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Diversity of Butterflies (Lepidoptera: Papilionoidea) in a Temperate Forest Ecosystem, Binsar Wildlife Sanctuary, Indian Himalayan Region

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ABSTRACT

Observational studies aiming to elucidate the differences in butterfly fauna along altitudinal gradients in Binsar Wildlife Sanctuary were carried out during 2014-2015. The study revealed a total of 2591 individuals belonging to 46 species and 35 genera under six families of butterflies. Four species under legal protection were also recorded. Family Nymphalidae was the most dominant with 22 species followed by Pieridae (12 species), Lycaenidae (4 species), Papilionidae, Riodinidae (3 species each) and Hesperiidae (2 species). Higher values of species richness, abundance and diversity were recorded for transects at the low altitudinal site. Species such as *Aglais caschmirensis* (Fruhstorfer), *Pieris canidia indica* Evans, *Pieris brassicae* Linnaeus and *Byasa polyeuctes letincius* (Fruhstorfer) were most abundant, while *Dodona ouida* Hewitson, *Udara dilectus* Moore, *Aulocera padama* Kollar, *Talicada nyseus* (Guérin-Méneville) and *Argynnis childreni* (Gray) accounting for 1.38% of the total individuals of butterflies, were least abundant species during the study period. Results of the study on diversity and distributions of butterflies are preliminary ones which would help in strengthening the biodiversity status of the Binsar Wildlife Sanctuary.

INTRODUCTION

The Indian Himalayan Region is a repository for rich biological diversity and to ensure its proper conservation, protected areas in the form of Biosphere Reserves, National Parks, Sanctuaries and Conservation Reserves have been established (Rodgers & Panwar 1988). Uttarakhand, the newest Himalayan state in India, stretching across 53,485 sq km, is blessed with ample natural resources and harbours a charismatic range of biodiversity. Almost 64.79% of its total geographical area is designated as forest area while forest cover is limited to 35% of the geographical area (FSI 2011). In recent decades, the state has witnessed a plethora of natural disasters aggravated by man-made factors which have affected the ecology of the region at a large scale (Tayal et al. 2015).

Despite the central role of nature reserves in global efforts for conservation of biodiversity, policies such as downgrading and downsizing of the protected areas have been contentiously adopted, especially in developing countries of the world (Mascia & Pailler 2010). Based on national priorities, the disparity in ranking the importance of protected areas underscore the need for resilient and robust conservation strategies which must be adopted in the present era with an unprecedented rate of biodiversity loss and extinction. The protected areas located in the Indian Himalayan Region especially those which are low profiled ones hold immense potential to enhance the components of biological representativeness, integrity and human sustenance in the region (Rawal & Dhar 2001). Binsar Wildlife Sanctuary (hereafter referred as BWLS), which is a natural habitat for many species of flora and fauna has recently received the attention of the government and non-government organizations and is being developed as a hot tourist destination in the calm and pristine environment of the Kumaon Himalaya. From different *in situ* conservation sites of the Indian Himalayan Region, numerous scientific records regarding distribution and diversity of butterflies have been published by various workers (Arora 1994, Arora 1995, Uniyal & Mathur 1998, Joshi et al. 2004, Joshi 2007, Joshi & Arya 2007, Singh 2009, Joshi et al. 2008, Kumar 2008, Bhardwaj & Uniyal 2013, Pandey et al. 2013, Tewari & Rawat 2013, Qureshi et al. 2014, Arya 2015, Sondhi & Kunte 2016, Singh & Sondhi 2016, Arya & Dayakrishna 2017, Kumar et al. 2017). Till date, no comprehensive approaches have been made to understand butterfly diversity of the BWLS. Considering the importance of butterflies as efficient pollinators essential for continuity of the ecosystem services (Tiple et al. 2006), their ecological roles in the food web and as indicators (Kunte 2000, Hill et al. 2002), for promoting conservation programs (New 2011) and ecotourism as well (Arya et al. 2018), it is imperative to evaluate species composition, status and habitat preferences of butterflies from the present region. Moreover, butterflies, in

particular, are facing a threat of range contraction both across the latitudinal and altitudinal gradients due to global climate change. Thus steps of inventorizing biodiversity patterns along such gradients have strong conservation implications (Acharya & Vijayan 2015). Keeping this in view, the present study was primarily aimed at examining species composition and diversity of butterflies along altitudinal gradients in the BWLS for their future conservation in the protected area. The present study also aims to generate information for conservation authorities regarding the development and management of the sanctuary.

MATERIALS AND METHODS

Study Area

BWLS, with a total geographical area of 47.67 sq km is located in Almora and Bageshwar districts of the state Uttarakhand (Fig. 1). The sanctuary lies under geographical coordinates 29°39'-29°44'N and 79°41'-79°49'E and the altitude ranges between 1200 to 2500 m above sea level. BWLS represents one of the oldest protected landscapes in the Kumaon Himalayan region characterized by hilly terrains, ravines and ridges providing a wide array of microhabitats to diverse flora and fauna. Before India's independence in 1947, the study area was notified as the 'Protected Forest' in 1893 and later its status was revived as the 'Reserve Forest' in 1897. After independence, the status was upgraded to 'Wildlife Sanctuary' by the Government of India in 1988. The region of BWLS is also renowned for its religious, historical, cultural and recreational values. The sanctuary is earmarked with two zones, core zone (4 sq km) and a buffer zone (43.67 sq km). Human activities are restricted in the core zone of the sanctuary which comprises biodiversity of strategic importance. The vegetation is represented by a characteristic moist temperate type of forest surrounded by villages and agricultural lands. The sanctuary is home to 40 species of trees, 26 shrubs, 50 herbs, 19 grasses and six ferns (Ilyas 1998) which are congenial for the survival of butterflies. The monthly mean temperature ranges from 2.2 to 15.5°C during winter and from 17.20 to 26.6°C during the summer season. The annual mean precipitation is about 1041.8 mm (Kala & Majila 2013).

Based on altitudinal variations, two distinct sites were selected for the sampling of butterflies. Two permanent transects with distinct habitat features each of length 800m on different altitudes were laid down at each study site. The characteristic features of each transect selected in the study site have been summarized in Table 1. Human activities such as agriculture practicing, livestock grazing and tourism are frequent at the lower altitudinal site, while the higher altitudinal site remained least disturbed during the observations made in the present study.

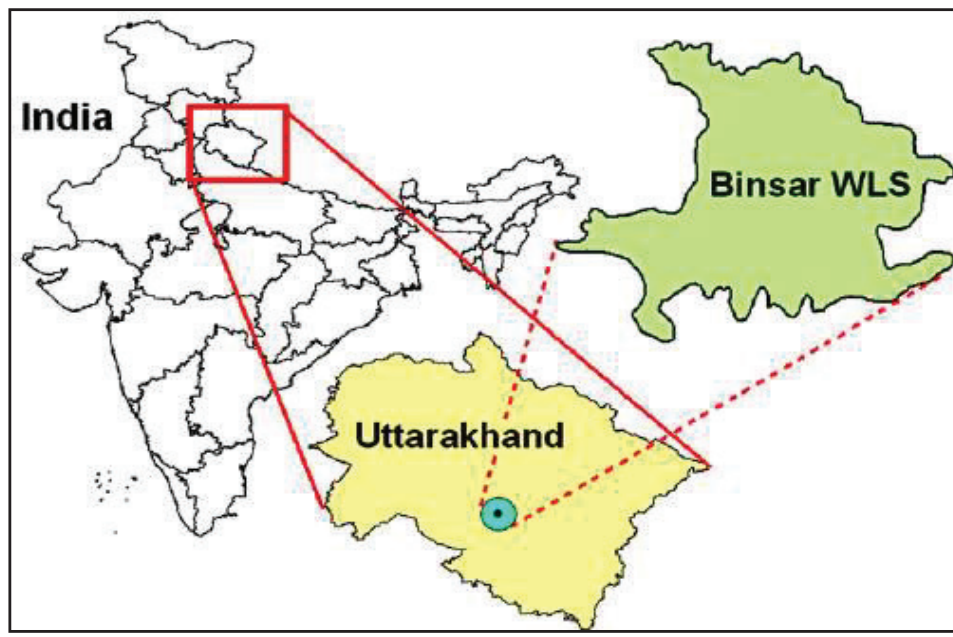

Fig. 1: Line drawing map showing the location of BWLS.

Sampling of Butterflies

Census on butterfly populations was undertaken in consecutive four days of each month at different sites of BWLS from July 2014 to June 2015. Both transects at lower altitudinal zone were walked with constant pace for one hour each between 08:30 hr to 11:30 hr and on the next day, between 12:00 hr to 15:00 hr for each sampling period. The same sampling method was followed for each transect at higher altitudinal zone from the next two consecutive days. 'Pollard Walk' method was adopted for the sampling of butterflies during cloudless days (Pollard 1979, Pollard & Yates 1993). The individuals of butterflies were counted up to 5m on both sides of each transect. Identification of butterflies was carried out in the field visually through photography and with the assistance of the field guides (Haribal 1992, Kehimkar 2014, Sondhi & Kunte 2018). Butterflies were neither killed nor collected during the present study. In the case, sight records where the identification was not possible, butterflies were captured by using the aerial net avoiding any harm and identified subsequently released at the same spot of capture. The climatic factors such as monthly temperature and relative humidity associated with each transect were also recorded using thermo-hygrometer.

Status of Butterflies

To determine the local status of the identified butterflies in the sanctuary, species were characterized into four groups based on the overall number of sightings in the study area, namely, fairly common (with more than 50 sightings), common (between 21-50 sightings), uncommon (between 11-20 sightings) and rare (with less than 10 sightings), respectively.

Similarity Index

The species composition between transects was measured using the formula of Magurran (1988): Similarity index (C) = 2c/a +b

Where, a is the number of species in area A; b is the number of species in area B; c is the number of shared species between the two areas.

Statistical Analysis

Data were pooled to compare the diversity of butterflies across different sites along altitudes. Various measures of diversity (Simpson, Shannon-Weiner, evenness, Margalef and Berger Parker) were computed by using the program PAST 3.4 (Hammer et al. 2014). Bray Curtis cluster and their similarity matrix of butterflies across different transects were analyzed with the help of ecological analysis software, BIODIVERSITY PRO VERSION 2 (Lambshead et al. 1997).

RESULTS AND DISCUSSION

During the study, a total number of 2591 individuals belonging to 46 species and 35 genera under six families of butterflies were counted from four permanent transects with 24 species common to all transects (Tables 2 and 3). Family Nymphalidae was the most dominant with 18 genera and 22 species followed by Pieridae (8 genera, 12 species), Lycaenidae (4 genera, 4 species), Papilionidae (2 genera, 3 species), Riodinidae (1 genus, 3 species) and Hesperiidae (2 genera, 2 species). Such variations at both generic and species levels, especially among butterfly communities, reflect the habitat complexity and range of larval host plants available in the

Table 1: Characteristic features of selected study sites in the BWLS.

Sampling Sites		Altitude (m a.s.l.)	Temp. Range (°C)	Relative Humidity (%)	Habitat characteristics and major vegetation
Low Altitude (1200-1700 m)	Transect 1 (Ayarpani)	1250	9-29	30-75	Pine dominant with large canopy gaps forest; *Pinus roxburghii*, *Pyrus pashia*, *Myrica esculenta*, *Quercus leucotrichophora*, *Cornus macrophylla, Berberis asiatica*
	Transect 2 (Binneshwar Mahadev)	1650	8.3-27	56-88	Oak forest with moderate canopy gaps; *Quercus semicarpifolia*, *Quercus leucotrichophora*, *Quercus floribunda*, *Aesculus indica*, *Juglans regia, Rubus ellipticus*
High Altitude (2100-2500 m)	Transect 3 (Jhandidhar)	2100	6-26	57-89	Oak-Deodar forest with dense canopy cover; *Quercus semicarpifolia*, *Quercus floribunda*, *Cedrus deodara, Daphne papyracea, Deutzia staminea*
	Transect 4 (Zero point)	2500	5.5-24	57.8-90	Hilltop grassland surrounded with *Quercus semicarpifolia*, *Rhododendron arboreum* and *Cedrus deodara*

Table 2: Butterfly species composition and their relative abundances at four transects in BWLS.

S.No.	Lepidoptera: Papilionoidea	Low Altitude Site			High Altitude Site			Relative Abundance (%)	Status
		T 1	T 2	Total	T 3	T 4	Total		
	Family: Nymphalidae								
1	*Aglais cashmirensis* (Fruhstorfer)	170	120	290	90	48	138	16.51	FC
2	*Argynnis childreni* (Gray)	6	3	9	-	-	-	0.34	R
3	*Argynnis hyperbius* Linnaeus	17	11	28	10	6	16	1.69	C
4	*Aulocera swaha* Kollar	35	16	51	15	4	19	2.70	FC
5	*Aulocera padma* Kollar	-	-	-	6	2	8	0.30	R
6	*Callerebia annada* (Moore)	17	16	33	12	5	17	1.92	C
7	*Callerebia scanda* (Kollar)	12	10	22	8	7	15	1.42	C
8	*Danaus chryssippus* (Linnaeus)	14	6	20	-	-	-	0.77	UC
9	*Euploea core* (Cramer)	35	16	51	-	-	-	1.96	FC
10	*Junonia iphita* Cramer	17	13	30	11	10	21	1.96	FC
11	*Kallima inachus* Boisduval	-	-	-	20	9	29	1.11	C
12	*Kaniska canace* (Linnaeus)	12	5	17	4	2	6	0.23	C
13	*Lasiommata schakra* (Kollar)	8	3	11	-	-	-	0.42	UC
14	*Lethe verma* Kollar	20	9	29	7	6	13	1.62	C
15	*Neptis sankara* (Kollar)	8	4	12	2	2	4	0.61	UC
16	*Neptis zaida* Westwood	20	-	20	10	5	15	1.35	C
17	*Peudergolis wedah* (Kollar)	12	6	18	-	-	-	0.69	UC
18	*Phalanta phalantha* (Drury)	28	14	42	-	-	-	1.62	C
19	*Sephisa dichroa* (Kollar)	6	2	8	3	2	5	0.50	UC
20	*Vanessa cardui* Linnaeus	25	11	36	10	7	17	2.04	FC
21	*Vanessa indica* Herbst	20	10	30	10	5	15	1.73	C
22	*Ypthima nareda nareda* (Kollar)	13	4	17	3	1	4	0.81	C
	Family: Pieridae								
23	*Belenois aurota* (Fabricius)	36	14	50	-	-	-	1.92	C
24	*Catopsilia pomona* Linnaeus	40	20	60	-	-	-	2.31	FC
25	*Colias fieldi* Menetries	17	8	25	8	7	15	1.54	C
26	*Eurema brigitta rubella* Wallace	12	6	18	9	5	14	1.23	C
27	*Eurema hecabe* Linnaeus	26	12	38	-	5	5	1.65	C
28	*Eurema laeta* Boisduval	16	7	23	10	6	16	1.50	C
29	*Gonepteryx rhamni nepalensis* Linnaeus	33	17	50	15	9	24	2.85	FC
30	*Aporia agathon agathon* (Gray)	-	10	10	10	2	12	0.84	C
31	*Aporia agathon phryxe* (Boisduval)	18	9	27	-	-	-	1.04	C
32	*Pieris brassicae* Linnaeus	65	50	115	42	38	80	7.52	FC
33	*Pieris canidia indica* Evans	100	96	196	82	38	120	12.19	FC
34	*Pontia daplidice* (Linnaeus)	-	-	-	12	3	15	0.57	UC
	Family: Lycaenidae								
35	*Heliophorus sena* Kollar	64	59	123	33	22	55	6.86	FC
36	*Lycaena panava* (Kollar)	31	16	47	-	10	10	2.04	FC

S.No.	Lepidoptera: Papilionoidea	Low Altitude Site			High Altitude Site			Relative Abundance (%)	Status
		T 1	T 2	Total	T 3	T 4	Total		
37	Talicada nyseus (Guérin-Méneville)	6	2	8	1	-	1	0.34	R
38	*Udara dilectus* Moore	-	-	-	5	-	5	0.19	R
	Family: Papilionidae								
39	*Byasa polyeuctes letincius* (Fruhstorfer)	37	30	67	10	7	17	3.24	FC
40	*Papilio bianor polyctor* Boisduval	23	20	43	15	7	22	2.50	FC
41	*Papilio polytes* Linnaeus	29	21	50	10	-	10	2.31	FC
	Family: Riodinidae								
42	*Dodona durga durga* (Kollar)	20	10	30	10	5	15	1.73	C
43	*Dodona eugenes* Bates	12	6	18	6	3	9	1.04	C
44	*Dodona ouida* Hewitson	5	-	5	-	-	-	0.19	R
	Family: Hesperiidae								
45	*Ochlodes brahma* Moore	10	6	16	-	-	-	0.61	UC
46	*Tagiades cohaerens cynthia* Evans	6	5	11	-	-	-	0.42	UC
	Total	1101	703	1804	499	288	787		

Abbreviations: T 1 = Transect 1; T 2 = Transect 2; T 3 = Transect 3; T 4 = Transect 4; FC = Fairly common; C = Common; UC = Uncommon and R = Rare

region (Chowdhury 2014). In terms of the total number of individuals reported, Nymphalidae was the most dominant family (43.07% of the total number of individuals), followed by Pieridae (35.24%), Lycaenidae (9.61%), Papilionidae (8.07%), Riodinidae (2.97%) and Hesperiidae (1.04%), respectively (Table 3). Such domination of Nymphalid butterflies might be due to the polyphagous nature of their larval forms and similar pattern with the predominance of family Nymphalidae have also been extensively registered from different protected areas of Uttarakhand (Joshi 2007, Joshi & Arya 2007, Joshi et al. 2008, Kumar 2008, Singh 2009, Bhardwaj & Uniyal 2013, Uniyal et al. 2013). As far as knowledge on butterfly diversity from BWLS is concerned, it is important to mention here that the present study is the first constituting systematic survey based on standardized methods. Due to differences in habitat and sampling time and efforts, it would be inappropriate to make quantitative comparisons in the diversity of butterflies from other protected areas of Uttarakhand. However, the richness of butterfly fauna in BWLS was fairly higher when compared to the nearby protected area, Askot Wildlife Sanctuary, with known records of 32 species so far (Pandey et al. 2013). Similarly, Arya & Dayakrishna (2017) reported 36 species of butterflies from Nandhaur Wildlife Sanctuary located at foothills of the Kumaon Himalayan Region. Also, Smetacek (2012) reported 243 species of butterflies from Nainital district in the Kumaon region during 1951-2010, which is a long term survey compared to the short term survey conducted in the current research.

Based on the observations, *Aglais caschmirensis* Kollar was the most abundant and frequently sighted species in all transects constituting 16.51% of the total individuals of butterflies recorded in the present study. The other frequently observed butterflies in the sanctuary includes species such as *Aulocera swaha* Kollar, *Junonia iphita* Cramer, *Vanessa cardui* Linnaeus, *Gonepteryx rhamni nepalensis* Linnaeus, *Pieris brassicae* Linnaeus, *Pieris canidia indica* Evans, *Heliophorus sena* Kollar, *Byasa polyeuctes letincius*

Table 3: Number of genera, species and individuals of different families of butterflies recorded from BWLS.

S. No.	Family	Number		
		Genera	Species	Individuals
1	Nymphalidae	18	22	1116
2	Pieridae	8	12	913
3	Lycaenidae	4	4	249
4	Papilionidae	2	3	209
5	Riodinidae	1	3	77
6	Hesperiidae	2	2	27

(Fruhstorfer) and *Papilio bianor polyctor* Boisduval. These species exhibited a declining trend in their abundance across transects that were laid along increasing altitudes. On the other hand, five species were recorded as rare including *Dodona ouida* Hewiston, *Udara dilectus* Moore, *Aulocera padama* Kollar, *Talicada nyseus* (Guerin-Meneville) and *Argynnis childreni* (Gray), which altogether accounted for 1.38% of the total individuals of butterflies recorded during the study period. These species were reported rarely from one or two transects. Butterfly species composition of sites at a lower and higher elevation was rather similar (similarity index of 0.789) and this was true across all three dominant families with similarity indices of Nymphalidae 0.777, Pieridae 0.8 and Lycaenidae 0.857.

Transect 1 supported maximum numbers of species of butterflies (41 species), followed by Transect 2 (40 species), Transect 3 (32 species) and Transect 4 (31 species), respectively. Twelve species of butterflies were recorded from transects at the lower altitudinal site (Transect 1 and 2) with the most frequently and commonly observed species among them being *Belenois aurota* (Fabricius), *Catopsilia pomona* Linnaeus, *Aporia agathon phryxe* (Boisduval), *Euploea core* (Cramer), *Phalanta phalantha* (Drury) while species such as *Lasiommata schakra* (Kollar), *Danaus chryssippus* (Linnaeus), *Pseudoergolis wedah* (Kollar), *Ochlodes brahma* Moore and *Tagiades cohaerens cynthia* Evans were recorded occasionally with 11 to 20 number of sightings. Four species of butterflies *Aulocera padama* Kollar, *Kallima inachus* Boisduval, *Pontia daplidice* (Linnaeus) and *Udara dilectus* Moore with varied degree of recorded relative abundance were restricted to the higher altitudinal site. In comparison with the findings of Hannyngton (1910-11), all recorded species have a wide distribution in the Kumaon Himalayan region. No endemism in the species was recorded. However,

Table 4: Various diversity indices calculated for the butterfly community across different transects in BWLS.

Diversity indices	Transect 1	Transect 2	Transect 3	Transect 4	Low Altitude Site	High Altitude Site
Species number	41	40	32	31	42	34
Individuals	1101	703	499	288	1804	787
Simpson D	0.947	0.9293	0.9179	0.9205	0.9412	0.9204
Shannon- Wiener	3.339	3.138	2.959	2.942	3.283	2.993
Evenness	0.6872	0.5765	0.6026	0.6115	0.6345	0.5864
Margalef	5.711	5.949	4.99	5.298	5.468	4.949
Berger Parker	0.1544	0.1707	0.1804	0.1667	0.1608	0.1753

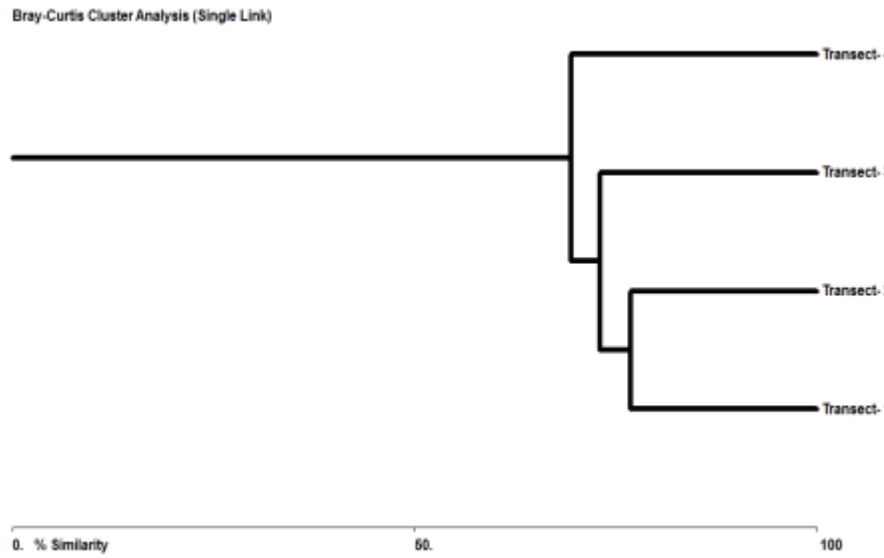

Fig. 2: Bray Curtis cluster analysis of quantitative data on butterflies.

five species are legally protected under the Indian Wildlife Protection Act of 1972 namely, *Neptis sankara* (Kollar) under Schedule I, *Aporia agathon agathon* (Gray), *Neptis zaida* Westwood and *Pontia daplidice* (Linnaeus) under Schedule II and *Euploea core* (Cramer) under Schedule V (Anonymous 2006).

It is a well-studied aspect of Lepidopteran ecology that habitats at the lower elevations yield more number of species than those at the higher elevations (Lien 2013). The significant differences in the values of the Shannon diversity index as a measure of alpha diversity along altitudes were observed during the study period (Table 4). The calculated diversity value was higher for Transect 1 (3.339), followed by Transect 2 (3.138), Transect 3 (2.959) and Transect 4 (2.942), respectively. The low dominance values indicate that species of butterflies were distributed more or less evenly across transects. Such values indicate a significant decrease in species richness and diversity of butterflies with the increase in altitude supporting the observations made by Lewis et al. (1998), Lien (2013) and Joshi & Arya (2007). The similarity of species composition among different transects has also been presented in Fig. 2. The similarity matrix from the quantitative data showed that taxonomic composition of butterflies was much similar in the mixed oak forests of transects that were laid at the lower altitudinal site, corresponding to the value of 76.82%, followed by Transect 2 and Transect 3 with a similarity index value of 73.04%. Transect 4 laid at high altitude in the hilltop grassland stood out clearly showing linkage at the similarity matrix value of 39.16%. The overall observations made in the present study suggest that habitat complexity, floral diversity and climatic variables such as temperature and relative humidity associated with each transect might act as major drivers and determinants of the altitudinal patterns of butterfly assemblages in the sanctuary.

Protected areas are critical for nature conservation and maintaining ecosystem services and thus inventorying biodiversity in such zones is of prime importance (Vina & Liu 2017). Owing to the diversified vegetation pattern along altitudes, the sanctuary provides sufficient natural resources required for survival of a good range of butterflies throughout the year. Despite the religious, cultural and biological significance of the BWLS, it remained a low profiled protected area of the state Uttarakhand. The unplanned and improper tourism management and tremendous pressure from factors such as slash and burn system, the prevalence of frequent forest fires especially in the pine forests during summers, overgrazing mainly close to the lower altitudinal zone of the sanctuary, pose potential threats of regional loss and extinction of biodiversity. Thus, our study suggests that the region must be monitored for other biological resources which would assist in managing and preserving endangered flora and fauna as well as in strengthening the status of the sanctuary. The preliminary results on butterflies revealed in the present study are also expected to provide necessary information to the conservation planning authorities for proper management of the BWLS while also allowing scope and direction for future research and opportunities of ecotourism in the sanctuary.

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