HIGH-ALTITUDE BUTTERFLY FAUNA OF GANGOTRI NATIONAL PARK, UTTARAKHAND: PATTERNS IN SPECIES, ABUNDANCE COMPOSITION AND SIMILARITY

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ABSTRACT
Mountain habitats have been under severe threats due to the enormous population increase during the last few decades, and thus it is important to conserve biodiversity in these landscapes before many species go extinct. Due to the focus on larger charismatic species in conservation, less glamorous and abundant taxa remain neglected. We studied butterfly diversity in Gangotri National Park, Uttarakhand, India during April-November 2008. Butterflies were sampled along 29 transects in Gangotri and Nilang valleys. Transects were distributed across various elevations, ranging from 2800 m amsl to 5200 m amsl. The vegetation in the park is very diverse and falls within five forest types due to the variations in topography, climate, aspect and elevation. A total of 1639 butterfly individuals representing 34 species, 29 genera and five families were recorded during the study. The highest butterfly species richness, abundance and diversity were recorded in Himalayan dry/moist temperate forest. The highest number of unique species was also recorded in Himalayan dry/moist temperate forest, and the number declined with increasing elevation. Among the five butterfly families, the highest species richness and abundance was accounted for by the family Nymphalidae. Three distinct butterfly communities were identified on the basis of cluster analysis that supported the idea that each vegetation type supports a distinct butterfly assemblage. About 47% of the butterflies were confined to a single vegetation type each, reflecting the specificity of their host plants. As most butterflies were found to be restricted to specific vegetation and elevation zones, regular monitoring and conservation of these habitats is important for conservation of butte flies and other biodiversity in the few remnant fragile high-altitude habitats.

INTRODUCTION
The Himalaya are part of the world's largest mountain complex and a buffer to major realms viz., the Oriental, Palaearctic and Ethiopian realms (Mani, 1994). Biogeographically, the Himalaya are categorized into two zones: (1) Zone 1, 1A Trans Himalaya (Ladakh Mountains) and 1B Tibetan plateau (b) Zone 2 is divided into four provinces (2A North Western, 2B Western, 2C Central and 2D Eastern Himalaya) (Rodgers et al., 2000). Rodgers and Panwar (1988) categorized the entire Himalayan region of Uttarakhand under one biogeographic province, the Western Himalaya (2B) (602,848 km^2). Gangotri National Park (NP) is the largest protected area (PA) in this zone and harbours a rich high-altitude biodiversity, which makes this PA important for protection and management of representative Western Himalayan biodiversity.

Drawing up an inventory of the biodiversity is of primary importance in biodiversity conservation for sustainable development, particularly in threatened and fragmented landscapes such as the Western Himalaya, which harbours a unique assemblage of flora and fauna of considerable conservation importance. In comparison with higher plants and larger animals, the inventory of insects in the Western Himalayan landscape is still fragmentary and incomplete. In order to know how and where to protect biodiversity, it is imperative that we learn more about the diversity of terrestrial arthropods, which may constitute 80% or more of the global diversity but have too often been neglected by resource managers and conservation planners (Wilson, 1988, 1992; Colwell & Coddington, 1994; Longino, 1994).

Assuming that carefully selected focal taxa can serve as a proxy for biodiversity overall (Kerr *et al*., 2000), several insect taxa have been tested for their utility as indicators in various ecosystems at multiple spatial scales (McGeoch, 1998). It has been suggested that butterflies have a role as indicators in conservation planning (Ehrlich & Murphy, 1987; Nelson & Andersen, 1994; DeVries *et al.*, 1997) and are often proposed as bioindicators of forest health and surrogate taxa for various biodiversity groups (Hayes *et al*., 2009). Butterflies meet many of the criteria proposed to define useful indicator groups: they have short

Highbrown Silverspot Fabriciana adippe: A rare butterfly that flies between 3500 and 5200 m in dry alpine scrub habitat in Nilang Valley

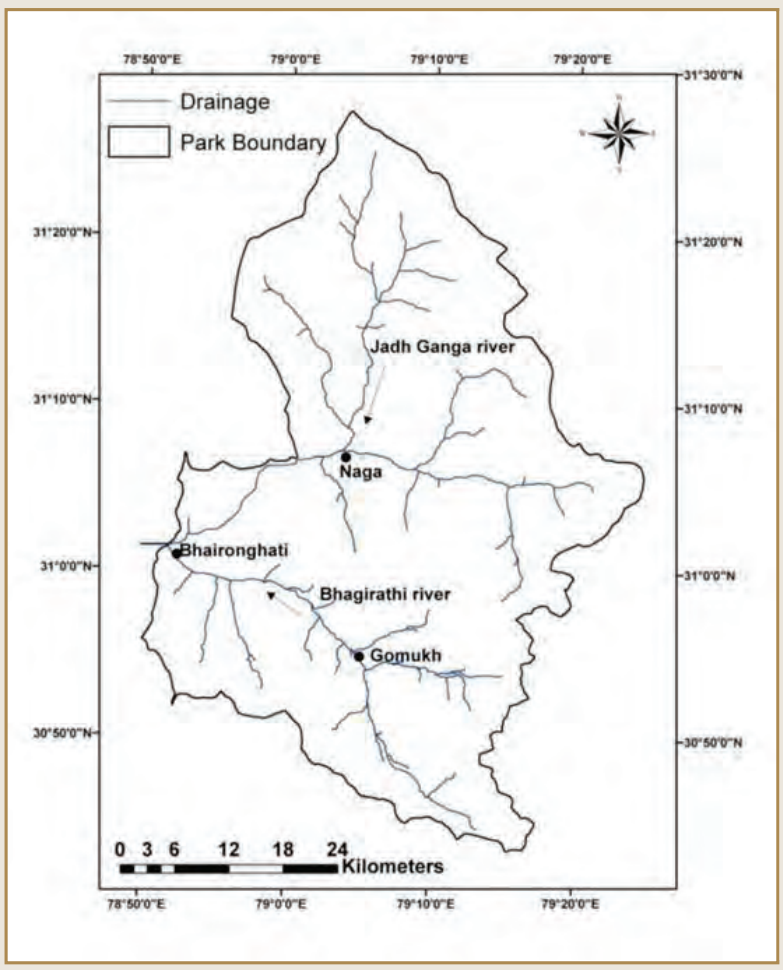
generation times, are day-flying, are diverse and are easily identifiable. Furthermore, butterfly taxonomy, distributions, and natural history are better studied than for any other insect taxon (Gilbert & Singer, 1975; Vane-Wright & Ackery, 1984). In the current paper, we studied the species richness, abundance and diversity of butterflies in various elevations and four major vegetation zones in Gangotri National Park, Uttarakhand in 2008. We assess the completeness of the inventory and document the family composition and community structure of butterflies. We discuss the similarity between the butterfly assemblages of different elevational transects.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in Gangotri National Park (NP) (30°50′-31°12′N, 78°45′-79°02′E), which is located in Uttarkashi District of the northern Indian state of Uttarakhand. It is the largest (2,390 km^2) protected area in the state. The north-eastern park boundary runs along the international boundary with China. The park area provides viable continuity with Govind National Park in the west and Kedarnath Wildlife Sanctuary in the south. The elevation ranges from 1,800 to 7,083 m amsl. It falls within biogeographical zone 2B of the western Himalaya (Rodgers & Panwar, 1988) (Fig. 1), including a considerable stretch of snow-clad mountains and glaciers. The Gangotri glacier, after which the park has been named, is one of the holy shrines of Hindus and is located inside the park. It attracts large numbers of tourists and pilgrims. High ridges, deep gorges, precipitous cliffs, crags, glaciers and narrow valleys characterize the area.

Figure 1.



Map of Gangotri National Park

A large variation in elevation and aspect inside the PA results in a diversity of vegetation, grouped in five major forests types (Champion & Seth, 1968):

1. Himalayan moist temperate forest

2. Himalayan dry temperate forest

3. Sub-alpine forest

4. Moist alpine scrub

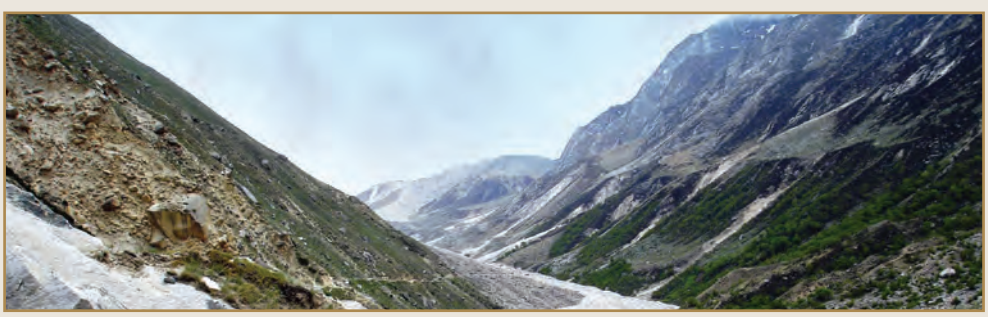
5. Dry alpine scrub

Gangotri NP is accessible through two major river valleys, *viz*., Gangotri and Nilang valleys. Although, the entire NP was categorized under Western Himalaya (2B) by Rodgers & Panwar (1988), Nilang Valley and the surrounding region can be safely categorized under Trans-Himalaya (Zone 1) (Chandola *et al*., 2008). A historical account of Nilang Valley has been provided by Atkinson (1981). Very few studies or surveys have been conducted in the area. So far, 15 species of mammal and 150 bird species have been documented from within the park (Parmanand *et al*., 2000). Naithani (1988) provided a botanical account involving 170 species of flowering plant from a part of Gangotri NP.

PLATE I VEGETATION ZONES SAMPLED IN GANGOTRI NP

Himalayan moist temperate forest

Sub-alpine forest



Moist alpine scrub

Dry alpine scrub

DATA COLLECTION

We studied the butterfly diversity along Gangotri and Nilang valleys in Gangotri NP. We divided the above-mentioned forests into four sampling zones (Plate I). Zone I included the dry and moist temperate forests. A total of 29 random forest trails/transects were established to sample butterflies during April-November 2008, across three seasons (spring, summer and autumn). We

sampled in areas ranging in elevation from 2600 m amsl to 5200 m amsl. All transects lengths were 500 m, and transects were traversed on foot within 45 min. We recorded all butterflies seen during each transect walk in an imaginary 5 × 5 × 5 (m^3) box around the observer. Abundance data were collected when the cloud cover was less than 70%, between 0900 and 1300 hrs, when the conditions are most favourable for butterfly flight. In addition to transects, we also used opportunistic sightings at mud puddles, nectar sources and other resource–rich sites to increase the inventory. Butterflies that could not be readily identified visually were either photographed or captured using a hand-held sweep net and were released after identification.

STUDY ORGANISM

We sampled all butterflies of the Hesperioidea and Papilionoidea (order Lepidoptera, suborder Rhopalocera). We documented five butterfly families *(i.e.* Hesperiidae, Papilionidae, Pieridae, Lycaenidae and Nymphalidae) and identified them to species level following Evans (1932), Wynter-Blyth (1957) and Haribal (1992). Here, we use the nomenclature of Kehimkar (2008).

DATA ANALYSIS

We pooled butterfly data from all transects falling within one vegetation zone. We considered the total number of species observed as the species richness and the number of individual butterflies counted during sampling as the species abundance. Species richness estimates (non-parametric) were calculated on the basis of individual-based species accumulation curves (Gotelli & Colwell, 2001). Sampling effort and efficiency were estimated using the program EstimateS (Colwell, 2009). We calculated Fisher's alpha index (Fisher *et al.*, 1943) to compare the diversity of butterflies across three vegetation zones using the program Past 1.73 (Hammer *et al*., 2007). We performed cluster analysis using this program (Hammer *et al*., 2007) and produced a dendrogram showing the similarities in the composition of the butterfly community between transects. The analysis was based on a Bray–Curtis dissimilarity matrix (single link) of ecological distance.

RESULTS

BUTTERFLY SPECIES RICHNESS, ABUNDANCE AND DIVERSITY

With an effort of 43.5 km in 58 days in 8 months, we recorded a total of 1,639 butterfly individuals representing 34 species, 29 genera and five families in Gangotri NP during the study (Tables 1 & 2) (Plate II). The highest species richness, abundance and diversity were recorded in vegetation zone I, followed by zones II, III and IV. Interestingly, there were 16 species that were restricted to a single vegetation zone. They represent 47% of the total butterfly species richness recorded in Gangotri NP.

Table 1.

Species richness, abundance, diversity and number of unique species encountered in each vegetation category

Habitat	Number of transects (N = 29)	Species richness	Abundance	Fisher's α	Unique species
Zone I	8	22	802	12.4	10
Zone II	8	12	412	7.1	3
Zone III	5	9	233	8.3	1
Zone IV	8	5	192	2.5	2
Total	29	48	1639	30.3	16

Table 2. Butterflies documented along 29 transects in Gangotri NP in 2008

S.no	Common name	Species	Relative abundance
	Hesperiidae		
1	Indian Awlking	*Choaspes benjaminii* (Guerin-Meneville)	0.12

2	Common Snow Flat	*Tagiades litigosa* Moschler	0.06
	Papilionidae		
3	Common Blue Apollo	*Parnassius hardwickii* Gray	0.92
4	Common Red Apollo	*Parnassius epaphus* Oberthür	2.93
5	Common Yellow Swallowtail	*Papilio machaon* Linnaeus	2.38
	Pieridae		
6	Common Brimstone	*Gonopteryx rhamni* (Linnaeus)	5.67
7	Common Emigrant	*Catopsilia pomona* (Fabricius)	4.64
8	Dark Clouded Yellow	*Colias fieldii* Ménétriés	5.43
9	Large Cabbage White	*Pieris brassicae* (Linnaeus)	0.61
10	Indian Cabbage White	*Pieris canidia* (Sparrman)	11.96
11	Bath White	*Pontia daplidice* (Linnaeus)	2.32
12	Hill Jezebel	*Delias belladonna* (Fabricius)	0.06
	Lycaenidae		
13	Indian Purple Hairstreak	*Esakiozephyrus mandara* Doherti	0.06
14	Common Silverline	*Spindasis vulcanus* (Fabricius)	0.12
15	Common Copper	*Lycaena phlaeas* (Linnaeus)	2.07
16	Powder Green Sapphire	*Heliophorus tamu* (Kollar)	0.12
17	Sorrel Sapphire	*Heliophorus sena* Kollar	3.36
18	Common Hedge Blue	*Actyolepis puspa* (Horsefield)	7.57
19	Common Meadow Blue	*Polyommatus eros*	3.66
	Nymphalidae		
20	Common Beak	*Libythea lepita* Moore	0.12
21	Plain Tiger	*Danaus chrysippus* (Linnaeus)	1.95
22	Common Wall	*Lasiaommata schakra* Kollar	3.66
23	Common Satyr	*Aulocera swaha* (Kollar)	0.43
24	Yellow Argus	*Paralasa mani* De Nicéville	0.06
25	Highbrown Silverspot	*Fabriciana adippe* Denis and Schiffermüller	0.92
26	Queen of Spain Fritillary	*Issoria lathonia* (Linnaeus)	4.09
27	Common Sailor	*Neptis hylas* (Linnaeus)	0.12
28	Himalayan Sailor	*Neptis mahendra* Moore	2.87
29	Himalayan Jester	*Symbrenthia hypselis* (Godart)	0.06
30	Indian Red Admiral	*Vanessa indica* (Herbst)	8.66
31	Painted Lady	*Vanessa cardui* (Linnaeus)	11.53
32	Indian Tortoiseshell	*Aglais cashmiriensis* (Kollar)	10.25
33	Eastern Comma	*Polygonia egea* (Cramer)	0.06
34	Blue Admiral	*Kaniska canace* (Linnaeus)	1.16

INVENTORY COMPLETENESS

We calculated six estimators of species richness. The ACE and Chao1 estimates of species richness gave the largest estimates of species richness in Gangotri NP. These estimators are generally used for inventory completeness values and give the ratio between the observed and estimated richness (Sorenson *et al*., 2002; Scharff *et al*., 2003). Estimates of species richness produced by Chao1 are a function of singletons and doubletons and exceed the observed species richness by greater margins as the relative frequency of singletons and doubletons increases. Chao1 measures are especially sensitive to patchiness and were effective in cases where species were randomly distributed (Magurran, 2004). Using the ACE and Chao1 estimates (largest estimates) for inventory completeness, the species richness estimated during the current study was determined to be 77-80%.

PLATE II Some of the butterflies of Gangotri NP

Tagiades litigosa Möschler

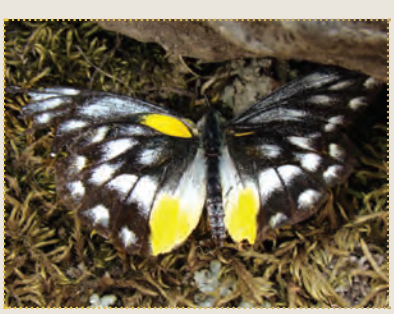
Choaspes benjaminii (Guerin-Meneville)

Parnassius epaphus Oberthür

Papilio machaon (Linnaeus)

Heliophorus sena Kollar

Lycaena phlaeas (Linnaeus)



Delias belladonna (Fabricius)

Gonopteryx rhamni (Linnaeus)

Pieris canidia (Sparrman)

Danaus chrysippus (Linnaeus)

Issoria lathonia (Linnaeus)

Vanessa cardui (Linnaeus)

Aglais cashmiriensis (Kollar)

Vanessa indica (Herbst)

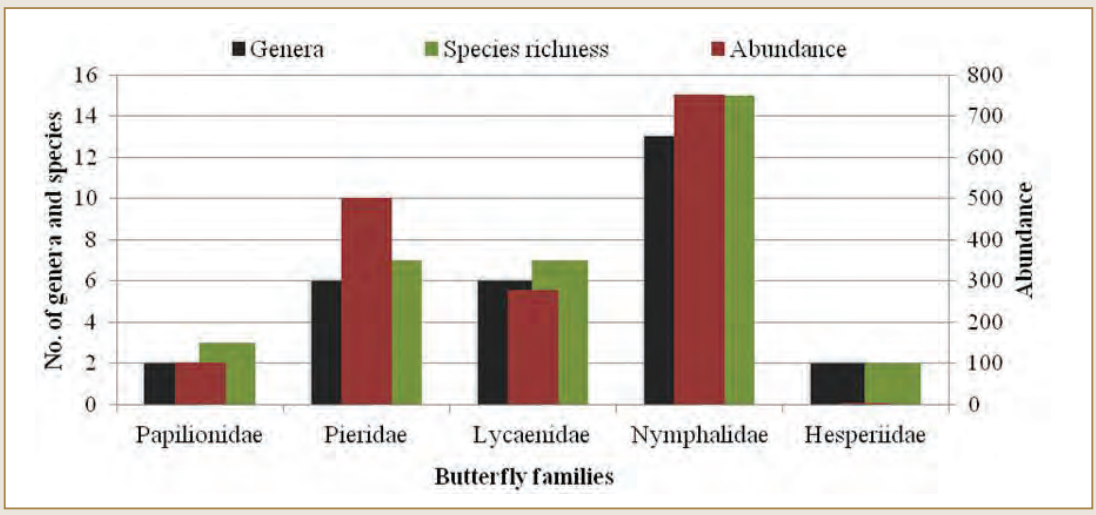
COMMUNITY COMPOSITION

The butterfly abundance ranges from 1 to 196 (Indian Cabbage White; *Pieris canidia*). The most dominant butterflies in the community were the Indian Cabbage White; *Pieris brassicae* (11.9%), Painted Lady; *Vanessa cardui* (11.5%), Indian Tortoiseshell; *Aglais cashmiriensis* (10.2%), Indian Red Admiral; *Vanessa indica* (8.6%) and Common Hedge Blue; *Actyolepis puspa* (7.5%) (Table 2). These five butterflies together account for 50% of the total butterfly abundance recorded. The community had six singletons (species that were recorded only once) and four doubletons (species that were recorded only twice). The community composition reveals that most of the butterflies were rare and restricted to a few vegetation and elevation zones only.

FAMILY COMPOSITION

We recorded five butterfly families, namely Hesperiidae, Papilionidae, Pieridae, Lycaenidae and Nymphalidae. The family Nymphalidae was the most dominant family and accounted for 753 individuals representing 15 species, followed by the Pieridae, Lycaenidae, Papilionidae and Hesperiidae (Fig. 2). We recorded a high genera richness, *viz*. 34 species belonging to 29 genera. The family Nymphalidae, represented by 15 genera, had the greatest number, followed by the Pieridae and Lycaenidae (both 6 genera) and Papilionidae and Hesperiidae.

Figure 2.

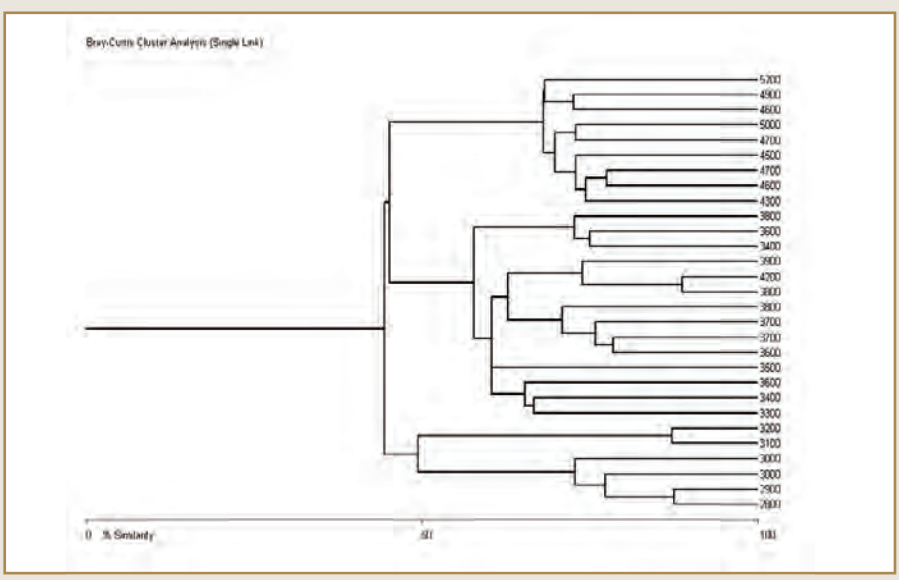


Genera, species richness and abundance of five butterfly families in Gangotri NP

SITE AND SPECIES SIMILARITY

The dendrogram obtained from cluster analysis of 29 transects in different elevation zones showed that the butterfly composition grouped into three major clusters (Fig. 3): (i) 2800-3200 m, (ii) 3300-3900 m and (iii) 4200-5200 m. Cluster analysis also revealed that the butterfly assemblages grouped into four sub-clusters. The results are consistent with elevation and vegetation zones. The high-altitude butterfly assemblage (4200-5200 m) was found in dry/moist alpine scrub habitat. The Himalayan moist temperate forest supports the unique butterfly assemblage found between 2800 and 3200 m.

Figure 3.



Dendrogram showing similarities between 29 elevational transects in Gangotri National Park (based on Bray-Curtis dissimilarity matrix—single link)

DISCUSSION

We were able to provide a reasonable estimate and sampled 77-80% of the butterfly fauna of Gangotri NP. We recommend sampling in all possible habitats and seasons to inventory the butterflies in the Himalayan landscape. It is extremely difficult to sample biodiversity in a given area as time and money are limited. Butterflies constitute a model system for large-sample, long-term monitoring studies to survey biodiversity quickly. To select and prioritize areas for biodiversity conservation, rapid assessments of biodiversity indicator taxa can be an important, helpful, quick and cost-effective tool for conservation managers.

There are approximately 417 species of butterfly in the western Himalaya (Wynter-Blyth, 1957). We would not expect to record a comparable number species at such a small site as Gangotri NP because it lacks representation from the lower elevations (500-2700 m), a major repository of species found in the western Himalaya. Gangotri NP holds a rich Himalayan biodiversity despite the fact that thousands of pilgrims visit Gangotri Valley during April-October each year, along with a large number of adventure tourists, who visit the area for trekking, camping, adventure activities and mountaineering and cause much harm to the Himalayan habitat and thus the biodiversity. Nilang Valley supports a different butterfly assemblage, similar to that of the Trans Himalayan region, which may be attributed to the fact that this area differs in its topography and vegetation composition from Gangotri Valley (which is siuated in the Great Himalayan ranges) as this valley resembles the Trans Himalayan region (an extension of the Zanskar ranges) more closely. The Nilang or Jadh Ganga Valley is an important habitat, but it is used by large herds of goats, sheeps and mules accompanied by herders from spring to autumn. An estimated 30,000 sheep, goats and mules graze these pastures intensively (Chandola *et al*., 2008). Nilang Valley is also exposed to military camps, disturbance activities such as livestock grazing and other development human activities (road construction for the military). Efforts are needed to check or minimise anthropogenic activities that lead to habitat degradation and fragmentation. Thus, management practices should be revised so as to give protection to these sites.

Very few studies have been carried out on the biogeographical distribution of the Himalayan butterfly fauna as many species have lost and extended their distribution ranges in the last 50 years. As the Himalayan forests are under severe threats of habitat degradation and forest fragmentation, there is an urgent need to carry out such studies on butterflies, especially for species that are endemic to the Himalayan region and its sub-regions. It is our expectation that the results presented and discussed here will help conservation planners and managers by aiding them in giving attention to the remaining fragmented habitats facing human alterations, which will intensify biodiversity conservation efforts in the area.

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