 14 days in summer and autumn season. Within each of the 10 habitats, 4 sites were selected from each of these 10 habitats to collect insect species. Entomofauna were collected using different methods. Sweep insect nets and various other methods such as hand picking, bait traps, and yellow pan traps were used for collection of insects. Sweep insect nets were used by performing 20 sweeps over a line transect of 100 m length. The sampling was carried out only during the day time. Along some aquatic habitats in the study area, sweeping was carried along the shores and banks of rivers and lakes. To increase the inventory of species in the sampled areas, opportunistic sampling was also carried out. Besides, walking surveys (10 min) were also performed in the morning, afternoon, and at the evening (Scanlon and Petit, 2008).

Preservation and identification

The collected species were killed by placing them in glass jar bottles containing cotton poured with ethyl-acetate. The jars were labeled and brought to the laboratory for further analysis. The samples were pinned by piercing the specified entomological pins through the body of the insects. The specimens were spread and mounted in a spreading board for further taxonomic studies. The identification of species was done using standard works (Wynter-Blyth, 1957; Kehimkar, 2008).

Statistical treatment

Shannon (H'), Simpson (1/D), Menhinick, Margalef, and Berger-Parker diversity indices were measured to compare the diversity of entomofauna between different habitats. Using statistical software PRIMER 7, we tried to make NMDS analysis for entomofauna species diversity versus environmental gradients by using both presence-absence and abundance data. In order to down-weigh the influence of the dominant class, the data was transformed by fourth-root transformation. The stress value was used to test the depictions according to the NMDS solutions (Clarke and Warwick, 2001).

RESULTS AND DISCUSSION

During the survey period, a total of 188 species belonging to 13 orders and 63 families were recorded from the 10 sampled habitats, details are provided in Appendix 1. The order Lepidoptera was the most diverse in number (60 species), followed by Hymenoptera (28 species), Coleoptera (25 species), Diptera (24 species), Odonata (18 species), Orthoptera (12 species), Hemiptera (10 species), Homoptera (3 species), Trichoptera (3 species), Neuroptera (2 species), Heteroptera (1 species), Phasmatodea (1 species), and Mantodea (1 species) (Fig. 2). Among the families, the family Nymphalidae was most diverse family with the higher number of organisms.

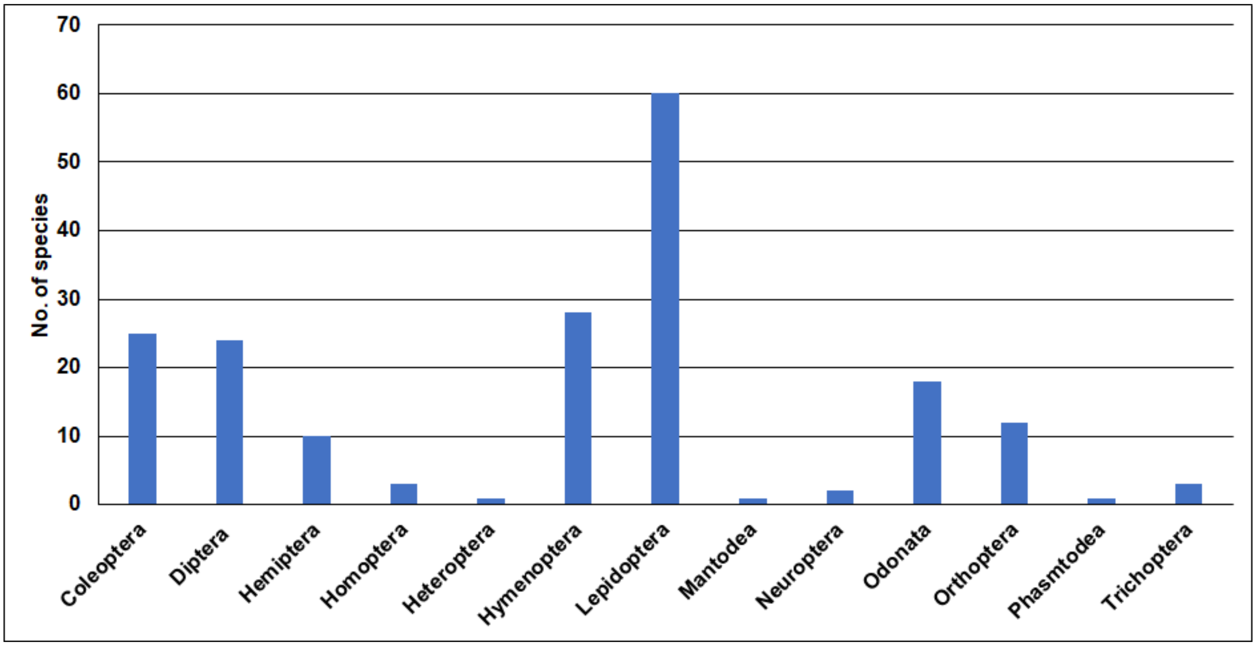

Fig. 2. Family composition showing number of families identified in the study area

Diversity in habitats

Based on the number of insect species recorded in 10 different habitats, the Gulmarg showed the highest number of 47 species followed by Shankaracharya (37 species), Jhelum (29 species), Dachigam (26 species), Hirpora (26 species), Sonmarg (26 species), Yousmarg (25 species), Nigeen Lake (22 species), Dal Lake (13 species), and Dhara (9 species) (Table 1). A considerable variance in the richness values was observed among different habitats. Field observations indicated that the observed variation in the richness of species is explained by vegetation types, with few vegetation types differing significantly from one another. Gulmarg ecosystem differed significantly from others this is due to the fact that Gulmarg being a mix of riverine and forest ecosystem thereby produces the transition/riparian zones responsible for the edge effect of the species. The insect species also established a peak in low-altitude areas of the Kashmir Himalaya. The low altitude areas showed maximum species richness, after that it decreases towards mid-altitude areas and showed minimum diversity and uniqueness in the higher altitude areas (Fig. 3).

Table 1. Diversity of species in different habitats of Kashmir Himalaya

S. No.	Ecosystem	Type of Ecosystem	No. of Individuals	No. of species
1.	Gulmarg	Riparian/Transitional	64	47
2.	Hirpora	Forest	44	26
3.	Yousmarg	Forest	27	25
4.	Dhara	Forest	12	9
5.	Nigeen Lake	Aquatic	126	22
6.	Sonmarg	Forest	39	26
7.	Shankracharya	Forest	42	37
8.	Dal Lake	Aquatic	73	13
9.	Dachigam	Forest	127	26
10.	Jhelum	Aquatic	53	29

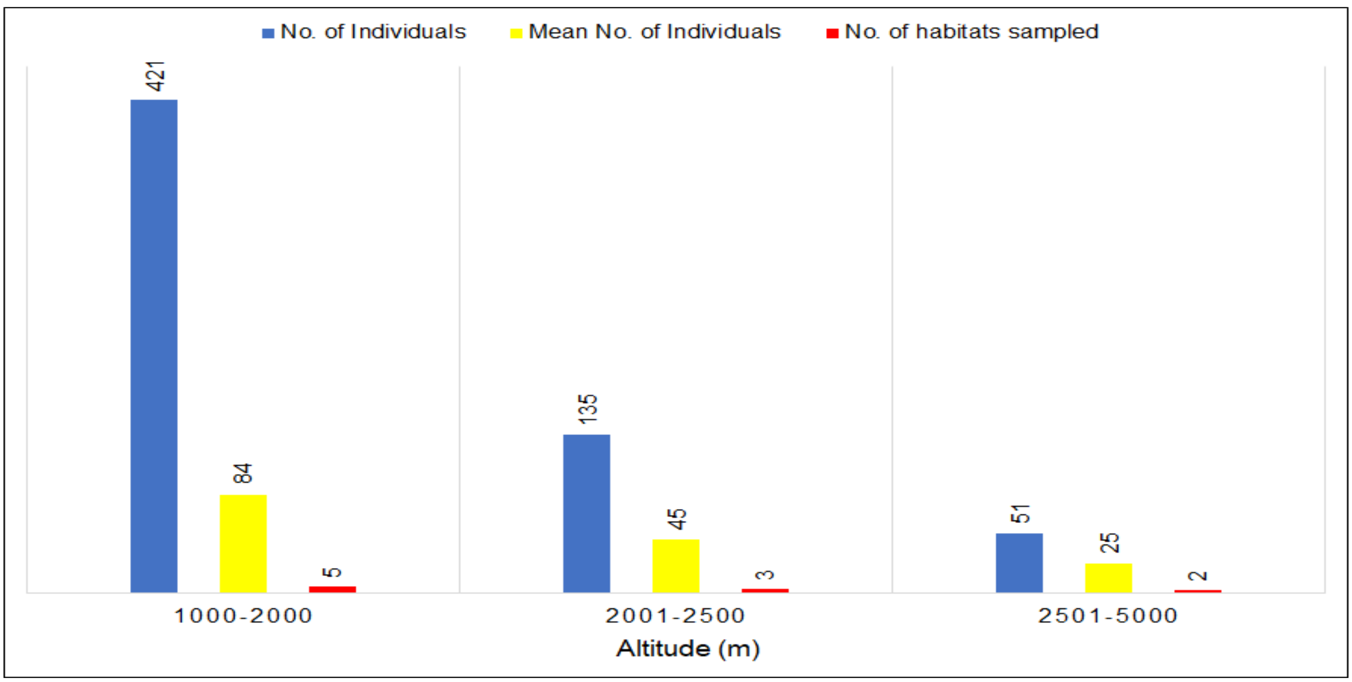

Fig. 3. Altitude wise distribution of entomofauna species in the study area

Diversity indices

Diversity indices of species were calculated and are reflected in (Table 2). Shannon index values were highest at Gulmarg (3.85) and lowest at Dhara (2.22). The Simpson index, however, showed almost the same pattern at all sites. Menhinick index values were found highest at Gulmarg (6.86) and lowest at Dhara (3.00). The Margalef index also showed the same trend being highest at the Gulmarg (11.95) and lowest at Dhara (3.64).

Table 2. Diversity indices of entomofauna collected in different habitats of Kashmir Himalaya

	Gulmarg	Hirpora	Yousmarg	Dhara	Nigeen	Sonmarg	Shankaracharya	Dal Lake	Dachigam	Jhelum
Taxa	47	26	25	9	22	26	37	13	26	29
Dominance	0.02	0.04	0.04	0.11	0.05	0.04	0.03	0.08	0.04	0.03
Shannon	3.85	3.26	3.22	2.20	3.09	3.26	3.61	2.57	3.26	3.37
Simpson	0.98	0.96	0.96	0.89	0.95	0.96	0.97	0.92	0.96	0.97
Menhinick	6.86	5.10	5.00	3.00	4.69	5.10	6.08	3.61	5.10	5.39
Margalef	11.95	7.67	7.46	3.64	6.79	7.67	9.97	4.68	7.67	8.32
Berger-Parker	0.02	0.04	0.04	0.11	0.05	0.04	0.03	0.08	0.04	0.03

Cluster analysis

The hierarchical cluster analysis shows the two main cluster formations in which the Gulmarg ecosystem form a separate cluster (Cluster I) having similarity with no other ecosystem whereas, a collective cluster II was formed for the other nine ecosystems (Fig. 4). Cluster II was further divided into many sub-clusters. The River Jhelum ecosystem and Shankrachaya forest ecosystem formed one sub-cluster and other ecosystems like Dachigam National Park, Yousmarg, Sonmarg, Hirpora, Nigeen Lake, Dhara, and Dal Lake having similarities and formed another sub-cluster.

Interestingly 23 species were sampled which were restricted only to the Gulmarg ecosystem, these include 7 species from Lepidoptera viz: *Aporia crataegi., Callerebia scanda., Hepialus sp., Lasiommata sp., Magpie sp., Pararge megaera., Plebejus argus,* 6 species from Hymenoptera viz: *Bombus sp., Crabro sp., Cuchoo wasp sp., Hairy sand wasp sp., Chrysididae sp., Platylumia brevis,* 4 species from Orthoptera viz: *Conophyma mitcheli., Conophyma sp., Hyphinomos sp., and Leva sp.,* 3 species from Coleoptera viz: *Corymbites pectinicornis., Criocephalus rusticus., Agriotes sp.,* 2 species from Homoptera viz: *Picromerus sp., Eurydema oleraceum.,* and 3 from Diptera viz: *Musca sp., Fannia canicularis., Hippobosca sp.* The species like *Colia slitholia, Pieris brassiceae,* and *Vespa vulgaris* were cosmopolitan, found almost in every ecosystem (Fig. 5).

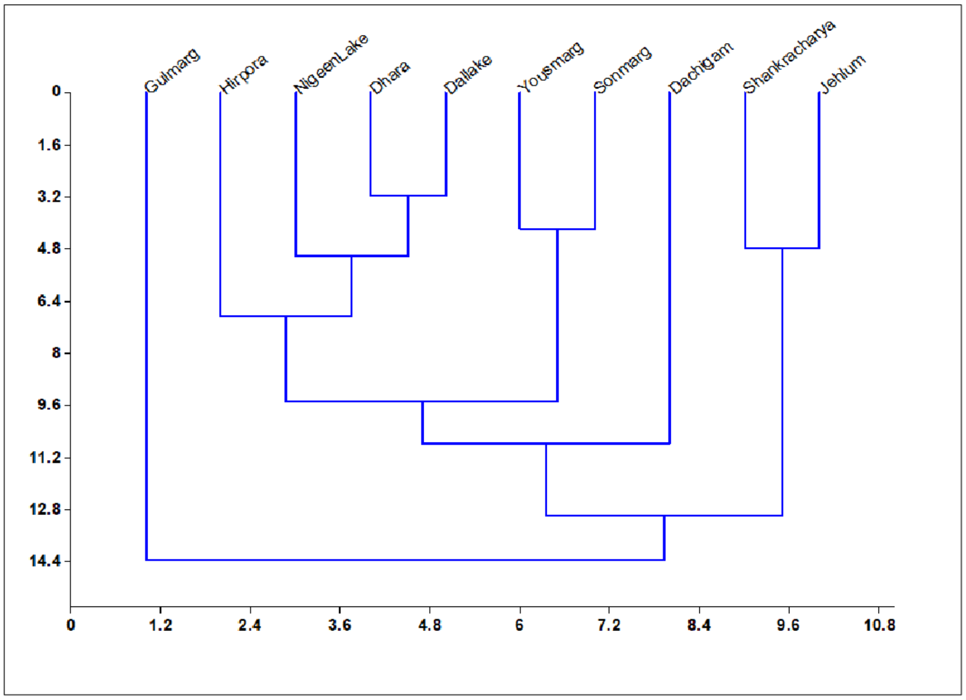

Fig. 4. Hierarchical cluster analysis between 10 sampled habitats in Kashmir Himalaya

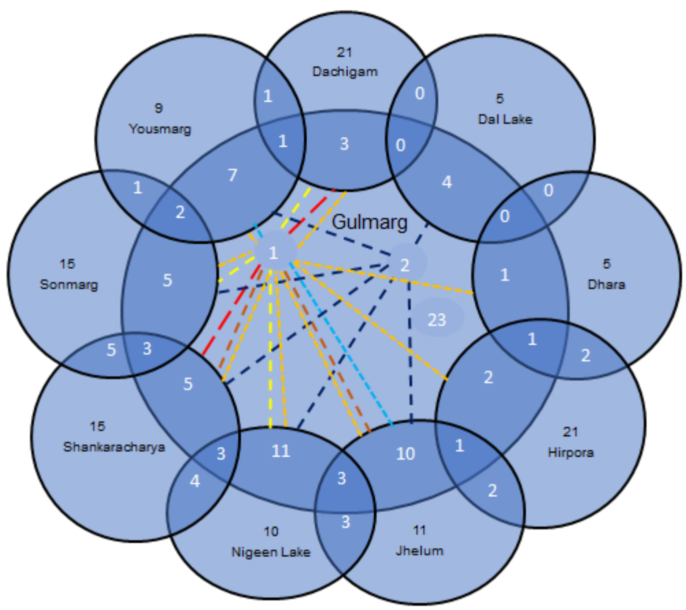

Fig. 5. Similarity and dissimilarity of entomofauna species between different habitats in Kashmir Himalaya

NMDS

Ordination of entomofauna community data based on the Bray-Curtis similarity index was performed using NMDS to evaluate assemblage of different habitats. NMDS is an indirect gradient analysis approach which produces an ordination based on a distance or dissimilarity matrix. NMDS attempts to represent as closely as possible the pairwise dissimilarity between objects in a low-dimensional space. The 2D stress value is 0.11. The ordination of the abundance data using NMDS (Fig. 6) in 2D space resulted in a clear separation between the locations of the sites. A major distinction in species composition was found among different habitats, Dachigam at the left side, Hirpora at right side, Dal Lake at the right top, Yousmarg and Sonmarg at the bottom, Dhara at the right bottom and other sites at the middle of the biplot.

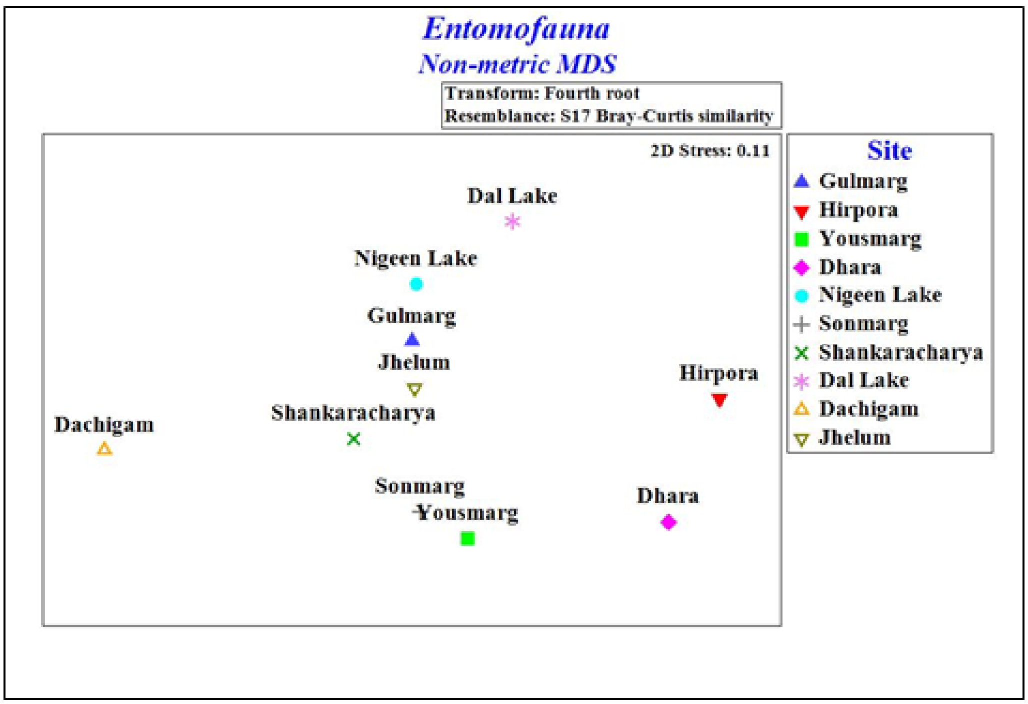

Fig. 6. Non-metric multidimensional scaling ordination plot of entomofauna species from 10 habitats

In Kashmir Himalaya, the distribution of entomofauna is expected to co-vary with the distribution of their host plants even on a small local scale within different vegetation types (Muller *et al.,* 2011; Bashir *et al.,* 2017). The order Lepidoptera was most diverse as compared to the other orders and this could be related to the high association of the lepidopteran taxa with vegetation characteristics such as density and richness of herbs, shrubs, plants, and canopy cover described as foremost predictors of species abundance (Kitching *et al.,* 2000). Besides, changes in stratification and vegetation may also reflect differences in the composition of communities at the generic and family level (Xu *et al.,* 2017). Among different habitats sampled, Gulmarg showed the highest diversity of species and this could be related to the presence of transition/riparian zones present in the area that thrives the species populations (Sabo *et al.,* 2005). The other reasons attributed to the differences among other habitats are the heterogeneity of habitats caused by the availability of natural gaps in between, moderate levels of disturbances, and the availability of sunshine (Arya and Joshi, 2014). A noteworthy difference in the composition of species between different habitats was observed. The observed differences in habitats are related to different environmental conditions and gradients at different places. The richness of entomofauna species in the lower-altitudes is related to the presence of optimum temperatures and brighter sunlight in these areas. Whereas, the harsh climatic conditions like cold low temperature, higher incidence of cloudy sky, and presence of a lesser number of plant species at higher altitudes may be the reasons for lower values of richness, low abundance, and low diversity of species at higher altitudes (Joshi *et al.,* 2004; Hoiss *et al.,* 2012). Further the highest abundance and diversity of species at lower altitudes could also be attributed to the high diversity, density, and higher richness of plant and tree species (Sharma *et al.,* 2016). This supports the idea that low altitude areas might function as keystone habitats in the Kashmir Himalaya as they contribute disproportionately to the biological diversity. However, it merits further attention and research to have more thorough and specific studies to reach on some concrete conclusions.

Aquatic ecosystems such as lakes, wetlands and rivers have contributed greatly to the rich biological diversity in the study area as the water bodies prolong the temporal window for flowering and growth of plants. Despite low coverage in the study area, the aquatic ecosystems harbored the high number of individuals and is a sign of greater microhabitat diversity and better feeding and breeding grounds prevailing in these habitats for completion of a part of species life cycles (Kawnsar-ul-Yaqoob *et al.,* 2008). The abundance of aquatic habitats in the mid-altitudes of Kashmir Himalaya has been associated with the presence of high food quality, availability of a larger number of micro-habitats, low water flow, and stable substrata common in these habitats (Straka *et al.,* 2020). Maneechan and Prommi, (2015) believe that the diversity of insects around aquatic ecosystems tends to increase with increased diversity of aquatic plants, nutrients, and water availability and these optimum environmental conditions favor their abundance around Dal Lake, Nigeen Lake, and river Jhelum ecosystem. Vu and Vu, (2011) also pointed out that with the increase and diversification of aquatic plants, the productivity and number of insects per unit area also increases.

CONCLUSION

Based on the present study, it was observed that the valley of Kashmir is able to support a high diversity of aerial entomofauna. The order

Lepidoptera was most diverse in the number of individuals, and thus can be used as an indicator to monitor plant zone and as substitute species for conservation and management practices. The highest diversity and richness of species occurred in habitats having high diversity, density, and higher richness of plant and tree species. High species richness and diversity prevail in the lower-latitudes up to 2000 m due to favorable environmental conditions and species richness and diversity decrease from mid-altitude to high altitude areas. Our results also indicate that the richness and diversity of species increase near riparian zones and aquatic habitats. Further, the study is hoped to offer a piece of baseline information that would be of great help to set an indicator for future changes in habitats and also for environmental impact assessment studies. Future research highlighting the response of entomofauna species to increasing temperatures and changing climate with major shifts on species climatic niche along three non-exclusive axes; range, physiology, and phenology seems indispensable.

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