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Distribution and Biodiversity Indices of predaceous Coccinellidae (Coleoptera) of Uttarakhand, North India

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ABSTRACT An extensive survey was conducted to explore the biodiversity of predaceous ladybirds (Coleoptera Coccinellidae) and to evaluate their biodiversity indices from five zoogeographical habitats in Uttarakhand, North India. A total of 1883 ladybird specimens with 18 species were recorded belonging to three sub-families (Chilocorinae Scymninae Coccinellinae), three tribes (Platynaspidini Scymnini Coccinellinae) and thirteen genera. Seven-spotted ladybird, *Coccinella septempunctata* (Linnaeus, 1758) was highly abundant (32.13% of total frequency), followed by *Menochilus sexmaculatus* (Fabricius, 1781) (23.69%). *Platynaspis saundersi* (Crotch, 1874) was the least abundant ladybird species. Shannon Wiener's index was the highest (2.1012) for Chamoli region exhibiting it as most species diverse habitat, which is the reason for the high pooled SW index of 2.0349 from Uttarakhand. Low Simpson's diversity index (D) was evaluated from Uttarkashi (0.1720) and Chamoli (0.1758) revealing a relative increase in coccinellid diversity from other habitats. Margalef index measuring the species richness was the highest in Chamoli (5.0634). High Pielou's evenness Index was evaluated from Uttarkashi and Chamoli suggesting that species are the most evenly distributed in these habitats. Sorenson's Index was highest (0.7368) between Nainital and Almora, which reveals maximum similarity in the species belonging to these two habitats. Similar habitats in altitude and climate have high similarity index, which suggests aggregation of ladybird species is highly dependent on climatic conditions and altitude.

KEY WORDS Ladybirds; Coccinellids; Shannon Weiner Index; Diversity Index; Species.

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INTRODUCTION

Ladybird beetles (Coleoptera Coccinellidae) are important group of insects having immense potential for the biocontrol of various phytophagous insect and acarine pests (Omkar & Pervez, 2016). Their ecology, prey-predator interactions and food relationships have been studied in great detail (Omkar & Pervez, 2016; Hodek et al., 2012). The Indian subcontinent is enriched by ladybird diversity with more than 261 reported species belonging to 57 genera that prey upon a wide range of aphids, scale insects, mealy bugs, phytophagous mites, whiteflies, nymphs of pentatomid bugs, etc. (Omkar & Pervez, 2000a). Numerous reports occur on sampling of different species of ladybirds in North India (Omkar & Pervez 1999, 2000b, 2002; Joshi & Sharma, 2008; Sharma et al., 2017) with almost no information on their diversity indices. However, data on these indices have been reported from a few provinces of Croatia (Franin et al., 2014), Iran (Biranvand et al., 2014; Jafari, 2014; Shayesteh et al.,

2015) and Pakistan (Hayat & Khan, 2014; Ahmed et al., 2017).

Biodiversity mainly comprises of two attributes, species richness and species evenness. The "richness" indicates the number of species present in a designated area whereas "evenness" stands for the relative abundance of each species (Vanclay 1992). Poorani (2002) listed the biodiversity of the Indian subcontinent. Omkar & Pervez (2004) catalogued the predator-prey association of Indian predaceous Coccinellidae that features an updated record of ladybird fauna and their prey range. However, biodiversity indices regarding ladybird fauna was lacking despite the vast richness in Indian ladybird biodiversity. Amongst various regions, Uttarakhand lies in northern India with a total area of 53,483 km^2. The region is mostly hilly and mountainous and is covered by forests. Average annual temperature is about 21.8 °C and 1896 mm of precipitation falls annually. The rich forest area and the average temperature is optimal for rich biodiversity. Joshi & Sharma (2008) reported some new species from Haridwar, Uttarakhand. Recently, Rasheed & Buhroo (2018) evaluated biodiversity indices of three districts of Kashmir and found that thirteen ladybird species are evenly distributed in these regions. Similarly, surveys of coccinellid diversity in the rice fields from different states of India revealed high diversity indices from Almora, Uttarakhand (Shanker et al., 2018). This indicates that the coccinellid study of the area has been less studied in the past and there is a need to explore it for future reference. Hence, the present study was aimed to evaluate the species diversity, richness, and evenness of the ladybird fauna in Uttarakhand, India.

MATERIAL AND METHODS

An extensive survey was conducted to collect the ladybirds from September 2017 to February 2018 in five different altitudes of Uttarakhand, North India viz. (i) Almora, (ii) Chamoli, (iii) Nainital, (iv) Udham Singh Nagar (USN) and (v) Uttarkashi (Fig. 1, Table 1). These places were chosen as they differ in the altitude and climatic conditions. The adult ladybirds were collected and brought to the laboratory. These ladybirds were initially characterized by their morphology. These were studied carefully under a WILD Stereoscopic trinocular assembly (Lyzer) connected to the computer. Further, published literature was taken as a source of reference in distinction on the species level. A few specimens of each ladybird species were manually kept in sealed glass tubes containing 70% alcohol and sent to Dr J. Poorani, Scientist, National Bureau of Agricultural Insect Resources, Bengaluru-560024, India for the identification of the species. Different biodiversity indices were evaluated to estimate the species diversity, abundance and similarities in host locality range for every prey-site using following formulae:

Figure 1. Map of India showing different zoogeographical habitats of India.

Site	Latitude (N)	Longitude (E)	Altitude (ft)
Almora	29.5892 ° N	79.6467 ° E	6106 ft
Chamoli	30.0708° N	79.5027° E	4600 ft
Nainital	29.3803° N	79.4636° E	6837 ft
Udham Singh Nagar	30.2937°N	79.5603°E	715 ft
Uttarkashi	30.7268 ° N	78.4354 ° E	3799 ft

Table 1. Study area of Uttarakhand, North India.

Shannon Weiner index (H)

$$H = -(\sum P_i \; Ln \; P_i)$$

Where, P_i is the proportion between the number of a particular species and the total number of individuals of all species, and Ln P_i is the natural logarithm of the above proportion. The H-value is usually between 1.5 and 3.5. It rarely surpasses 4.5. If this value is near 4.6, then it indicates that biodiversity is evenly distributed between all the species.

Simpson's diversity index (D)

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

Where n_i = number of organisms of each species, and N = the total number of organisms of all species. This index could be understood by deciphering the values from 0 to 1. As zero represents infinite diversity and one means no diversity, this shows precisely that biodiversity of a particular ladybird species decreases as it increases in the index.

Sorenson's Index (SQ) of species similarity

$$SQ = \frac{2C}{S1 + S2}$$

Species similarity between two communities was calculated by Sorenson's index (SQ), where C is the number of species that are commonly present in two communities or zoogeographic habitats, S1 is the total number of species found in community 1, and S2 is the total number of species found in community 2. The value of SQ ranges from 0 to 1. With this index, 0 represents no similarity and one complete similarity. That is, the bigger the value, the higher the similarity (Southwood & Henderson, 2000).

Margalef's Index (d)

$$d = \frac{S - 1}{Log_e N}$$

Where "S" is the number of species and "N" is the total number of individuals. This index (Margalef 1968, 1969) measures the species richness from different zoogeographical habitats of Uttarakhand.

Pielou's evenness Index

$$J = \frac{H}{Ln(S)}$$

Where "S" is the total number of species in the community (richness) and "H" is Shannon's diversity index. Different SW Indices and heights were subjected to Pearson's correlation using SAS (2002). It is a measure of equitability, which suggests how evenly the individuals are distributed amongst different species.

RESULTS AND DISCUSSION

A total of 1883 specimens were collected during the study periods which were identified into eighteen species of thirteen genera from three subfamilies (Table 2). Of these, 582, 551, 356, 235 and 159 ladybird specimens were collected from Chamoli, Udham Singh Nagar (USN), Nainital, Almora and Uttarkashi, respectively (Table 3). High numbers of ladybirds were collected from the hilly area with lesser altitude of Terai, Chamoli and USN, as temperature during daytime ranged between 20°C to 30°C in these areas, which seem to be optimal to the ladybirds (Pervez & Omkar, 2004). However, other three habitats experienced temperature ranging 10 to 20 °C, which seems less suitable for the ladybirds. Temperature seems to be the key factor for the abundance of both ladybirds and their habitats in terms of host plant availability.

Seven-spot ladybird, *Coccinella septempunctata* was the maximally distributed species (32.13% of frequency distribution), followed by *Menochilus sexmaculatus* (23.69%) and *Hippodamia variegata* (11.31%). These generalist ladybirds are eurytopic and cosmopolitan in distribution, as they can tolerate a wide range of temperature. *Platynaspis saundersi* was the stenotopic least abundant species (0.21% frequency distribution). From the data, the species abundance in its locality is well understood, and an idea could be generated regarding their habitat.

Shannon-Wiener's (SW) index was 1.4623, 1.4772, 1.5817, 2.0555, and 2.1012 for five habitats, viz. Nainital, USN, Almora, Uttarkashi, and Chamoli, respectively. The pool data from these habitats resulted in a total SW index of 2.0349 (Fig. 2). SW Index was inversely correlated with increase

in the altitude (r = -0.032; P<0.05). High SW Index for Chamoli was largely due to lesser altitude and moderate temperature range that support ladybird biodiversity. Low values of SW Index for Nainital and USN state an unequal abundance of biodiversity, which is likely due to the difference in their altitudes. Jeffreis et al. (2013) studied the characteristics and drivers of high altitude flights and noted great differences in the flight capabilities, which is the major reason for the unequal abundance in the zoogeographical habitats that have great altitude differences. Invasive ladybirds, especially *Harmonia axyridis* (Roy et al., 2016) and *C. septempunctata*, had a tendency to displace the indigenous species and establish themselves in the new habitats. These are mostly generalist ladybirds with wide prey range and thermal tolerance, which enable them to successfully establish themselves in new habitats. Usually, indigenous ladybirds have stenotypic habits and could not resist this invasion and become intraguild prey or emigrate from these habitats. In the current study, *C. septempunctata* and *M. sexmaculatus* are two such invaders and had dominated the local ladybird fauna. They exploited their food resources, which were both aphid and non-aphid resources.

Simpson's index is used to measure the abundance of the individual in the sampling unit or sampling area. This index could be understood by deciphering the values from 0 to 1. As zero repre-

S. No.	Sub family	Tribe	Species Identified	Number	Frequency (%)
1.	Chilocorinae	Platynaspidini	***Platynaspis saundersii*** Crotch,1874	04	0.21
2.	Scymninae	Scymnini	*Scymnus posticalis* Sicard, 1913	31	1.65
3.	Coccinellinae	Coccinellinae	*Aiolocaria hexaspilota* (Hope,1831)	10	0.53
4.			*Alloneda dodecaspilota* (Hope, 1831)	12	0.64
5.			*Calvia albida* Bielawski, 1972	26	1.38
6.			*Menochilus sexmaculatus* (Fabricius, 1781)	446	23.69
7.			*Coccinella septempunctata* (Linnaeus, 1758)	605	32.13
8.			*Coccinella transversalis* Fabricius, 1781	212	11.26
9.			*Harmonia eucharis* (Mulsant, 1850)	56	2.97
10.			*Harmonia sedecimnotata* (Fabricius, 1801)	36	1.91
11.			*Hippodamia variegata* (Goeze, 1777)	213	11.31
12.			*Illeis cincta* (Fabricius, 1798)	14	0.74
13.			*Illeis confusa* Timberlake, 1943	10	0.53
14.			*Micraspis discolor* (Fabricius, 1798)	76	4.04
15.			*Oenopia sauzeti* (Mulsant, 1866)	24	1.27
16.			*Propylea dissecta* (Mulsant, 1850)	78	4.14
17.			*Propylea luteopustulata* (Mulsant, 1850)	22	1.17
18.			*Palaeoneda auriculata* (Mulsant, 1866)	08	0.42
TOTAL				**1883**	**100**

Table 2. Subfamilies, Tribes, Number and Frequency of ladybird species collected from five zoogeographic areas.

sents infinite diversity and one means no diversity, this shows precisely that biodiversity of a particular ladybird species decreases as it increases in the index. The calculated values of Simpson's diversity index (D) were 0.1720, 0.1758, 0.2682, 0.2712, and 0.2712 from zoogeographic habitats, viz. Uttarkashi, Chamoli, USN, Almora, and Nainital. The pooled value of Simpson's diversity index (D) for Uttarakhand, North India was 0.1899. Moreover, the value of this index is not varying too much among different localities establishing quite sparse distribution and richness. Simpson indices ranged from 0.36 to 0.58 (Akhavan et al., 2013) and from 0.67 to 0.90 (Biranvand et al., 2014) in different regions of Iran. The low values of this index in the current study revealed that Uttarakhand, North India is highly enriched in the coccinellid diversity with high diversity in Uttarkashi and Chamoli regions.

Margalef index measuring the species richness from different zoogeographical habitats of Uttarakhand was 2.1889, 2.7435, 3.3740, 4.5426, and 5.0634 for USN, Nainital, Almora, Uttarkashi, and Chamoli, respectively. Total Margalef's index for Uttarakhand, North India was 5.1911. Shanker et al. (2018) evaluate this index to be 10.14 from the rice fields of Almora, which is three times more than our data. This suggests that ladybirds tend to aggregate more in the rice fields than our crops.

	Different Zoogeographic Habitats					
Ladybird Species	**Almora**	**Chamoli**	**Nainital**	**US Nagar**	**Uttarkashi**	**Total**
Platynaspis saundersi	0	4	0	0	0	**4**
Scymnus posticalis	6	20	5	0	0	**31**
Aiolocaria hexaspilota	0	0	0	0	10	**10**
Alloneda dodecaspiolota	0	0	0	0	12	**12**
Calvia albida	0	18	0	0	8	**26**
Menochilus sexmaculatus	58	55	102	221	10	**446**
Coccinella septempunctata	102	156	150	141	56	**605**
Coccinella transversalis	25	34	56	90	7	**212**
Harmonia eucharis	0	45	0	0	11	**56**
Harmonia sedecimnotata	0	22	0	0	14	**36**
Hippodamia variegata	24	166	0	0	23	**213**
Illeis cincta	0	10	0	4	0	**14**
Illeis confusa	2	4	0	4	0	**10**
Micraspis discolor	10	12	23	25	6	**76**
Oenopia sauzeti	2	14	6	0	2	**24**
Propylea dissecta	0	0	12	66	0	**78**
Propylea luteopustulata	6	14	2	0	0	**22**
Palaeoneda auriculata	0	8	0	0	0	**8**
Total	**235**	**582**	**356**	**551**	**159**	**1883**

Table 3. Number of individuals of different ladybird species recorded from five different zoogeographic habitats of Uttarakhand, India.

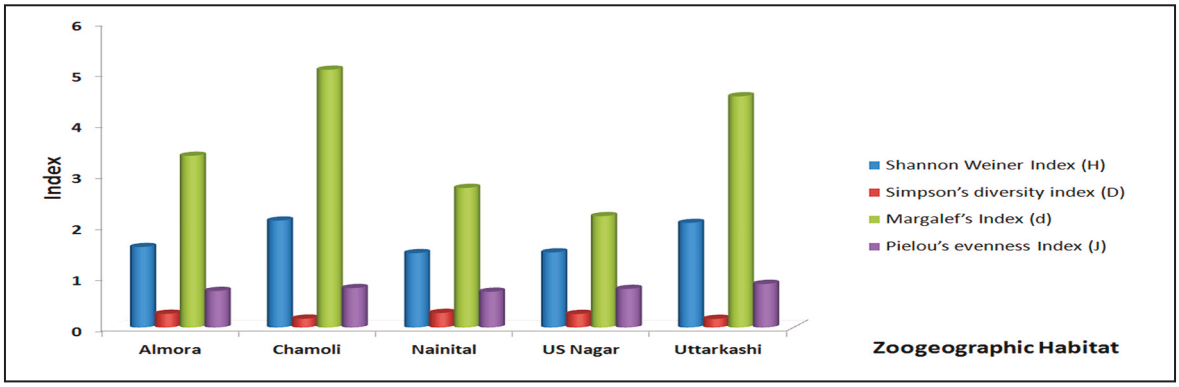

Figure 2. Different Biodiversity indices of the ladybird species from five zoogeographical habitats of Uttarakhand, N- India.

Zoogeographic Habitats	Almora	Chamoli	Nainital	USN	Uttarkashi
Almora	0.0000	0.6923	0.7368	0.5556	0.5455
Chamoli	0.6923	0.0000	0.6087	0.5455	0.6923
Nainital	0.7368	0.6087	0.0000	0.6667	0.4211
USN	0.5556	0.5455	0.6667	0.0000	0.4444
Uttarkashi	0.5455	0.6923	0.4211	0.4444	0.0000

Table 4. Sorenson's Index (SQ) of species similarity amongst the ladybird diversity fauna from five different zoogeographic habitats of Uttarakhand, North India.

This index ranged from 2.325 to 5.316 in Pakistan (Hayat et al., 2016).

Pielou's evenness Index is a measure of equitability, which suggests how evenly the individuals are distributed amongst different species. The value of this index was 0.7032, 0.7199, 0.7591, 0.7759, and 0.8572 for Nainital, Almora, USN, Chamoli, and Uttarkashi, respectively. Sorenson's Index (SQ) of species similarity amongst the ladybird diversity from five zoogeographic habitats of Uttarakhand, North India has been presented (Table 4). Sorenson's Indexwas to the maximum (0.7368) when compared between Nainital and Almora, while similarity was to the minimum between Uttarkashi and Nainital. This index clearly indicates that similar climatic and zoogeographic conditions support similar biodiversity regardless of the distance between them.

It is concluded that ladybird diversity is highly enriched in Uttarakhand with *C. septempunctata* and *M. sexmaculatus* dominating the ladybird fauna. Confined and stenotypic species (e.g., *P. saundersi*) are least abundant, which is largely due to the invasion of these generalists species. Zoogeographical areas, like Chamoli, have high abundance of ladybird species and species richness due to moderate climatic conditions. Similar habitats in altitude and climate have high similarity index, which suggests aggregation of ladybird species is highly dependent on climatic conditions and altitude.

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